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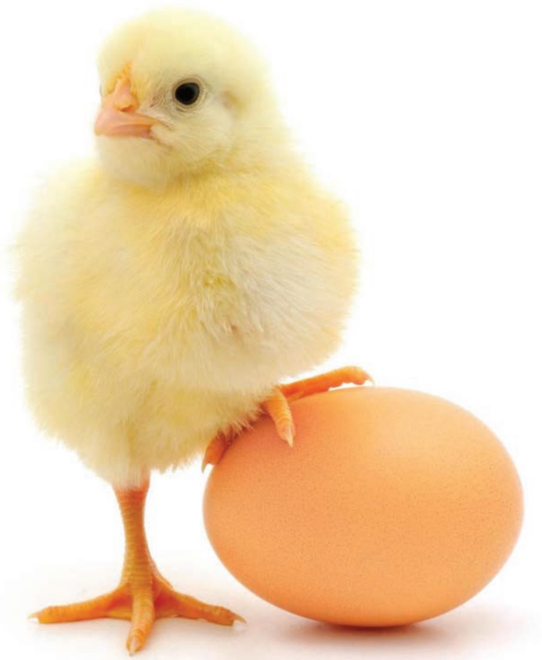

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Research Article
Effect of Enogen® Feed Corn on Pelleting Characteristics of a Poultry Diet and Subsequent Broiler Growth Performance and Carcass Traits*

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Abstract
Background and Objective: Enogen® Feed corn, a high-amylase corn variety, has shown to improve average daily gain and feed efficiency compared to conventional corn when fed to finishing swine and cattle. This effect has not been evaluated in poultry. Further, high amylase activity in Enogen® Feed corn may influence the pelleting process, specifically starch gelatinization. This experiment evaluated the effects of corn type and conditioner retention time on pelleting characteristics and broiler growth and carcass traits. **Materials and Methods:** Twelve hundred male broiler chicks (Cobb-Vantress, Siloam Springs, AR) were used in a 45-day experiment with a 2×2 factorial treatment structure of corn source [conventional (CON) and Enogen® Feed corn (EFC; Syngenta Crop Protection, Inc.)] and conditioner retention time (30 or 80 sec). Conventional corn was replaced by EFC on a kg:kg basis. Pelleting and starch characteristics of the diets were collected and analyzed. Chicks were randomly allocated to groups of 15 and assigned to 1 of 80 floor pens. Chicks received experimental treatments beginning on day 5 of age. A starter diet was fed from day 0-10 of the study, a grower diet from day 11-24 and a finisher diet from day 25-45 of the experiment. Pen weights and feed consumption were measured on day 11, 25, 39 and 45 for calculation of body weight gain, feed intake and feed efficiency. Half of the chicks from each treatment were harvested on day 39 and the remaining half were harvested on day 45 for determination of carcass weight and dressing percentage. **Results:** Pelleting of EFC resulted in greater starch solubility in cooled pellets compared to pelleted CON diets. Broiler performance was not affected by conditioner retention time. Broilers fed EFC consumed more feed, had heavier body weights and heavier carcasses than broilers fed CON; however, there was no difference in carcass feed efficiency among treatments. **Conclusion:** Replacing CON with EFC in poultry diets appears to enhance starch gelatinization during pelleting but did not affect feed efficiency in broilers.

Key words: Alpha amylase, broilers, Enogen®, poultry diet, starch, corn

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INTRODUCTION

Starch is the primary energy source in livestock diets and constitutes up to 50% of poultry diets. Starch is largely supplied by cereal grains and in the U.S., specifically corn. Much research has been dedicated to evaluating grain processing methods that increase starch availability, such as grinding and thermal processing[1-4]. The purpose of these processing methods is to disrupt the outer shell of the corn kernel and expose the starch endosperm to make it more accessible for enzymatic digestion in the animal. Starch digestion is largely driven by amylase, a glycolytic enzyme that degrades starch into sugars. Therefore, grain processing can improve starch digestion by increasing the surface area of starch molecules and providing more substrate for amylase to bind.

Enogen® Feed corn (EFC) is a corn variety which contains a bacterial transgene that produces an -amylase enzyme[5]. Originally developed to improve the efficiency of ethanol production, recent studies have revealed potential benefits in animal performance when EFC is included in livestock diets. Increased amylase activity of EFC corn is designed to assist in the rapid degradation of starch to sugars, thereby providing more available energy for growth. Research has shown a 5% increase in feed efficiency and a 4.1% increase in starch digestion when conventional corn is replaced by EFC in the diets of stocker and finishing cattle[5]. An experiment in swine revealed a tendency for improved average daily gain for pigs consuming EFC compared to conventional corn during the last 82 days of the finishing period[6]. Evaluation of EFC in poultry diets has not yet occurred.

Effects of EFC on feed processing characteristics are also of interest. It is currently unknown how a corn variety with high amylase may react in the pelleting process. Pelleting requires addition of heat and moisture in the form of steam. Steam is typically mixed with mash feed in the steam conditioner for 15-30 sec but can be retained up to 120 sec depending on equipment and processing parameters. Pressure is then applied to the steamed feed mixture as it is pressed through the pellet die. The combination of moisture and frictional heat increases starch gelatinization, which is an irreversible process that leads to greater starch availability[7]; thus, the amylase activity in EFC would be expected to further increase the degree of starch gelatinization in pelleted feed.

This experiment was designed to discover the effects of corn type and conditioner retention time on pelleting characteristics of a poultry diet and subsequent broiler growth performance and carcass traits. Research in this area will help to uncover beneficial effects of EFC in broilers that many researchers were not able to explore. Thus, a new theory on broiler efficiency due to feeding a high-amylase corn variety may be arrived at.

MATERIALS AND METHODS

This research was conducted according to the experimental protocols approved by the Institutional Animal Care and Use Committee at Kansas State University.

Twelve hundred male broiler chicks (Cobb-Vantress, Siloam Springs, AR) were used in a 45-d randomized complete block experiment with treatments arranged as a 2×2 factorial, with factors consisting of corn source [conventional (CON) and EFC] and conditioner retention time (30 and 80 sec). Corn was ground to 700 μm in the starter phase and 900 μm in the grower and finisher phases using a hammermill (Bliss, Model 22115). Starter, grower and finisher broiler diets were mixed in a 907 kg Hayes and Stolz horizontal counterpoise mixer (Table 1). For treatments containing EFC, conventional corn was replaced by EFC on a kg:kg basis.

For the pelleting trial, diets were steam conditioned (Wenger twin staff pre-conditioner, Model 150) for 30 or 80 sec at 75°C and subsequently pelleted using a 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill) equipped with a 4-32 mm pellet die. Production rate was set at 10 kg per min, approximately 65% of the rated throughput for the pellet mill. Pelleting of the starter, grower and finisher diets provided three replications for each treatment; therefore, diet served as the blocking factor. Conditioner retention times were calculated by adjusting the conditioner screw speed and dividing the amount of feed in the conditioner by the production rate. For each run, a conventional corn-soybean meal flush diet was used to warm the mill up to 75°C, the first treatment was pelleted and the mill was shut down to allow the pelleted feed to cool and to adjust conditioner screw settings for the next treatment. Conditioning temperature, hot pellet temperature (HPT) and production rate were recorded at 3 time points during each run (Table 2). Pellet mill amps and volts were also monitored throughout each run to calculate energy consumption.

Prior to pelleting, a total of 10 mash samples per treatment were collected for analysis of soluble starch. During each processing run, 3 conditioned mash and 3 pellet samples were collected throughout the run. Conditioned mash samples were immediately analyzed for soluble starch and pellets were immediately placed in an experimental counter-flow cooler for 10 min. Once pellets were cool, they were analyzed for soluble starch and pellet durability index (PDI).

Table 1: Ingredient and nutrient composition (as-is basis) of broiler diets containing either conventional or Enogen® Feed corn[1]

Phases:	Starter		Grower		Finisher	
Corn[2] type:	CON	EFC	CON	EFC	CON	EFC
Ingredient (%)						
Ground corn[1]	61.49	61.49	66.21	66.21	67.66	67.66
Soybean meal	32.75	32.75	28.00	28.00	25.40	25.40
Choice white grease	1.45	1.45	2.10	2.10	3.20	3.20
L-lysine HCl	0.22	0.22	0.17	0.17	0.19	0.19
DL-methionine	0.29	0.29	0.26	0.26	0.25	0.25
L-threonine	0.11	0.11	0.06	0.06	0.07	0.07
Monocalcium phosphate	1.42	1.42	1.12	1.12	1.14	1.14
Limestone	1.47	1.47	1.27	1.27	1.28	1.28
Salt	0.23	0.23	0.23	0.23	0.23	0.23
Vitamin/mineral	0.25	0.25	0.25	0.25	0.25	0.25
Sodium bicarbonate	0.23	0.23	0.23	0.23	0.23	0.23
Choline chloride	0.10	0.10	0.10	0.10	0.10	0.10
Analyzed nutrients (%)						
Crude protein	21.40	20.60	18.90	18.70	17.30	18.40
Ether extract	3.20	3.30	4.20	3.80	5.00	4.50
ADF	3.40	3.70	3.30	2.70	3.20	3.00
Starch	38.86	39.10	43.50	45.10	42.60	42.90
Calcium	1.00	0.91	0.85	0.85	0.70	0.82
Phosphorous	0.68	0.67	0.60	0.61	0.54	0.55
Potassium	0.98	0.95	0.86	0.87	0.77	0.75
Sodium	0.18	0.17	0.17	0.17	0.15	0.18
Lysine	1.39	1.32	1.21	1.18	1.10	1.15
Methionine	0.57	0.53	0.51	0.52	0.45	0.49
Threonine	0.90	0.86	0.77	0.75	0.71	0.74
Tryptophan	0.28	0.26	0.24	0.24	0.21	0.22
Arginine	1.38	1.33	1.22	1.20	1.11	1.15
Valine	1.04	1.00	0.91	0.90	0.86	0.91
Isoleucine	0.95	0.91	0.82	0.81	0.77	0.83

[1]Enogen® Feed corn (Syngenta Crop Protection, Inc.) replaced conventional yellow dent corn on a kg:kg basis. [2]CON: Conventional yellow dent corn, EFC: Enogen® Feed corn

Table 2: Effect of conventional or Enogen® Feed corn diets steam-conditioned for 30 or 80 s on hot pellet temperature, starch solubility, pellet durability index and pellet mill energy consumption[1]

Corn types:	CON		EFC			Probability, <		
Conditioner retention time[2], (s):	30	80	30	80	SEM[3]	Corn type	Retention time	Corn×Retention
Production rate (kg min^{-1})	10.3	10.5	10.3	10.3	0.09	0.28	0.35	0.23
Conditioning temp (°C)	75.3	75.3	75.1	75.3	0.22	0.51	0.73	0.56
Hot pellet temp (°C)	84.4	84.9	84.1	84.9	0.48	0.54	0.03	0.72
Starch solubles (%)								
Initial mash	2.9	3.0	2.7	2.8	0.19	0.15	0.41	0.90
Conditioned mash	2.7	2.7	2.8	2.7	0.14	0.73	0.73	0.57
Cooled pellets	5.5	5.3	6.0	6.1	0.26	0.01	0.67	0.52
Pellet durability index (%)	84.6	85.1	84.4	83.9	5.67	0.39	0.99	0.58
Energy consumption (kWh t^{-1})	23.0	22.2	22.6	22.4	0.55	0.79	0.30	0.49

[1]A corn-soy based poultry diet was mixed in a 907 kg Hayes and Stolz counterpoise mixer. The corn fraction of the diet was made up of conventional (CON) or Enogen® Feed corn (EFC) with EFC replacing CON on a kg:kg basis. Diets were steam-conditioned (Wenger twin staff pre-conditioner, Model 150) for 30 or 80 sec at 75°C and subsequently pelleted using a 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill) with a 4 mm×32 mm pellet die (L:D 8). [2]The screw feeding the steam conditioner was set to achieve a production rate of 10 kg min^{-1}. Conditioner retention times were calculated by adjusting the conditioner screw speed and dividing the amount of feed in the conditioner by the production rate. [3]Pooled standard error of least squares means (n = 3)

For the performance trial, chicks were maintained on a 24 h lighting schedule in a thermostatically controlled room with *ad libitum* access to feed and water. Chicks were housed in 1.2×2.4 m floor pens with 7-10 cm of pine shavings. Each pen was fitted with single hanging feeder and 4 nipple waterers. Chicks were randomly allocated to groups of 15, weighed and randomly assigned to 1 of 80 floor pens. Treatments were randomly assigned to pens and blocked by location for a total of 20 replications per treatment. Chicks were fed a common diet from 0-4 days of age before

Table 3: Effect of conventional or Enogen® Feed corn diets steam-conditioned for 30 or 80 sec on broiler performance[1]

	Corn type:							
	CON		EFC			Probability, <		
Conditioner retention time[2], (s):	30	80	30	80	SEM[3]	Corn type	Retention time	Corn×Retention
BW (kg)								
day 0	0.18	0.17	0.17	0.17	0.001	0.12	0.22	0.07
day 11	0.57	0.58	0.58	0.58	0.004	0.32	0.92	0.68
day 25	1.97	1.98	2.00	2.00	0.016	0.01	0.63	0.81
day 39	3.60	3.59	3.65	3.66	0.031	0.04	0.91	0.69
day 45	4.37	4.34	4.39	4.38	0.034	0.31	0.53	0.87
day 0-11								
ADG (g day^{-1})	36.25	36.46	36.96	36.65	0.333	0.16	0.89	0.41
ADFI (g day^{-1})	56.54	56.78	56.37	56.06	0.401	0.27	0.93	0.50
FCR	1.56	1.56	1.53	1.53	0.009	0.01	0.99	0.68
day 11-25								
ADG (g day^{-1})	99.14	99.64	101.28	101.62	0.941	0.01	0.57	0.91
ADFI (g day^{-1})	126.40	127.90	130.30	131.19	1.316	0.01	0.25	0.77
FCR	1.27	1.28	1.28	1.29	0.005	0.07	0.18	0.88
Day 25-39								
ADG (g day^{-1})	116.22	115.17	117.17	118.23	1.336	0.14	1.00	0.43
ADFI (g day^{-1})	179.74	179.92	184.19	185.98	1.845	0.01	0.54	0.61
FCR	1.56	1.57	1.58	1.59	0.015	0.22	0.51	0.66
Day 0-39								
ADG (g day^{-1})	87.76	87.57	89.06	89.44	0.779	0.03	0.90	0.68
ADFI (g day^{-1})	126.08	127.03	129.03	129.27	1.253	0.02	0.58	0.74
FCR	1.44	1.45	1.46	1.45	0.008	0.53	0.61	0.31
Day 25-45								
ADG (g day^{-1})	119.36	117.48	118.95	117.80	1.175	0.97	0.21	0.76
ADFI (g day^{-1})	212.51	211.69	216.77	215.43	2.076	0.06	0.61	0.90
FCR	1.78	1.80	1.82	1.83	0.013	0.01	0.31	0.64
Day 0-45								
ADG (g day^{-1})	93.07	92.49	93.74	93.29	0.743	0.33	0.49	0.93
ADFI (g day^{-1})	147.44	147.35	150.29	150.24	1.386	0.05	0.96	0.99
FCR	1.58	1.59	1.60	1.61	0.008	0.03	0.26	0.90
Removals (%)	1.20	1.20	1.10	1.10	0.270	0.79	0.99	0.93

[1]A total of 1200 male broiler chicks were used in a 45-day experiment with 15 birds per pen and 20 pens per treatment. Chicks were fed a corn-soy based diet where the corn fraction of the diet was made up of conventional (CON) or Enogen® Feed corn (EFC) and EFC replaced CON on a kg:kg basis. A starter diet was fed from day 0-11, a grower diet from day 11-25 and a finisher diet from day 25-45. In the finishing phase, chicks were weighed and harvested in two groups; half of the birds from each treatment were weighed and harvested on day 39 and the remaining chicks were weighed and harvested on day 45. [2]Diets were steam-conditioned (Wenger twin staff pre-conditioner, Model 150) for 30 or 80 sec at 75°C and subsequently pelleted using a 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill) with a 4×32 mm pellet die (L:D 8). [3]Pooled standard error of least squares means (day 0-25, n = 20; day 25-45, n = 10)

initiation of the experiment. Therefore, day 0 of the experiment corresponded with 5 days of age for the chicks. A starter diet was fed from study day 0-10, a grower diet from day 11-24 and a finisher diet from day 25-45. In the case of mortality, chick weight, feeder weight, treatment and pen number were recorded. Pen weights and feed consumption were measured on day 11, 25, 39 and 45 for calculation of body weight gain, feed intake and feed efficiency (Table 3). Additionally, half of the chicks from each treatment were harvested on day 39 and the remaining half were harvested on day 45 for determination of carcass weight and dressing percentage (Table 4). Data were analyzed using the GLIMMIX procedure in SAS 9.4 with pen as the experimental unit and pen location as the blocking factor. Main effects included corn type and conditioner retention time. Results were considered significant if $p \leq 0.05$ and were considered marginally significant between $p > 0.05$ and $p \leq 0.10$.

RESULTS

There was no evidence ($p > 0.23$) for a corn type ×conditioner retention time interaction for any responses in the pelleting trial. Production rate and conditioning temperature were as expected for each treatment, averaging 10.4 kg min^{-1} and 75.3°C, respectively (Table 2). Hot pellet temperature increased ($p = 0.03$) when conditioner retention time increased from 30-80 sec (84.3 vs 84.9°C, respectively). There was no evidence of difference ($p = 0.54$) in HPT due to

Table 4: Effect of conventional or Enogen® Feed corn diets steam-conditioned for 30 or 80 s on broiler carcass characterisitics[1]

	Corn type:					Probability, <		
	CON		EFC					
Conditioner retention time[2], (s):	30	80	30	80	SEM[3]	Corn type	Retention time	Corn×Retention
Carcass weight (kg)								
day 39	2.50	2.50	2.57	2.57	0.022	0.01	0.86	0.94
day 45	3.06	3.05	3.11	3.11	0.041	0.03	0.89	0.67
Dressed carcass (%)								
day 39	69.50	69.50	70.36	70.05	0.283	0.02	0.58	0.59
day 45	70.26	70.37	70.80	71.24	0.445	0.01	0.24	0.49
Carcass feed efficiency	2.06	2.07	2.06	2.06	0.022	0.81	0.79	0.75

[1]A total of 1200 male broilers were used in a 45-day experiment with 15 birds per pen and 20 pens per treatment. Chicks were fed a corn-soy based diet where the corn fraction of the diet was made up of conventional (CON) or Enogen® Feed corn (EFC) and EFC replaced CON on a kg:kg basis. Half of the birds from each treatment were harvested on day 39 and the remaining chicks were harvested on day 45. [2]Diets were steam-conditioned (Wenger twin staff pre-conditioner, Model 150) for 30 or 80 s at 75°C and subsequently pelleted using a 30-horsepower pellet mill (1012-2 HD Master Model, California Pellet Mill) with a 4×32 mm pellet die (L:D 8). [3]Pooled standard error of least squares means (n = 10)

corn type. Percentage of starch solubles present in cooled pellets was greater (p = 0.03) in EFC diets (6.1%) compared to CON diets (5.4%) but there was no evidence of difference (p>0.15) in starch solubles in the initial mash or conditioned mash due to corn type or retention time. Pellet durability index and pellet mill energy consumption were also not different (p<0.30) between treatments.

There was no evidence (p>0.31) for a corn type× conditioner retention time interaction for any responses in the performance trial. Additionally, there were no main effects of conditioner retention time observed (p>0.18) for body weight (BW), average daily gain (ADG), average daily feed intake (ADFI), or feed conversion ratio (FCR) (Table 3). From day 0-11, FCR was improved (p<0.01) in chicks consuming EFC but there was no evidence of differences (p>0.16) in BW, ADG, or ADFI among treatments. From day 11-25, ADG and ADFI were greater (p<0.01) for chicks fed EFC compared to those fed CON. Body weight was also greater (p<0.01) for chicks consuming EFC compared to CON on day 25 (2.00 vs 1.98 kg, respectively). For the chicks that were harvested on day 39, ADFI was greater (p<0.01) in the finishing phase for chicks fed EFC diets (185.1 g day^{-1}) compared to those fed CON diets (179.8 g day^{-1}). Additionally, final BW on day 39 was greater (p<0.04) for chicks consuming the EFC treatments compared to those consuming the CON treatments (3.66 vs 3.60 kg, for EFC and CON, respectively). For the second group of chicks harvested on day 45, there was no evidence of difference (p = 0.31) in final BW but ADFI on day 45 was greater (p = 0.05) and, contrary to the starter phase, FCR was poorer (p = 0.03) in chicks fed EFC. From day 0-39, BW, ADG and ADFI were increased (p<0.04) for chicks consuming EFC diets compared to CON diets. From day 0-45, however, greater ADFI (p = 0.05) and poorer FCR (p = 0.03) were observed for chicks receiving EFC.

Chicks consuming EFC diets had greater (p<0.03) carcass weights than chicks consuming CON diets at day 39 (2.57 vs 2.50 kg, respectively) and day 45 (3.11 vs 3.06 kg, respectively; Table 4). Furthermore, carcass dressing percentage was also greater (p<0.02) for chicks on the EFC treatments than the CON treatments at day 39 (70.2 vs 69.5%, respectively) and day 45 (71.0 vs 70.3%, respectively). When feed efficiency was calculated on a carcass basis, there was no evidence of difference (p>0.79) between treatments (Table 4).

DISCUSSION

Results of this experiment show no evidence of difference in pelleting parameters, such as HPT, PDI, or pellet mill energy consumption, when pelleting EFC or CON diets. This is similar to the findings of Truelock *et al.*[8], who observed only minor increases in HPT and no differences in PDI or energy consumption when EFC replaced CON in pelleted diets. In the current trial, an increase in soluble starch was observed in cooled pellets of EFC diets compared to CON pellets. Pelleting of corn-soybean meal-based diets is known to increase starch gelatinization[7], an irreversible process potentiated by moisture and heat in the pelleting process. Furthermore, previous research has indicated that pelleted diets containing EFC have potential for greater gelatinized starch than pelleted CON diets[8], possibly due to increased amylase activity in EFC. These observations likely explain the increase in soluble starch detected in the experiment herein.

Broiler diets containing EFC resulted in greater ADFI in the grower and finisher phases and increased ADG from 5-43 days of age compared to CON. Improvements in FCR when feeding EFC were only observed in the starter phase. There has been no previous research on the effects of EFC in poultry; however, studies in cattle and swine have revealed improvements in

ADG of varying magnitudes. An experiment evaluating steam-flaked EFC in finishing cattle diets revealed a 5.6% increase in ADG[9] while EFC in the diets of finishing pigs only tended to improve ADG by 1.2%[6]. Although the current study is the first of its kind using EFC to supply exogenous -amylase in broiler diets, there has been previous research in poultry examining effects of -amylase enzyme preparations derived from various *Bacillus* species. In these experiments, exogenous -amylase derived from *Bacillus amyloliquefaciens* or *Bacillus stearothermophilus* improved ADG in broilers consuming corn-soy diets by 4.5-9.4% and FCR by 3-4.2% for birds up to 42 day of age[10,11]. Meanwhile, another study has reported no differences in ADG and poorer FCR when a *Bacillus licheniformis*-derived amylase was fed to broilers up to 42 day of age[12].

For the experiment conduct herein, EFC increased broiler carcass weight and dressing percentage. There was no evidence that EFC influenced carcass characteristics in swine[6], although hot carcass weights of finishing cattle were 1.6% greater when steam-flaked EFC replaced CON in the diet[9]. Supplementation of a bacterial derived-amylase in broiler diets has revealed no effect on carcass weight[12]; however, these authors also reported no significant effects of an exogenous-amylase on ADG or feed intake in 42-day-old broilers. In the present study, the increase in carcass weight observed in broilers consuming EFC compared to CON is likely explained by the associated increase in ADFI and ADG. The mechanism by which EFC affects carcass dressing percentage is not fully understood. It should be noted that aside from improving gut morphology and nutrient digestion[10,11], bacterial-derived exogenous -amylase supplementation has also been reported to increase intestinal enzyme activity in 21-day-old broilers[13]. Specifically, the authors described a quadratic increase in intestinal protease and trypsin activity with increasing amylase supplementation and no effect on the activity of intestinal lipase. This revelation may provide evidence for the ability of exogenous-amylase to enhance protein digestion in relation to lipolysis such that dressing percentage is improved with amylase supplementation. Nonetheless, broiler feed efficiency calculated on a carcass basis was not different between treatments in the current experiment. Body composition was not determined in the present study, therefore it is not possible to determine if differences in energy deposition may have influenced results.

Finally, there was no evidence that conditioner retention time affected processing of EFC differently than CON nor did it have an impact on broiler performance. Increased conditioner retention time is known to improve pellet quality[14], which in turn has been shown to influence broiler performance[15]. There was no evidence, however, that increasing conditioner retention time from 30-80 sec had an effect on pellet quality, soluble starch, or broiler performance in the current study.

Limitations of the current study include the inability to evaluate the effect of EFC on digestibility in broilers. It would be interesting to investigate potential effects of EFC on starch digestibility in broilers to better understand metabolic effects of increased amylase. Further research is warranted in this area.

CONCLUSION

Overall, the results from this experiment suggest that replacing CON with EFC in poultry diets should have little effect on the efficacy of the pelleting process or the quality of pellets produced. The increased amylase content of EFC appears to enhance starch gelatinization during pelleting, leading to greater soluble starch in the pelleted diet and, theoretically, greater starch availability in the animal. Furthermore, there were improvements in ADG and carcass weight when EFC replaced CON in pelleted broiler diets. However, this did not translate to improved feed efficiency, as feed intake also increased.

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REFERENCES

1. Rowe, J.B., M. Choct and D.W. Pethick, 1999. Processing cereal grains for animal feeding. Aust. J. Agric. Res., 50: 721-736.
2. Hancock, J.D. and K. Behnke, 2001. Use of Ingredient and Diet Processing Technologies (Grinding, Mixing, Pelleting and Extruding) to Produce Quality Feeds for Pigs. In: Swine Nutrition, Lewis, A.J. and L.L. Southern, (Eds.). Elsevier Science Florida, USA pp: 469-498,.
3. Lundblad, K.K., S. Issa, J.D. Hancock, K.C. Behnke and L.J. McKinney *et al.*, 2011. Effects of steam conditioning at low and high temperature, expander conditioning and extruder processing prior to pelleting on growth performance and nutrient digestibility in nursery pigs and broiler chickens. Anim. Feed Sci. Technol., 169: 208-217.
4. Al-Rabadi, G.J., B.J. Hosking, P.J. Torley, B.A. Williams and W.L. Bryden *et al.*, 2016. Regrinding large particles from milled grains improves growth performance of pigs. Anim. Feed Sci. Technol., 233: 53-63.

5. Syngenta Crop Protection, LLC, 2019. Enogen Corn for Ethanol. Syngenta US. https://bit.ly/3u8368h.
6. Ochonski, P., F. Wu, E. Arkfeld, J.M. Lattimer, J.M. DeRouchey *et al*., 2019. Evaluation of High Amylase Corn on Growth Performance and Carcass Characteristics of Finishing Pigs. Kansas Agric. Exp. Station Res. Rep., Vol. 5, 10.4148/2378-5977.7850.
7. Lewis, L.L., C.R. Stark, A.C. Fahrenholz, J.R. Bergstrom and C.K. Jones, 2014. Evaluation of conditioning time and temperature on gelatinized starch and vitamin retention in a pelleted swine diet. J. Anim. Sci., 93: 615-619.
8. Truelock, C.N., M.D. Tokach, C.R. Stark and C.R. Paulk, 2019. Pelleting and Starch Characteristics of Diets Containing High Amylase Corn. Kansas Agric. Exp. Station Res. Rep., Vol. 5, 10.4148/2378-5977.7851.
9. Cunningham, H.C., K.M. Cammack, K. Hales, H.C. Freetly and A.K. Lindholm-Perry, 2017. 871 Lipid metabolism and mitochondrial energy production are key pathways involved in adipose tissue of cows transitioning from feed restriction to ad libitum diets. J. Anim. Sci., 95: 373-373.
10. Gracia, M.I., M.J. Aranibar, R. Lazaro, P. Medel and G.G. Mateos, 2003. Alpha-amylase supplementation of broiler diets based on corn. Poult. Sci., 82: 436-442.
11. Onderci, M., N. Sahin, K. Sahin, G. Cikim, A. Aydin, I. Ozercan and S. Aydin, 2006. Efficacy of supplementation of α-amylase-producing bacterial culture on the performance, nutrient use and gut morphology of broiler chickens fed a corn-based diet. Poult. Sci., 85: 505-510.
12. Amerah, A.M., L.F. Romero, A. Awati and V. Ravindran, 2016. Effect of exogenous xylanase, amylase and protease as single or combined activities on nutrient digestibility and growth performance of broilers fed corn/soy diets. Poult. Sci., 96: 807-816.
13. Jiang, Z., Y. Zhou, F. Lu, Z. Han and T. Wang, 2008. Effects of different levels of supplementary alpha-amylase on digestive enzyme activities and pancreatic amylase mRNA expression of young broilers. Asian-Aust. J. Anim. Sci., 21: 97-102.
14. Behnke, K.C., 2001. Factors influencing pellet quality. Feed Technol., 5: 19-22.
15. Lilly, K.G.S., C.K. Gehring, K.R. Beaman, P.J. Turk, M. Sperow and J.S. Moritz, 2011. Examining the relationships between pellet quality, broiler performance and bird sex. J. Applied Poult. Res., 20: 231-239.