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Non Ruminant Nutrition

The effects of dacitic (rhyolitic) tuff breccia and corn distillers' dried grains with solubles (DDGS) inclusion on pellet mill electrical efficiency, production rate, and subsequent pellet quality

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Abstract

Two experiments were conducted to evaluate the effect of Azomite (AZO) and 30% distillers' dried grains with solubles (DDGS) on pellet mill (PM) electrical consumption (kWh/MT), production rate, and pellet quality. Experiment 1 was conducted as a 2 × 2 × 2 factorial with main effects of diet formulation (0% or 30% DDGS), PM (1 or 2), and AZO (0% or 0.25%) with 4 replications per treatment. PMs were equipped with a 4.4 × 39.0-mm (L:D 8.9) or 4.4 × 35.8 mm (L:D 8.2) die with PM production rates held constant at 31.8 metric ton (MT)/h and conditioning temperature was held constant at approximately 82 °C. Experiment 2 was designed as a 2 × 2 factorial of treatments with 4 replicates per treatment to evaluate the impact of AZO and DDGS on PM production rates and pellet quality. PM production rate was adjusted by the feeder screw to maintain 70% motor load, a 4.0 × 35.8-mm (L:D 8.75) PM die was used, and conditioning temperature held constant at approximately 82 °C. For experiment 1, a DDGS × PM interaction ($P = 0.040$) was observed. Diets containing 30% DDGS had a decreased kWh/MT compared to the control when using PM-1, whereas no differences were observed for kWh/MT between 0% and 30% when using PM-2. A DDGS × PM interaction ($P = 0.019$) was observed for kWh/MT standard deviation (STD). Diets containing DDGS increased STD compared to the control when pelleted with PM-2; however, there was no evidence of difference between the DDGS and control diets when pelleted with PM-1. There was an AZO × DDGS interaction ($P < 0.05$) for kWh/ton STD. No differences were observed in kWh/ton STD when pelleting corn–soy diets with or without AZO while AZO reduced kWh/ton STD in 30% DDGS diets. Diets containing AZO had reduced ($P < 0.05$) kWh/MT and pellet durability index (PDI) compared to diets pelleted without AZO. PDI was improved ($P < 0.05$) for diets containing DDGS. For experiment 2, diets containing AZO had increased ($P < 0.05$) PM production rate compared to those without AZO. The inclusion of 30% DDGS reduced ($P < 0.05$) PM production rate compared to the corn–soy diet. There was a tendency for an AZO × DDGS interaction ($P = 0.083$) for PDI. Azomite inclusion to corn–soy diets reduced PDI while there was no evidence of difference in diets containing DDGS. In conclusion, the addition of 0.25% AZO to the diet improved PM efficiency; however, this potentially leads to a reduced PDI depending on diet type and PM settings.

Lay Summary

The objective of these experiments were to evaluate the effect of Azomite (AZO) and diet formulation containing 30% distillers' dried grains with solubles (DDGS) on pellet mill (PM) electrical consumption (kWh/MT), production rate, and pellet quality. Experiment 1 was conducted as a 2 × 2 × 2 factorial with main effects of diet formulation (0% or 30% DDGS), PM (1 or 2), and AZO (0% or 0.25%) with 4 replications per treatment. Experiment 2 was designed as a 2 × 2 factorial of treatments with 4 replicates per treatment to evaluate the impact of AZO and DDGS-based diets on PM production rates and pellet quality. For experiment 1, PM kWh/ton and standard deviation varied between mills when 30% corn DDGS were added to the diet. However, addition of AZO at 0.25% reduced PM kWh/ton and its standard deviation. For experiment 2, the inclusion of 30% DDGS to the diet and resulting reduction in conditioning temperature reduced PM production rates as expected but the inclusion of AZO to the diets improved PM production rates by 8.3% and 5.2% for corn–soy and DDGS diets, respectively. The addition of 30% DDGS improved pellet durability index (PDI) for both experiments while the addition of AZO reduced PDI for both corn–soybean meal and 30% DDGS diet formulations.

Key words: AZOMITE, electrical consumption, pellet, pellet durability index, production rate

Introduction

Increases in ingredient costs make it more advantageous to pellet feed due to improvements in growth performance, commonly attributed to increased gain-to-feed (G:F) (De Jong et al., 2016; Nemechek et al., 2016; Paulk and Hancock, 2016). However, deciding to pellet feed leads to constraints that can be created at the feed mill by reductions in feed production rates. Pellet mill (PM) production rate is influenced by conditioning temperatures, conditioner retention times, pellet die thickness, and diet composition.

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Distillers' dried grains with solubles (DDGS) are a co-product of the dry-milled ethanol production and can be utilized as a feed ingredient because of its energy and protein contnent. However, the addition of DDGS in the diet has been shown to have negative effects on production rates at as little as 10% in the diet (Fahrenholz, 2008). Meanwhile, DDGS inclusions up to 30% have been used to negate increased ingredient costs.

To mitigate the negative effects of DDGS on PM production rate, feed manufacturers could elect to include pelleting aids, but efficacies may vary depending on diet formulation. One such pelleting aid is Azomite (AZOMITE Mineral Products, Inc., Nephi, UT) (AZO), which is a *dacitic tuff breccia* and classified as a hydrated sodium calcium aluminosilicate. Hydrated sodium calcium aluminosilicates are considered anticaking agents and could be used to reduce binding properties between particles, making it beneficial to add to diets with DDGS (United States Code of Federal Regulations, 21CFR582.2729). Previous research has suggested that the porous shape and anticaking properties reduce residual feed particles left on the inner surface of PM dies, resulting in conditioned mash to be extruded easier through the die (Boltz et al., 2021; Tillman et al., 2020; and Jones et al., 2022). Previous research using AZO has been conducted on diet formulations with up to 16% of the total diet consisting of corn-derived DDGS (Jones et al., 2022). However, no literature has been published to determine the effect of AZO on diets containing 30% DDGS. Therefore, the objective of these experiments was to evaluate PM electrical consumption, production rate, and subsequent pellet durability index (PDI) when pelleting diets formulated with or without AZO and either 0% or 30% DDGS in the diet.

Materials and Methods

Experiment 1

This experiment was arranged as a 2 × 2 × 2 factorial with main effects of dietary inclusion of DDGS (0% or 30% of the diet), AZO (0% or 0.25% of the diet), and 2 separate PMs. This experiment was conducted at the JBS Live Pork Hedrick feed mill (Hedrick, IA). Experimental diets were formulated to be isocaloric and formulated to meet the recommended nutritional requirements for 43 to 71 kg pigs (NRC, 2012). For all replications, supplemental choice white grease added at the mixer was held constant at 1% of the total diet, as shown in Table 1. To determine PM electrical consumption, PM production rates and conditioning temperature were held constant. Therefore, two 500-horsepower PMs (Andritz, Model 32-700, Esbjerg, Denmark) each equipped with a 1,960 L conditioner (Andritz, Model CM1101K) were used to test our objective. Conditioner retention time was approximately 50 s. PM 1 was equipped with a 4.4 × 38.9 mm die (L:D 8.9) while PM-2 was equipped with a 4.4 × 35.8 mm die (L:D 8.2). Both PMs were controlled by the Repete Automation System (Sussex, WI). PM production rate was started at 27.2 metric ton (MT) per hour and 76.7 °C. After achieving the production parameters (approximately 15 min), PM production rate and conditioning temperature were increased to 31.8 MT/h and 79.4 °C, respectively. The conditioning temperature was then increased to 82 °C and production rate was held constant at 31.8 MT/h with a 1% variance dead band setting for the remainder of the replications. Treatment orders were randomly assigned to PMs to be pelleted once per day by each mill. Treatment replications consisted of 43.5 MT. A 43.54-MT "flush" was pelleted after each AZO treatment to coat the PM die and die holes with residual feed particles. The "flush" diet was a common corn–soybean meal-based gestation diet. Pellets resided in the counterflow cooler (Geelen Counterflow, Haelen, Netherlands) for approximately 10 min after being extruded through the PM die. Therefore, pellet samples were collected approximately 10 min after pelleting parameters were achieved with subsequent pellet samples collected every 10 min after. Pellets were collected from a port in the bottom of the discharge drag below the cooler for PDI analysis as described below.

PM electrical data was collected by a Dent power recorder (Dent Instruments ELITEpro XC, Bend, OR). Electrical data collection was recorded in amps with data point collection occurring every 15 s during pelleting. Due to PM roll slippages during the PM runs, 25 min of PM run time was evaluated for PM electrical usage and efficiency. This resulted in 100 data points analyzed per PM treatment replication. The following equations were used to determine the electrical consumption and standard deviation (STD) of electrical consumption which was derived from Stark (1994):

$$\text{kWh per MT} = \frac{\sqrt{3} \times \text{Amps} \times \text{Voltage} \times \text{Power Factor}}{(\text{MT per hour} \times 1,000)}$$

$$\text{STD of kWh per MT} = \frac{\sqrt{3} \times \text{STD. of Amps of} \times \text{Voltage} \times \text{Power Factor}}{(\text{MT per hour} \times 1,000)}$$

For the purposes of this experiment, voltage, power factor, and MT/h were held constant at 480, 0.87, and 31.8, respectively.

Experiment 2

Experiment 2 was completed at the O.H. Kruse Feed Technology and Innovation Center at Kansas State University (Manhattan, KS) to determine the impact of AZO and DDGS inclusions on PM production rates and subsequent pellet quality. Treatments were arranged as a 2 × 2 factorial within a 4 × 4 Latin Square with 4 replicates per treatment. The diets formulated were similar to that of the first experiment with mixer-added fat, soybean oil, inclusion held constant at 1% of the total diet (Table 1). Treatments 1 and 2 contained 0% and 30% DDGS with 0.25% AZO added to the diet while treatments 3 and 4 contained 0% and 30% DDGS, respectively. All replications consisted of 2.72 MT and were mixed with a 907-kg dual ribbon mixer (Model MX-40, Hayes-Stolz Industrial Manufacturing Co., Burleson, TX). Treatment replications were steam conditioned for approximately 30 s (California Pellet Mill 18 INF 6.5) and subsequently pelleted with a 100-horsepower PM (California Pellet Mill, 3016-4) equipped with a 4.0 × 35.0-mm die (L:D 8.75). PM motor load was held constant at 70% with adjustments made to the PM feeder screw to maintain 70% motor load. This allowed for the determination of dietary treatment effects on production rate.

Sample collection included mash, conditioned mash, hot pellet and conditioning temperatures, cooled pellets, and production rates. Hot pellet samples were collected in a thermos with the maximum temperature achieved being recorded. Conditioning temperatures were observed from the

Table 1. Ingredient Composition of experimental diets, as-fed basis

Item	Corn–soybean meal	Corn–SBM-DDGS
Ingredient, %		
Corn	74.20	50.89
Corn DDGS	—	30.00
Soybean meal, Dehull, Sol Extr	21.00	13.10
Choice white grease[1]	1.00	2.50
Monocalcium phosphate	0.40	—
Calcium carbonate	1.25	1.35
Sodium chloride	0.55	0.40
Biolys liquid 32.5%	0.90	1.23
Methionine hydroxy analog	0.15	0.03
L-Thr	0.16	0.09
L-Trp	0.02	0.03
Vitamin trace mineral	0.15	0.15
Azomite[2]	±	±
Total	100	100
Calculated analysis		
Standardized ileal digestible (SID) AA %		
Lys	0.98	0.98
Ile:Lys	57	61
Leu:Lysine	128	162
Methionine:Lys	34.3	30
Met & Cys:Lys	57	57
Thr:Lys	62	62
Trp:Lys	17	18
Val:Lys	65	73
His:Lys	39	42
Total Lysine, %	1.09	1.15
ME, kcal/kg	3,351	3,392
NE, kcal/kg	2,540	2,573
CP, %	15.40	19.45
Crude fiber, %	2.00	3.71
Ether extract, %	3.71	6.29
Ash, %	4.31	4.63
Starch, %	46.97	35.12
Ca, %	0.63	0.59
P, %	0.42	0.48
Available P, %	0.33	0.37

[1]All treatments had 1% mixer-added fat with the balance applied at via post pellet liquid application for 30% DDGS treatments.
[2]AZOMITE, AZOMITE Mineral Products.

control screen at the time of hot pellet sample collection. Pellet samples were collected from the chute opening on the front of the PM and placed in an experimental counterflow cooler for 10 min. Three PM production rates were collected by capturing pellets from the front discharge of the PM for 10 s and then immediately weighed.

Pellet durability index

Pellet samples for both experiments were analyzed for PDI with a 30 s Holmen 100 test (TEKPRO, North Walsham, UK) via air agitation. Pellet samples were sieved using a Tyler #5 (4.0 mm) and #6 screen (3.4 mm) (W.S. Tyler, Mentor, OH) for experiments 1 and 2, respectively, and 100 g of sieved pellets were placed in the Holmen 100 chamber. After air agitation, remaining pellets were sieved once more with their respective sieves and weighed. PDI was then calculated by dividing the final screened pellet weight by the initial weight and multiplying by 100.

Statistical analysis

Data were analyzed as a 2 × 2 × 2 factorial for experiment 1 with main effects of AZO (0% or 0.25% of the diet), DDGS (0% or 30% of the diet), and PM-1 or 2 and all possible interactions. For experiment 2, data were analyzed as a 2 × 2 factorial with main effects of AZO (0% or 0.25% of the diet) and DDGS (0% or 30% of the diet) and their interactions. Both experiments were analyzed using the PROC-GLIMMIX procedure of SAS 9.4 (SAS Institute, Inc., Cary, NC). The fixed effect was treatment with the day of pelleting serving as the random effect for both experiments.

Results

Experiment 1

There was no evidence of a three-way interaction for AZO, DDGS, and PM for any of the analyzed response criteria. Therefore, two interactive means (DDGS × PM and AZO × DDGS) are reported in Tables 2 and 3. For kWh/MT, there was no evidence of interaction for AZO × DDGS or AZO × PM. An interaction was observed for DDGS × PM ($P = 0.04$) for kWh/MT (Table 2). Diets containing 30% DDGS had a decreased kWh/MT compared to the control when using PM-1, whereas no differences were observed for kWh/MT between 0% and 30% when using PM-2. PM electrical standard deviation (STD) was analyzed for this study to further quantify the effects of AZO in common swine diets. A DDGS × PM interaction ($P = 0.019$) was observed for kWh/ton STD. Diets containing DDGS increased STD compared to the corn–soybean meal diets when pelleted with PM-2; however, there was no evidence of difference between the DDGS and corn–soybean meal diets when pelleted with PM-1. There was an AZO × DDGS interaction ($P < 0.05$) for kWh/ton STD. No differences were observed in kWh/ton STD when pelleting corn–soybean meal diets with or without AZO while AZO reduced kWh/ton STD in 30% DDGS diets. Diets containing AZO had reduced ($P < 0.05$) kWh/MT and PDI compared to diets pelleted without AZO (Table 3). DDGS diets had improved PDI ($P < 0.05$) compared to corn–soy diets.

Experiment 2

PM motor load was held constant for all replications at 70% of rated capacity. The target conditioning temperature was 76.7 °C for all treatment replications. However, conditioning temperature achieved for 30% DDGS inclusion treatments was reduced to 64.5 °C. PM conditioning temperatures were adjusted for diets containing 30% DDGS to allow for diets to be pelleted at a constant amperage without plugging. Therefore, the authors acknowledge that diet type is confounded with conditioning temperature; therefore, the diet program (including diet type and pelleting parameters) is being evaluated, not just the diet type. The conditioning temperatures resulted in hot pellet temperatures of 81.60 and 81.87 °C for control diets without AZO and with AZO, respectively. While treatments containing 30% DDGS resulted in hot pellet temperatures of 75.92 and 75.07 °C for diets without and with AZO inclusion (Table 4). There was no evidence of an AZO × DDGS interaction for PM production rate

Table 2. Effects of DDGS addition and PM on PM electrical usage and PDI (experiment 1)[1]

	Corn–soy diet		DDGS			Probability, *P*<		
Item	PM-1	PM-2	PM-1	PM-2	SEM	DDGS × PM	PM	DDGS
kWh/MT[2]	7.64[a]	7.41[ab]	7.12[b]	7.39[ab]	0.112	0.040	0.850	0.027
Std. deviation[3]	0.07[a]	0.04[a]	0.10[a]	0.16[b]	0.019	0.019	0.349	0.002
Pellet durability index, %[4]	50.17	43.12	78.13	73.05	2.09	0.601	0.002	0.001

[1]This experiment was set up as a 2 × 2 × 2 factorial with main effects of Azomite (0% or 0.25%), DDGS (0% or 30%), and PM (1 and 2). There was no evidence of a 3-way interaction ($P > 0.10$). Electrical data were collected in amps by the Dent power recorder (Dent Instruments, Bend, OR) with data points collected in 15 s intervals for the duration of the pelleting run. Data analyses were conducted on 25-min pelleting runs at desired parameters of 82 °C and 31.8 MT/h. PM warm up was kept consistent throughout the experiment.

[2]$\text{kWh/MT} = \frac{(\sqrt{3}\times\text{Avg. Amps}\times\text{Voltage}\times\text{Power Factor})}{(1{,}000\times\text{MT per hour})}$.

[3]$\text{Std. kWh/MT .} = \frac{(\sqrt{3}\times\text{Standard deviation of Amps}\times\text{Voltage}\times\text{Power Factor})}{(1{,}000\times\text{MT per hour})}$

[4]Pellet durability measured by the sieving 100 g of pellets with a #5 sieve (W.S. Tyler) and air agitating for 30 s then sieving off remaining fines.

[a,b,c]Means with differing superscripts are significantly different within row and column ($P < 0.05$).

Table 3. Effects of Azomite (AZO) and DDGS addition on PM electrical usage and PDI (experiment 1)[1]

	Corn–soy diet		DDGS			Probability, *P*<		
Item	No AZO[4]	AZO[4]	No AZO[4]	AZO[4]	SEM	AZO[4] × DDGS	AZO[4]	DDGS
kWh/MT[2]	7.65	7.40	7.51	7.01	0.117	0.274	0.004	0.032
Std. deviation[3]	0.06[b]	0.06[b]	0.18[a]	0.08[b]	0.019	0.033	0.019	0.002
Pellet durability index, %[5]	50.57	42.73	77.64	73.45	3.58	0.328	0.002	0.001

[1]This experiment was set up as a 2 × 2 × 2 factorial with main effects of Azomite (0% or 0.25%), DDGS (0% or 30%), and PM (1 and 2). Electrical data were collected in amps by the Dent power recorder (Dent Instruments, Bend, OR) with data points collected in 15 s intervals for the duration of the pelleting run. Data analyses were conducted on 25-min pelleting runs at desired parameters of 82 °C and 31.8 MT/h. PM warm up was kept consistent throughout the experiment.

[2]$\text{kWh/MT} = \frac{(\sqrt{3}\times\text{Avg. Amps}\times\text{Voltage}\times\text{Power Factor})}{(1{,}000\times\text{MT per hour})}$.

[3]$\text{Std. kWh/MT} = \frac{(\sqrt{3}\times\text{Standard deviation of Amps}\times\text{Voltage}\times\text{Power Factor})}{(1{,}000\times\text{MT per hour})}$.

[4]Azomite, AZOMITE Mineral Products, Inc.

[5]Pellet durability measured by the sieving 100 g of pellets with a #5 sieve (W.S. Tyler) and air agitating for 30 s then sieving off remaining fines.

[a,b,c]Means with differing superscripts are significantly different within row and column ($P < 0.05$).

Table 4. Effects of Azomite[1] (AZO) and DDGS addition on PM production rate and PDI (experiment 2)

	0% DDGS		30% DDGS		SEM	Probability, *P* <		
	0% AZO	0.25% AZO	0% AZO	0.25% AZO		AZO × DDGS	AZO	DDGS
Conditioning temperature, °C	75.53	76.25	65.06	64.30	2.124	0.511	0.985	0.001
Hot pellet temperature, °C	81.60	81.87	75.92	75.07	1.581	0.557	0.756	0.001
Production rate, MT/h[2]	3.61	3.91	3.08	3.24	0.103	0.255	0.001	0.001
kWh/MT	16.41[b]	15.57[c]	19.07[a]	18.92[a]	0.507	0.023	0.002	0.001
Pellet durability index, %[3]	83.16	73.42	86.19	84.23	2.642	0.083	0.011	0.003

[a,b,c]Means within rows with different superscripts denote an interaction and are significantly different ($P < 0.05$).
[1]Azomite, AZOMITE Mineral Products, Inc.
[2]Production rate determined by collecting pellets from the front of the PM for 10 s then weighing.
[3]Pellet durability measured by the sieving 100 g of pellets with a #6 sieve (W.S. Tyler) and air agitating for 30 s then sieving off remaining fines.

(Table 4). Diets containing AZO had increased ($P < 0.05$) PM production rate compared to diet pelleted without AZO. The inclusion of 30% DDGS and subsequent reduction in conditioning temperature reduced ($P < 0.05$) PM production rate compared to diets pelleted without DDGS. An AZO × DDGS interaction ($P = 0.0232$) was observed for kWh/MT. The addition of AZO to corn–soybean meal diets reduced electrical consumption required to pellet 1 MT while the same degree of reduction was not observed in the 30% DDGS diet. There was a tendency for an AZO × DDGS interaction ($P = 0.083$) for PDI. Azomite inclusion to corn–soybean meal diets reduced PDI while there was no evidence of difference in diets containing DDGS.

Discussion

Components of the pelleting process, such as steam conditioning and feed retention time in the conditioner and die, expose feed to various degrees of heat, moisture, pressure, and sheer which changes the pellets' physical and chemical characteristics. When ingredients used in diet formulation are exposed to the steam conditioning process and extrusion through the die, the heat and moisture plasticize the soluble fractions of the diet and increase the agglomeration of dietary components (Lundblad et al., 2009). The interactions between these various components and their chemical composition influence the rate at which the feed moves through the die and ultimately affects PM production rate. Previous research has demonstrated that DDGS may be included in up to 40% of the diet without negatively affecting PM electrical consumption when diets are isocaloric (no mixer-added fat for any treatments) and balanced to meet nutritional requirements of growing pigs (Fahrenholz, 2008). However, oil content within DDGS could reduce friction of feed as it passes through the die thus requiring less electrical consumption to be extruded. In the experiment conducted herein, inclusion of 30% DDGS reduced kWh/MT in one PM while the same degree of reductions in electrical consumption was not observed within the second PM. This illustrates that individual PMs (even the same models) can potentially react differently to diet formulation when under the same environmental conditions. The variation in the response to the data conducted herein compares to that of Fahrenholz (2008) and may also depend on differences in composition of DDGS. However, the author did not provide nutrient analysis of the DDGS used within the experiment.

Inconsistent electrical consumption throughout the duration of the pelleting run was observed with electrical consumption increasing and decreasing throughout the pelleting run. Therefore, the STD of PM electrical consumption was calculated to understand the impact of DDGS and AZO on individual PMs and the consistency of the pelleting process. By calculating standard deviations, a better understanding of electrical consumption was observed between the two diet formulations. PM electrical STD is an estimate of the consistency of a PM's operation. This demonstrates less electrical consumption from inadvertent electrical surges to the PM which allows operators to control PMs more efficiently. In multiple pellet line facilities, increased electrical consumption STD between PMs requires operators to prioritize the PM that has increased STD and reducing efficiency of other PMs within the facility by demanding more attention be paid to the PM with increased STD. The inclusion of DDGS increased the STD of kWh/MT during pelleting in PM-2 while the same increase in STD of kWh/MT was not observed within PM-1. However, the inclusion of AZO to treatments containing DDGS reduced the STD of kWh/MT while the same degree of reduction was not observed for the corn–soybean meal treatments. Within the current experiment, STD of electrical consumption was exacerbated by DDGS inclusion but the die scoring and polishing capabilities, proposed by Boltz et al. (2021), of AZO was able to negate the potential negative impacts of DDGS inclusion on electrical consumption consistency.

The inclusion of AZO reduced PM electrical consumption by 3.27% and 6.66% for corn–soybean meal and 30% DDGS diets, respectively. These observations agree with previous research conducted by Bowen et al. (2022) that observed that the inclusion of AZO to the diet reduced PM motor load by 1% when production rate was held constant for diets that contained 5% DDGS. The difference in the degree of response to AZO could potentially be explained by the difference in DDGS inclusions (30% vs. 5%) rates within diets. However, it is important to note that the diets utilized by Bowen et al. (2022) had decreased concentrations of corn, increased concentrations of soybean meal, limestone, and dicalcium phosphate, but equal amounts of mixer-added fat compared to the experiments conducted herein.

PM production rate is one of the largest key performance indicators for feed manufacturers, as this can be directly related to the cost of feed production. Due to logistical constraints at the manufacturing site in experiment 1, the production rate experiment was conducted at the O.H. Kruse Feed Technology Innovation Center. It was observed that the addition of DDGS in the diet and reducing conditioning temperature reduced PM throughput by 15% and 17% without and with AZO, respectively. However, the addition of AZO improved PM throughput by 8.31% and 5.19% for corn–soybean meal and 30% DDGS diets, respectively. These observations agree with Boltz et al. (2021) and Tillman et al. (2020) that AZO improves PM throughput by 7% and 6% respectively. Whereas the inclusion of DDGS has been previously shown to decrease PM production rate, which can be attributed to a reduction of feed bulk density as DDGS inclusion increases (Fahrenholz, 2008). PM throughput improvements with AZO could be due to the scrubbing and polishing factors that have been proposed. Boltz et al. (2021) suggested that the improvements to PM production rates due to AZO inclusion is due to the coarse texture of AZO and scrubbing the PM die of residual feed particles left in pellet die holes. Removing feed particles from the die hole could create less drag for new feed particles to push through. Like the findings of the current study, Jones et al. (2022) observed that the inclusion of AZO to diets containing up to 16% DDGS had improved PM throughput. However, the authors state the variability in PM throughput between days could be a result of the variation in DDGS composition or treatment did not contain enough feed. It was hypothesized that the variation could also be due to the nature of AZO scrubbing the pellet die surface and with too small of treatment sizes (tonnage), not enough feed would be deposited back on the die for accurate assessments to be made pelleting DDGS with or without AZO.

PDI values are used as a predictive measure to quantitatively estimate pellet quality as opposed to categorical assessments based on visual estimations (Stark, 1994). Previous research has shown that addition of DDGS in the diet, reduced PDI scores (Fahrenholz, 2008; Tillman et al., 2020). Contrary to the previous literature, PDIs were improved by the addition of 30% DDGS in the diets by 27 percentage points for diets without AZO when production rate was kept constant. Whereas PDIs were improved by 31 percentage points for diets containing DDGS and AZO compared to the corn–soybean meal diets with AZO. Feoli (2008) also observed improvements to PDIs for diets containing 30% corn DDGS; however, these findings of improvements to PDI for DDGS inclusive diets are minimal. Stark (1994) observed that increasing protein content of the diet improved PDI which could explain the observed improvements for diets containing DDGSS (19% CP) compared to corn–soybean meal diets (15% CP). Meanwhile, the inclusion of AZO to diets reduced PDIs by 8 percentage points and 4 percentage points for corn–soybean meal and 30% DDGS diets, respectively. These findings are in contrast with the observations by Tillman et al. (2020), who observed that the inclusion of AZO to the diet had no effect on PDI. To improve the pellet durability for the current experiments, increasing conditioning temperature for diets containing AZO could allow for increased heat and moisture penetration into the feed particles (Behnke, 1994). The improvements observed in PDIs in experiments 1 and 2 for diets containing 30% DDGS is not commonly observed. Behnke (2007) attributed the reductions in PDI for DDGS-based diets to its reduced starch content and increased oil content.

In conclusion, PM kWh/ton and standard deviation vary between mills when 30% corn DDGS are added to the diet. However, addition of AZO at 0.25% reduced PM kWh/ton and its standard deviation. The inclusion of 30% DDGS to the diet reduced PM production rates as expected but the inclusion of AZO to the diets improved PM production rates by 8.3% and 5.2% for corn–soy and DDGS diets, respectively. The addition of 30% DDGS improved PDI for both experiments while the addition of AZO reduced PDI for both corn–soybean meal and 30% DDGS diet formulations.

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Conflict of interest statement

The authors affirmatively acknowledge that they were free from influence by any company and its employees that would result in any conflict of interest. J. Ferrel is a current employee of AZOMITE Mineral Products, Inc. AZOMITE Mineral Products, Inc., provided partial financial support for the project. He was involved with the initial discussions pertaining to experimental design and final review of the publication but did not conduct the experiment.

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