Influence of feed ingredients, conditioning temperature, and a dacitic tuff breccia (AZOMITE) on pellet production rate and pellet quality

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Primary Audience: Feed Mill Managers, Nutritionists, Production Managers

SUMMARY

Feed manufacturing is an integral component of the poultry industry. A study was conducted to evaluate the impact of feed ingredients, conditioning temperature, and AZOMITE (**AZ**) level on production rate and pellet quality measured by pellet durability index (**PDI**). A $2 \times 2 \times 2 \times 3$ factorial arrangement within the randomized complete block design was used, for a total of 24 treatments. A broiler grower diet was tested under two conditioning temperatures (82.2°C and 87.8°C), two distillers dried grains with solubles (**DDGS**) levels (0 and 8%), two meat and bone meal (**MBM**) levels (0 and 4%), and three levels of AZ (0, 0.25, 0.50%). Conditioning temperature, DDGS, MBM, and AZ levels all influenced production rate. Interactions between the different factors were assessed and interpreted. These interactions indicate that the inclusion of AZ increases production rate in diets containing DDGS. Both DDGS and MBM decreased production rate compared with relative controls, whereas AZ at 0.25% and 0.50% increased the production rate. Increasing conditioning temperature from 82.2°C to 87.8°C improved production rate and had a positive influence on PDI. The level of MBM and AZ did not impact PDI; however, the inclusion of DDGS had a negative impact on PDI. Although AZ did not increase throughput and PDI simultaneously, its ability to improve pellet production while maintaining PDI indicates usefulness in feed manufacturing. These results indicated that temperature and AZ can be used to offset some of the negative effects of DDGS on pelleting production rate.

Key words: feed manufacturing, DDGS, MBM, temperature, tuff breccia

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DESCRIPTION OF PROBLEM

Improved pellet quality has been reported to positively impact broiler growth performance and feed efficiency [1–3]. There are many factors that may influence pellet quality, which is often measured and recorded as pellet durability index (**PDI**). Previous research [4, 5] has reported that feed formulation accounts for up to 40% of pellet quality. Conditioning temperature and particle size each comprise 20% of pellet quality, while die specifications (pressing) and cooling make up 20% of pellet quality. Distillers dried grains with solubles (**DDGS**) is one ingredient in US poultry diets that is reported to

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negatively impact pellet quality [6, 7]. However, field reports suggest that meat and bone meal (**MBM**) also influences pellet characteristics negatively, although only little scientific evidence exists. High fat inclusions in poultry diets have also been reported to reduce pellet durability [8]. However, with today's technology, feed mills can add fat using post-pellet liquid application systems, which minimizes the interest of this ingredient as an influencer of pellet quality.

Pellet quality and production rate (also referred to as pelleting rate or throughput) are typically inversely related. As production rate increases, the PDI typically decreases and vice versa [6]. Silica-based products have been incorporated into feed formulations to improve pelleting production rates. However, the inclusion of these products has not increased pellet production rate consistently [7]. These silica products are believed to help debride the protein matrix that forms a glass-like film within the lumen of the die [6]. This action is commonly referred as *scouring* or *scrubbing* of the pelleting die and helps to maximize throughput. In addition, sources of rock phosphorus are known to influence throughput and pellet quality [9]. Researchers have reported that the type of phosphate and even equivalent phosphates of different sources can influence pellet mill relative energy usage and throughput [9]. Although inorganic phosphates may increase production rate, they are expensive, and there are growing concerns about managing phosphorus waste. To reduce feed costs and mitigate pollution with phosphorus, phytases are being incorporated to break down the phytate phosphorus contained in feed ingredients to help use the phosphorus in the diet [6].

AZOMITE (**AZ**; Azomite Mineral Products, Nephi, UT) is a pyroclastic flow deposit composed of amorphous aluminosilicate and trace elements. This product is used in feed mills for its anticaking properties, although research has been conducted to assess influences on poultry performance [10, 11]. Similar to reports on inorganic phosphate, field reports suggest that under controlled conditions, a decrease in pellet mill energy may be observed if the throughput remains constant when using AZ. As nutritionists continue to decrease the usage of inorganic phosphates that have traditionally increased throughput, AZ may serve as an alternative to maintain or improve production rate without negatively influencing pellet quality. The objective of the present study was to evaluate the impact of AZ, feed ingredients, and conditioning temperature on pellet mill throughput and PDI using a practical industry diet. By focusing on ingredient composition and conditioning temperature, a large portion of factors influencing pellet quality were assessed simultaneously.

MATERIALS AND METHODS

Diet Composition

Diets were mainly composed of corn and soybean meal and were formulated based on digestible lysine levels and metabolizable energy requirements of a commercial broiler grower diet (Table 1) [12]. Mixer-added fat inclusion from soybean oil was fixed at 1.5% in all diets. The inclusion of DDGS and MBM resulted in slightly different apparent metabolizable energy and CP values across all treatments. Mono-dicalcium phosphate was used at a constant level across all treatments. The digestible lysine was maintained in all dietary treatments by setting minimum formulation ratios relative to digestible lysine, per published recommendation [13]. Other essential nutrients were formulated to meet or exceed published recommendations [14].

Feed Manufacturing

Feed was produced at the Auburn University feed mill following good manufacturing practices. A total of 1,818 kg for each of the four basal diets were created. They consisted of a control diet (corn-soybean meal), 8% DDGS and 4% MBM. Basal diets were split into three batches of 455 kg, which were mixed with one of the three levels of AZ and conditioned at either 82.2°C or 87.8°C for two repeated days. Dry ingredients were blended using a twin shaft mixer (Model 726; Scott Equipment Co., New Prague, MN) to produce the basal diets. The same mixer was then used to mix a 455-kg basal diet with the three levels of AZ. The mixing process consisted of a 30-s dry cycle and a 120-s wet cycle. Wet cycle started after 1.5% soybean oil was added into the dry ingredients.

Table 1. Ingredient and nutrient composition of grower diets with and without DDGS and/or MBM.

Item	Control	8% DDGS	4% MBM	8% DDGS and 4% MBM
Ingredient, %				
Corn	68.12	63.71	69.36	64.54
Soybean meal, 46% CP	26.92	23.36	22.59	19.47
Soybean oil	1.50	1.50	1.50	1.50
Calcium carbonate	1.11	1.19	0.75	0.82
Sodium chloride	0.41	0.37	0.33	0.29
DL-Methionine	0.29	0.27	0.29	0.27
L-Lysine	0.16	0.23	0.17	0.23
L-Threonine	0.09	0.09	0.09	0.09
Mono dicalcium phosphate	0.61	0.48	0.14	0.01
Phytase enzyme[1]	0.02	0.02	0.02	0.02
NSP enzyme[2]	0.02	0.02	0.02	0.02
Vitamin premix[3]	0.08	0.08	0.08	0.08
Trace mineral premix[4]	0.10	0.10	0.10	0.10
Choline chloride, 70%	0.08	0.08	0.08	0.08
DDGS[5]	-	8.00	-	8.00
Meat and bone meal, 58%	-	-	4.00	4.00
Orhers[6]	0.50	0.50	0.50	0.50
Calculated analysis, % (unless otherwise noted)				
AME, kcal/kg	3109	3088	3151	3127
CP	18.0	18.3	18.2	18.8
Digestible lysine	0.95	0.95	0.95	0.95
Calcium	0.91	0.91	0.91	0.91
Available P	0.49	0.49	0.49	0.49
Sodium	0.24	0.24	0.24	0.24

Abbreviations: AME, apparent metabolizable energy; DDGS, distillers dried grains with solubles; MBM, meat and bone meal; NSP, non-starch polysaccharide enzyme.

[1]Quantum Blue 5G (AB Vista Feed Ingredients, Marlborough, UK) provides per kg of diet: 500 FTU/kg of phytase activity.

[2]Econase XT 25 (AB Vista Feed Ingredients, Marlborough, UK) provides per kg of diet: 16,000 BXU/kg of xylanase activity.

[3]Vitamin premix includes per kg of diet: Vitamin A (Vitamin A acetate), 18,7390 IU; Vitamin D (cholecalciferol), 6,614 IU; Vitamin E (DL-alpha tocopherol acetate), 66 IU; menadione (menadione sodium bisulfate complex), 4 mg; Vitamin B12 (cyanocobalamin), 0.03 mg; folacin (folic acid), 2.6 mg: D-pantothenic acid (calcium pantothenate), 31 mg; riboflavin (riboflavin), 22 mg; niacin (niacinamide), 88 mg; thiamin (thiamin mononitrate), 5.5 mg; D-biotin (biotin), 0.18 mg; and pyridoxine (pyridoxine hydrochloride), 7.7 mg.

[4]Mineral premix include per kg of diet: Mn (manganese sulfate), 120 mg; Zn (zinc sulfate), 100 mg; Fe (iron sulfate monohydrate), 30 mg; Cu (tri-basic copper chloride), 8 mg; I (ethylenediamine dihydriodide), 1.4 mg; and Se (sodium selenite), 0.3 mg.

[5]Distiller dried grain with solubles with 9% fat.

[6]Azomite or corn meal depending on the treatment.

Diets were conditioned for 45-s retention time at either 82.2°C or 87.8°C and pelleted through a 4.4 × 35-mm pellet die using a pellet mill (Model 1112-4; California Pellet Mill Co., Crawfordsville, IN). Pellets exiting the pellet mill were collected and cooled with ambient air. Samples were collected when the targeted conditioning temperature was met. Three samples per treatment were collected every 3 min to measure the pelleting rate. PDI was determined by two methodologies: 1) ASABE Standard S269.5 and 2) Holmen tester. Six samples per treatment were collected for PDI analysis. The geometric particle size and particle size distribution of DDGS and SBM were determined by the ASABE Standard S319.4 using a Ro-Tap shaker. The average particle size of SBM and DDGS was 934 and 382 μm, respectively. To accurately assess production rate, steam pressure was fixed at 30 psi and motor load was fixed at 40%.

Statistical Analysis

Two conditioning temperatures (82.2°C and 87.8°C), two DDGS levels (0 and 8%), two

Table 2. Main effects of varying conditioning temperature, DDGS, MBM, and AZ of a practical grower diet on pelleting rate and pellet quality.

Temperature[1] (°C)	DDGS[2] (%)	MBM[3] (%)	AZ (%)	Production Rate (MT/h)	PDI-Tumbler[4]	PDI-Holmen[5]
82.2				0.638[b]	86.43[b]	81.10[b]
87.8				0.710[a]	87.57[a]	83.10[a]
	0			0.690[a]	87.41[a]	82.71[a]
	8			0.658[b]	86.59[b]	81.49[b]
		0		0.681[a]	87.04	82.17
		4		0.667[b]	86.96	82.03
			0	0.657[b]	87.06	82.62
			0.25	0.679[a]	86.87	81.96
			0.5	0.687[a]	87.07	81.72
SEM				0.003	0.169	0.259
P value of main effects						
Temp				0.0001	0.001	0.0001
DDGS				0.0001	0.017	0.019
MBM				0.0190	0.830	0.790
AZ				0.0001	0.855	0.338

[a,b]Means with different superscripts within each main effect are significantly different at $P < 0.05$.

Abbreviations: AZ, AZOMITE; DDGS, distillers dried grains with solubles; MBM, meat and bone meal.

[1]Temp = conditioning temperature; diets were either manufactured at 82.2°C and 87.8°C.

[2]Distiller dried grains with solubles with 9% fat.

[3]Meat and bone meal with 58% CP.

[4]PDI-Tumbler = pellet durability index determined by ASABE Standard S269.5 procedure.

[5]PDI-Holmen = pellet durability index determined by Holmen procedure.

MBM levels (0 and 4%), and three levels of AZ (0, 0.25, and 0.50%) factorial arrangement within the randomized complete block design were used, for a total of 24 treatments. Repeated day, when treatments were made and tested, was used as a blocking factor. Data were analyzed using a fit model of JMP [15], where main effects and interactions were treated as fixed effects and repeated day was treated as a random effect. The null hypotheses of the factorial design were that the main effects of DDGS, MBM, conditioning temperature, and AZ were not significant. The null hypothesis of the interaction effect was also not significant, which means the main effects were independent to each other. The mean values among treatments were compared using Tukey's honestly significant different procedure, with statistical significance considered at $P \leq 0.05$ unless otherwise indicated.

RESULTS AND DISCUSSION

Conditioning temperature, DDGS, MBM, and AZ levels influenced production rate ($P < 0.05$). Increasing conditioning temperature significantly improved PDI from both methodologies, while increasing MBM and AZ did not have any impact to PDI. However, increasing DDGS inclusion had a significant negative impact on PDI ($P < 0.05$; Table 2). There was no significant interaction between conditioning temperature and other variables for production rate and both PDI measurements ($P < 0.05$; Table 3). Increasing conditioning temperature from 82.2°C to 87.8°C significantly improved production rate approximately 11% and PDI from 1.3to 2.5%, regardless of the other variables (Figure 1).

In addition to the significant main effects of all variables for production rate, the two-way interaction effect between DDGS and AZ and three-way interaction effect between DDGS, MBM, and AZ were also significant ($P < 0.05$). However, there was no significant difference for four-way interaction effect between conditioning temperature, DDGS, MBM and AZ ($P > 0.05$; Table 3). These findings suggest the need for further evaluation of the interaction between two variables across the level of the third variable (Figure 2) before making an interpretation about the main effects of DDGS, MBM, and AZ.

Figures 2A–2G illustrate the three-way interaction between DDGS, MBM, and AZ by testing two-way interactions between DDGS

Table 3. Interaction effects of varying conditioning temperature, DDGS, MBM, and AZ of a practical grower diet on pelleting rate and pellet quality.

Temperature[1] (°C)	DDGS[2] (%)	MBM[3] (%)	AZ (%)	Production rate (MT/h)	PDI-Tumbler[4]	PDI-Holmen[5]
82.2	0	0	0	0.677	86.37	81.95
			0.25	0.654	86.62	81.49
			0.5	0.656	87.41	80.80
		4	0	0.624	86.75	80.76
			0.25	0.649	86.61	82.45
			0.5	0.647	87.68	82.19
	8	0	0	0.614	86.18	81.11
			0.25	0.629	86.83	81.65
			0.5	0.648	85.57	80.24
		4	0	0.605	85.76	80.15
			0.25	0.631	85.81	80.50
			0.5	0.633	85.60	79.99
87.8	0	0	0	0.745	87.44	83.08
			0.25	0.730	87.39	82.39
			0.5	0.737	89.37	84.95
		4	0	0.706	87.66	85.10
			0.25	0.729	88.02	83.75
			0.5	0.737	87.59	82.95
	8	0	0	0.636	88.15	84.00
			0.25	0.712	86.94	82.34
			0.5	0.735	86.22	81.39
		4	0	0.654	88.23	84.15
			0.25	0.698	86.74	81.15
			0.5	0.704	87.16	81.30
Pooled SEM				0.003	0.169	0.259
N				144	288	288
P value of all treatments				0.7407	0.6706	0.5885
P value of the interaction effects						
Temp*DDGS				0.1381	0.6835	0.6746
Temp*MBM				0.7521	0.8690	0.9028
DDGS*MBM				0.3567	0.9452	0.3916
Temp*AZ				0.1154	0.6072	0.1684
DDGS*AZ				0.0017	0.0652	0.5184
MBM*AZ				0.4940	0.9599	0.9818
Temp*DDGS*MBM				0.6294	0.3480	0.7812
Temp*DDGS*AZ				0.3226	0.5525	0.8261
Temp*MBM*AZ				0.5466	0.7333	0.4072
DDGS*MBM*AZ				0.0322	0.3863	0.5983
Temp*DDGS%*MBM%*AZ%				0.7407	0.6706	0.5885

Abbreviations: AZ, AZOMITE; DDGS, distillers dried grains with solubles; MBM, meat and bone meal.
[1]Temp = conditioning temperature; diets were either manufactured at 82.2°C and 87.8°C.
[2]Distiller dried grains with solubles containing 9% crude fat.
[3]Meat and bone meal containing 58% CP.
[4]PDI_Tumbler = pellet durability index determined by ASABE Standard S269.5 procedure.
[5]PDI_Holmen = pellet durability index determined by Holmen procedure.

and AZ at each inclusion of MBM (Figures 2A, 2B), interaction between MBM and AZ at each inclusion of DDGS (Figures 2C, 2D), or interaction between DDGS and MBM at each inclusion of AZ (Figures 2E–2G).

Figures 2A and 2B illustrate two-way interaction between DDGS and AZ at each level of MBM. When the diet contained 8% DDGS without MBM (Figure 2A), feed production rate (MT/h) was significantly reduced by 12.13% ($P < 0.05$). Adding AZ at 0.5% had a significant impact on production rate bringing it back up to the same level as a diet without DDGS. When 4% MBM was added to the diet (Figure 2B), the

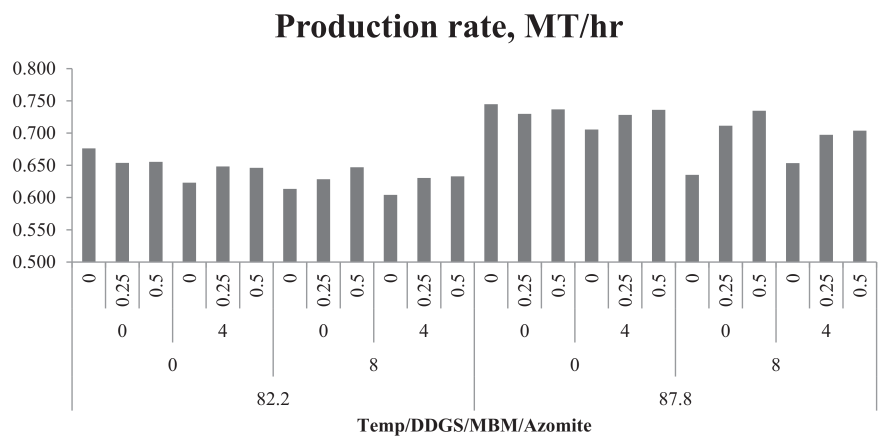

Figure 1. Graphical illustration of production rate (MT/h) of 24 treatments according to a 2-conditioning temperature (82.2°C or 87.8°C) × 2 DDGS levels (0 or 8%) × 2 MBM levels (0 or 4%) × 3 AZ levels (0, 0.25, or 0.50%) factorial arrangements. Abbreviations: AZ, AZOMITE; DDGS, distillers dried grains with solubles; MBM, meat and bone meal.

effect of DDGS inclusion was minimized from a 12.13% reduction in production rate to a 5.33% decrease in production rate. However, adding a minimum of 0.25% AZ significantly improved production rate ($P < 0.05$) by 3.6% without DDGS and 5.6% with DDGS.

Figures 2C and 2D illustrate two-way interaction between MBM and AZ at each level of DDGS. When the diet contained 4% MBM without DDGS (Figure 2C), feed production rate (MT/h) was reduced by 6.5% ($P < 0.05$). Addition of AZ did not have an impact on production rate under these conditions. However, when 8% DDGS was introduced to the diet (Figure 2D), MBM inclusion, either at 0 or 4%, resulted in the same production rate. By adding a minimum of 0.25% AZ, production rate was significantly improved by 7.3% and 5.6% when diets contained 0% MBM or 4% MBM, respectively ($P < 0.05$).

Figures 2E–2G illustrate two-way interactions between DDGS and MBM at each level of AZ. When the diet contained 8% DDGS without using AZ, feed production rate (MT/h) was reduced by 12.13% ($P < 0.05$). Adding 4% MBM into the diet without DDGS reduced production rate by 6.5% while there was no difference in production rate reduction when the diet already contained 8% DDGS (Figure 2E). When AZ was introduced to the diet at either 0.25 or 0.5% (Figures 2F, 2G), the negative effect of MBM (4%) and/or DDGS (8%) to production rate was minimized. There was no difference between 0 and 8% DDGS with and without MBM when AZ was presented at 0.25% (Figure 2F). However, there was a significant reduction in production rate when a diet contained both MBM and DDGS with 0.5% AZ compared with the diet containing 0.5% AZ alone (Figure 2G).

Pellet durability was increased as a result of raising the conditioning temperature. These results agree with other research on conditioning temperature and pellet durability, which reports increases in PDI with increased conditioning temperature [2, 16]. The main difference between the present study and previous research is the conditioning temperature range tested. In the present study, conditioning temperatures of 82.2°C and 87.9°C were compared, which is a narrower range than the 82.2°C and 93.3°C range compared by other researchers [16]. Further research is needed to determine the influence of conditioning temperatures in the increments between 82.2°C and 87.9°C on pellet production and PDI.

The current research supports previous findings that DDGS decrease pellet production rate in poultry diets [6, 7]. It differs from previous research because the decreased production rate was documented at 8% DDGS inclusion, which is lower than previously documented DDGS

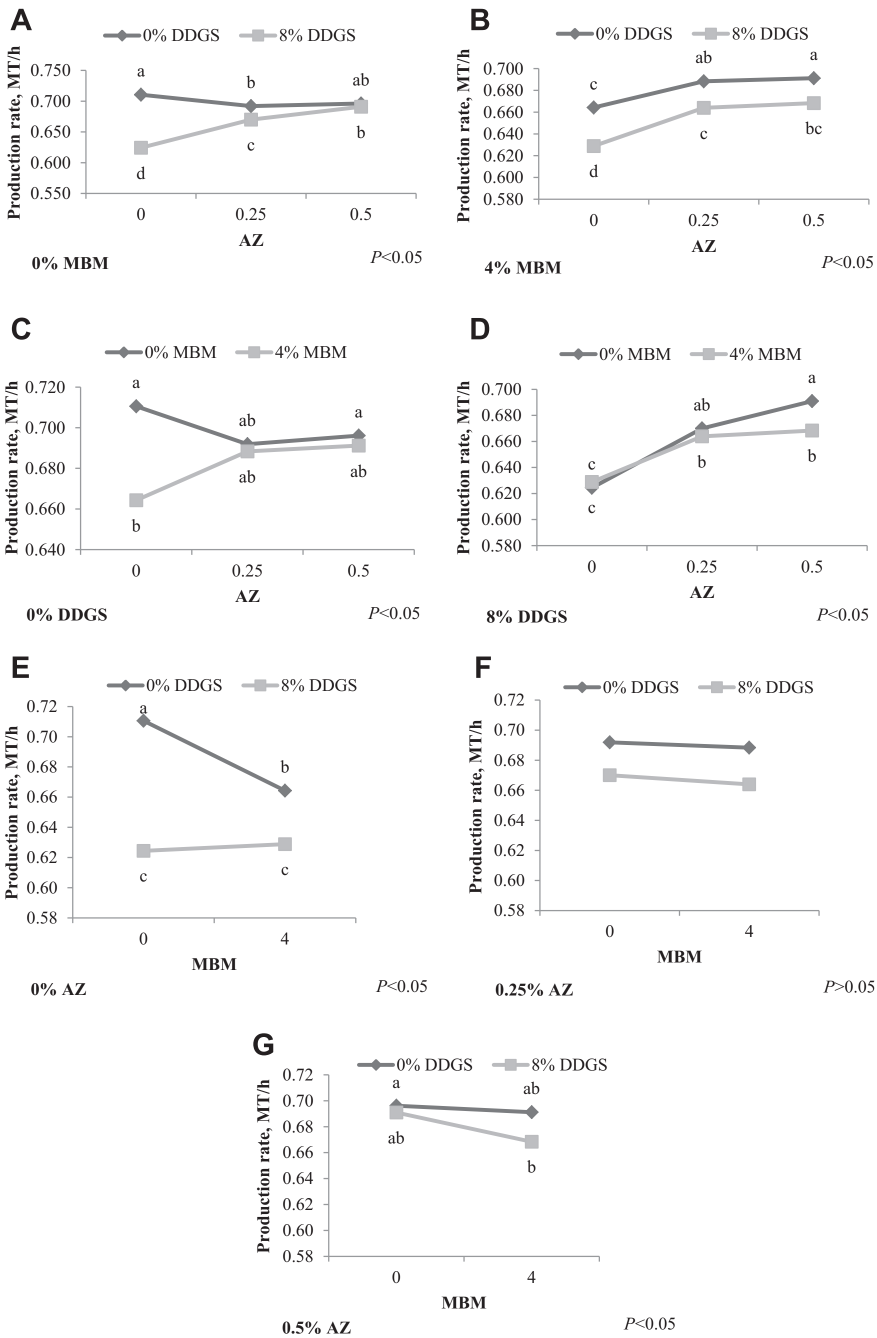

Figure 2. Analysis of three-way interaction between DDGS, MBM, and AZ by fixing one variable constant. (A) Interaction between various DDGS levels (0 and 8%) and AZ levels (0, 0.25, and 0.5%) without MBM in the diet. (B) Interaction between various DDGS levels (0 and 8%) and AZ levels (0, 0.25, and 0.5%) with MBM at 4% in the diet. (C) Interaction between various MBM levels (0 and 4%) and AZ levels (0, 0.25, and 0.5%) without DDGS in the diet. (D) Interaction between various MBM levels (0 and 4%) and AZ levels (0, 0.25, and 0.5%) with DDGS at 8% in the diet. (E) Interaction between various MBM levels (0 and 4%) and DDGS levels (0 and 8%) without AZ in the diet. (F) Interaction between various MBM levels (0 and 4%) and DDGS levels (0 and 8%) with AZ at 0.25% in the diet. (G) Interaction between various MBM levels (0 and 4%) and DDGS levels (0 and 8%) with AZ at 0.5% in the diet. Abbreviations: AZ, AZOMITE; DDGS, distillers dried grains with solubles; MBM, meat and bone meal.

inclusions [7]. Although this is the high end of DDGS inclusion rates for a broiler grower diet, it provides a valuable reference point for industry leaders and future research. An additional factor to consider in this interpretation is the variability in DDGS composition. It is well established that the processing method will change the composition of a given DDGS sample [17]. This variability may result in inconsistent pellet production results.

Despite field reports that MBM influences throughput, the effects of this ingredient had not previously been well documented. In the absence of AZ and DDGS inclusion, the current research reveals that the inclusion of MBM at 4% decreased the pellet production rate in the commercial broiler grower diet used in this experiment. Further work is needed to understand the interaction between MBM and pellet manufacturing under different conditions, including other diet formulations. Additional factors including composition of the MBM will also need to be evaluated as composition may influence how this ingredient changes pellet production rate.

Abundance of nitrogen and phosphorus in waste products of livestock production has been identified as a crucial area of interest regarding environmental impacts [18]. Although it can be mitigated somewhat by composting and management techniques, results are inconsistent, especially regarding the control of phosphorus waste [19]. When poultry litter is applied to agricultural crops, there is a potential for leaching and runoff, which can result in detrimental environmental phenomena, such as harmful algal blooms [20]. As phytases become increasingly popular, there is a decrease in waste phosphorus in poultry litter. A consequence of adding the phytase and taking out inorganic phosphorus sources might include decreased throughput [6].

The current experiment suggests that poultry formulations with DDGS benefit from AZ inclusions (both 0.25 and 0.50%). Evaluation of AZ in finishing and withdrawal diets would be another logical step for future research as these diets typically have the highest inclusions of DDGS. Further research comparing different formulations is warranted to understand the best inclusions and formulations to incorporate AZ to promote pellet production.

As pellet throughput increases, PDI typically decreases, which may be because of lower retention time and less compression in the pellet die [20, 21]. The longer the mash stays within the die, the higher the pressure and consequently the better the pellet. In the present study, both 0.25 and 0.50% AZ inclusions kept PDI constant while increasing pellet production rate. Although AZ did not increase throughput and PDI simultaneously, its ability to improve pellet production while maintaining PDI highlights efficacy in feed manufacturing. Researchers have suggested that silica products may work to improve pellet throughput by scrubbing the accumulated proteinaceous matrix out of the pellet die holes [6]. Further research is needed to understand how AZ improved pellet production in this experiment.

Knowledge of how specific feed ingredients influence pellet quality is important to those responsible for providing diets to commercial flocks, as quality has a direct influence on broiler performance [3]. This information regarding conditioning temperatures may also be helpful when decisions are made regarding pellet production, pellet quality, and nutrient degradation. Beyond the broiler industry, the cumulative findings of the current experiment might also help other industries that pellet their final product.

CONCLUSIONS AND APPLICATIONS

1. Increasing conditioning temperature by 5.6°C, from 82.2°C to 87.8°C, improved pellet production rate and increased pellet durability.
2. MBM (4%) and DDGS (8%) decreased the pellet production rate of broiler grower rations under controlled experimental conditions.
3. DDGS (8%) decreased pellet durability in this broiler grower ration.
4. Inclusion of AZ at 0.25% and 0.50% improved pellet production rates when MBM (4%) and/or DDGS (8%) were used in the diet. The biggest response with AZ was reported when a broiler diet contained 8%

DDGS, especially at the higher dosage of AZ (0.50%). When high amounts of DDGS and MBM are used in the diet, the most effective AZ inclusion is 0.25%.

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