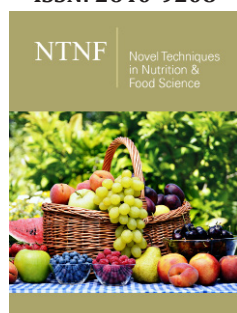


Influence of Ring Die Parameters and Dietary Supplementation with the Mold Inhibitor DMX-7 on Pellet Feed Quality and Growth Performance in Weaned Piglets

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Abstract

This study investigated the effects of ring die parameters and dietary mold inhibitor DMX-7 on pellet feed quality and the growth performance of weaned piglets. A total of 600 weaned piglets (28-day-old) were randomly assigned to three groups, which differed in die hole length-to-diameter ratios (L/D=6:1, L/D=12:1) and DMX-7 supplementation: T1 (L/D=6:1, basal diet), T2 (L/D=12:1, basal diet) and T3 (L/D=12:1, basal diet+0.15% DMX-7+1.3% water). The trial lasted for 30 days. Results showed that the T3 group's feed pellets exhibited superior surface smoothness, compactness and the least severe Maillard reaction. Significantly higher moisture content, starch gelatinization degree and Pellet Durability Index (PDI) were observed in T3 compared to T1 and T2. Moreover, piglets in the T3 group demonstrated increased final body weight, Average Daily Gain (ADG) and Average Daily Feed Intake (ADFI), accompanied by a reduced Feed Conversion Ratio (FCR) when compared to the T1 group. In conclusion, a higher die L/D ratio improved pellet quality and DMX-7 supplementation further enhanced both feed pellet processing quality and piglet growth performance.

Keywords: Weaned piglets; Ring die parameters; Mold inhibitor; Pellet feed processing quality; Growth performance

Introduction

In recent years, the rapid development of the modern intensive and large-scale pig production, coupled with advances in animal nutrition research, has highlighted the importance of the interaction between pellet feed processing and the nutritional utilization of weaned piglets. The early development of piglet organs directly impacts their subsequent production performance and survival rate during the fattening period [1]. Piglets, characterized by incompletely developed gastrointestinal tracts in the early post-weaning phase, rely heavily on liquid milk or milk powder. However, in practice, plant-based solid feed is commonly provided post-weaning, which can stimulate the gastrointestinal tract, damage intestinal tissue and subsequently lead to reduced feed intake and diarrhea [2]. Additionally, weaned piglets are highly sensitive to anti-nutritional factors and mycotoxins present in plant-based solid feed. Feed processing involves multiple factors influencing pellet feed quality, including the feed formula, raw material particle size, conditioning, pelleting process and cooling conditions. Among these, the conditioning and pelleting processes alone account for over 35% of the impact. Previous studies have demonstrated that the pelleting process can gelatinize starch in grains, eliminate anti-nutritional factors (such as trypsin inhibitors) and inactivate harmful pathogens (such as *Escherichia coli*) in feed materials, thereby enhancing nutrient digestion and absorption, safeguarding intestinal health and reducing the diarrhea rate in piglets [3,4]. Conversely, high temperature and pressure during conditioning and pelleting may increase

the loss of heat-sensitive nutrients, exacerbate the Maillard reaction in feed and decrease the nutritional value of protein and amino acids [5]. Currently, improving pellet feed processing quality and promoting the healthy growth of weaned piglets have emerged as crucial issues in the pig industry. A newly developed mold inhibitor, DMX-7, has been reported to preserve feed freshness, prevent mold growth, inhibit insects and regulate water activity. Comprising components such as ammonium propionate, propionic acid, sodium hydroxide, magnesium chloride and calcium chloride, DMX-7 holds potential benefits. Nevertheless, limited research has explored whether supplementing mold inhibitors can effectively enhance pellet feed processing quality and animal production performance. Against this backdrop, this study aimed to test the hypothesis that adjusting ring die parameters and supplementing DMX-7 in the diet could improve the processing quality of pellet feed and the growth performance of weaned piglets.

Materials and Methods

Experimental design

A total of 600 piglets (Large White×Landrace×Duroc) weaned at 28 days of age, with an average initial body weight of 8.05 ± 0.11 kg, were remained on trial until 58 days of age. Piglets were randomly divided into 3 treatment groups: control group (T1), treatment 2 (T2) and treatment 3 (T3), with 10 replicates per group and 20 piglets per replicate. The diets offered were identical in nutritional composition; the only difference was the die hole length-to-diameter ratio used during pelleting. Diets for all groups were manufactured using a CPM pellet mill (California Pellet Mill, San Francisco, CA) equipped with a die featuring 3.0 mm diameter holes. Piglets in the T1 group were fed pellet feed manufactured with a die hole length-to-diameter ratio of 6:1 and a basal diet. Piglets in the T2 group were fed pellet feed manufactured with a die hole length-to-diameter ratio of 12:1 and a basal diet. Piglets in the T3 group were fed pellet feed manufactured with a die hole length-to-diameter ratio of 12:1, a basal diet supplemented with 0.15% DMX-7 and 1.3% added water for 30 days. All piglets were housed in groups within pens with plastic floors in an environmentally controlled room maintained at an ambient temperature of 28°C. Piglets had free access to feed and water. Feed intake, vitality and fecal consistency were observed and recorded daily. The experiment used corn-soybean meal basal diets provided by Anhui Wellhope Agri-Tech Co., Ltd. The chemical compositions are given in Table 1. The novel mold inhibitor (DMX-7), provided by Shanghai Wanmeng Biotechnology Co., Ltd., is rich in ammonium propionate, propionic acid, sodium hydroxide, magnesium chloride, calcium chloride and other components. The diet for each group was produced according to the feed processing parameters shown in Table 2. The DMX-7 and water for the T3 group diet were added to the mash feed in the mixer via spraying. Experimental diets were batch-manufactured as a mash and then pelleted to achieve the different die hole length-to-diameter ratios, minimizing variation between dietary treatments. Composition of premix per kg of diet: Cu (as copper sulfate) 4,000mg, Fe (as ferrous sulfate) 8,40 mg, Mn (as manganese sulfate) 1,500mg, Se (as sodium selenite) 17mg, Vitamin A 500,000

IU, Vitamin D3 100,000 IU, Vitamin E 1,000mg, Vitamin K3 100mg, Vitamin B1 100mg, Vitamin B2 400mg, Vitamin B6 75mg, Niacin, 2,000mg, Pantothenic acid 1,000mg, Folic acid, 50mg.

Table 1: The composition and nutrient content of the basal diet (air dry basis).

Ingredients	Contents (%)	Nutrient levels	Contents (%)
Corn	56	Crude protein	17
Soybean meal	10.5	Total calcium	0.7
Wheat flour	7.5	Total phosphorus	0.55
Extruded soybean	5	Net energy (NE), MJ/kg	10.46
Fermented soybean meal	5	Digestible Lys	1.15
Whey powder	5	Digestible Met	0.4
Steamed fish meal 67%	2	Digestible Met+Cys	0.68
Sucrose	2	Digestible Thr	0.78
Soybean oil	1.5	Digestible Trp	0.23
Dicalcium phosphate	1.3		
Limestone	0.65		
Acidifier	0.4		
Sodium chloride	0.35		
Sodium bicarbonate	0.25		
98% Lysine hydrochloride	0.3		
L-Threonine	0.1		
DL-Methionine	0.1		
Tryptophan	0.02		
Antioxidants	0.03		
Premix	2		
Total	100		

Table 2: Feed processing parameters.

Group	Diameter of Die Hole	length-to-diameter ratio of die hole	DMX-7	Water
T1	3.0 mm	6: 1	-	
T2	3.0 mm	12: 1	-	
T3	3.0 mm	12: 1	0.15%	1.30%

Measurement and methods

Pellet feed processing index sampling: For each treatment, feed was sampled 5 times: After the mixing process and during the packaging process. The interval between each sampling event was consistent and each sample weighed at least 2kg. After sampling, samples were packed in sealed bags and stored at 4°C for subsequent analysis.

Particle appearance: The surface morphology of pellet feed samples was observed using a scanning electron microscope ($\times 100$ magnification) and photographed.

Feed moisture: The moisture content of the mixed mash feed samples and the pellet feed samples collected during packaging was determined according to the national standard method [6].

Starch gelatinization degree: The starch gelatinization degree of pellet feed samples was measured using methods reported by Xiong [7].

Pellet hardness: The hardness of pellet feed samples was measured directly using a pellet hardness meter (KQ-3 type). Approximately 20g of the feed sample was quartered. Twenty pellets of uniform length (approximately 1 cm) were randomly selected from each quarter and their radial breaking force was measured. The result was calculated as the average hardness.

Pellet diameter: The diameter of pellet feed samples was measured directly using vernier calipers. Approximately 20g of the sample feed was quartered. Twenty pellets of uniform length (approximately 1cm) were randomly selected from each portion and their diameter was measured radially. The result was calculated as the average value.

Pellet durability index (PDI): The PDI of pellet feed was measured using the standard rotary box method of the American Society of Agricultural and Biological Engineers (WKT131 tester, WEMO-Techniek, NL) [8]. A 200g sample was weighed and placed into the tester. The box was rotated at 1500 rpm for 60 seconds. The remaining intact pellet feed was weighed and the PDI was calculated according to the following formula:

$$\text{PDI (\%)} = (\text{Weight of remaining pellet feed} / \text{Total weight of the sample}) \times 100$$

Growth performance: Piglets were individually weighed on the day of weaning (start of trial) and at the end of the experiment. Individual animals were identified by ear tags. Daily feed intake per pen was measured each morning by weighing the previous day's feed refusals. This allowed for the calculation of Average Daily Feed Intake (ADFI), Average Daily Gain (ADG) and Feed Conversion Ratio (FCR) for each replicate group.

Statistical analysis

Experimental data are expressed as mean $\pm$ Standard Deviation (SD). One-Way Analysis of Variance (ANOVA) was performed using SPSS software (version 18.0). Duncan's multiple range test was used for post-hoc comparisons when significant differences ($P < 0.05$) were detected by ANOVA.

Results

Effect of ring die parameters and dietary DMX-7 supplementation on the surface morphology of pellet feed

The effect of ring die parameters and dietary DMX-7 supplementation on the surface morphology of pellet feed is shown in Figures 1 & 2. Pellet feed from the T3 group demonstrated superior surface smoothness and enhanced inhibition of the Maillard reaction compared to the other groups (Figure 1). As shown in Figure 2, pellet feed from the T3 group exhibited fewer longitudinal cracks and better compactness than that from the other groups. Moreover, pellet feed from the T2 group showed better resistance to longitudinal cracks and higher compactness than that from the T1 group. However, there was no significant difference in pellet surface smoothness or Maillard reaction degree between the T1 and T2 groups.

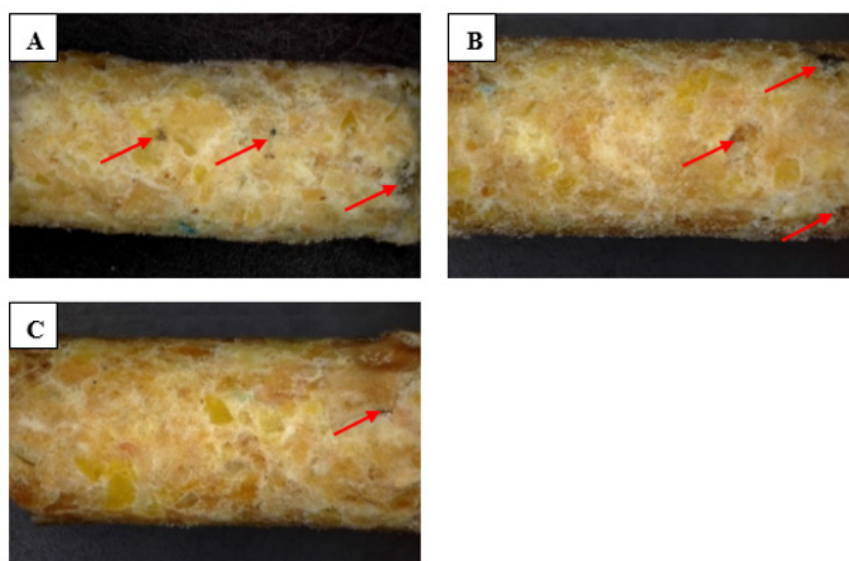


Figure 1: Effect of ring die parameters and dietary DMX-7 supplementation on the surface smoothness and inhibition of the Maillard reaction of pellet feed.

A. T1 group (pellet feed manufactured with die hole L/D ratio 6:1, basal diet)

B. T2 group (pellet feed manufactured with die hole L/D ratio 12:1, basal diet)

C. T3 group (pellet feed manufactured with die hole L/D ratio 12:1, basal diet+0.15% DMX-7+1.3% water). The same as follows

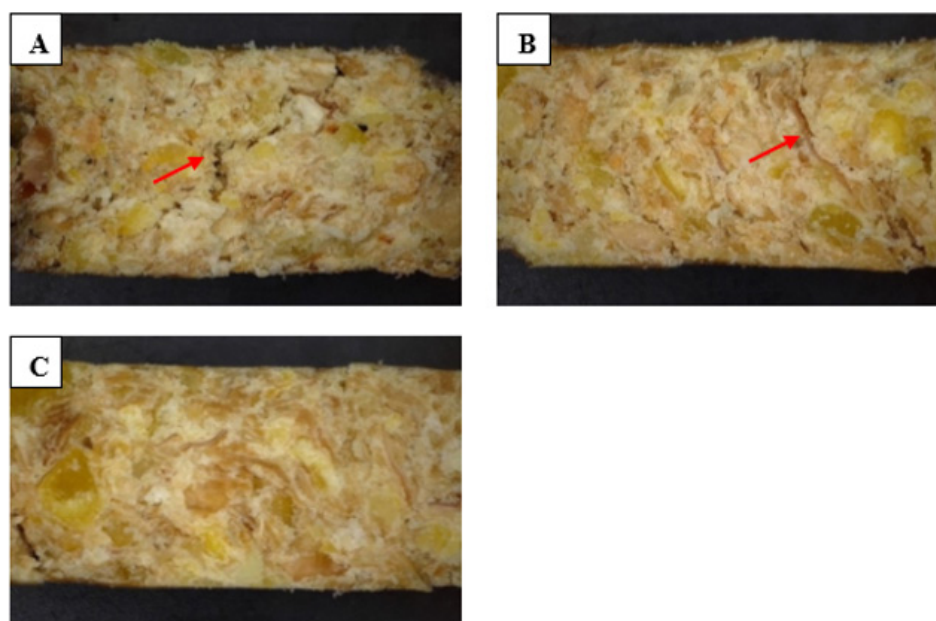


Figure 2: Effect of ring die parameters and dietary DMX-7 supplementation on the longitudinal cracks and compactness of pellet feed.

Effect of ring die parameters and dietary DMX-7 supplementation on pellet feed processing quality

As shown in Table 3, the moisture contents of mash feed in the mixer and of final pellet feed, as well as the starch gelatinization degree and the PDI of pellet feed in the T3 group, were significantly higher than those in the other groups ($P < 0.05$). In addition, the starch gelatinization degree, pellet hardness and PDI of pellet feed in the T2 group were significantly greater than those in the T1 group ($P < 0.05$). However, there was no significant difference in pellet diameter among the three groups ($P > 0.05$).

Table 3: Effect of ring die parameters and dietary DMX-7 supplementation on pellet feed processing quality.

Item	T1	T2	T3
Moisture contents of mash feed at mixer/%	12.49±0.08b	12.52±0.10b	13.32±0.10a
Moisture contents of final pellet feed/%	12.62±0.05b	12.49±0.06b	13.43±0.09a
Starch gelatinization degree/%	24.02±0.34c	29.77±0.72b	34.81±0.44a
Pellet hardness/N	15.90±1.04b	24.30±1.30a	22.77±2.01a
Pellet diameter/mm	3.33±0.07	3.27±0.05	3.30±0.03
Pellet Durability Index (PDI)/%	35.28±0.22c	44.25±0.18b	65.45±0.30a

Effect of ring die parameters and dietary DMX-7 supplementation on growth performance of weaned piglets

The growth performance data of weaned piglets are presented in Table 4. There was no significant difference in initial body weight among the three groups ($P > 0.05$). The final body weight, ADFI and ADG of piglets in the T3 group were increased by 5.61% and 1.57%, 4.85% and 2.26% and 11.78% and 7.67%, respectively, compared to the T1 and T2 groups. Compared with the T1 group, the FCR of

piglets in the T3 group was significantly decreased ($P < 0.05$), but there was no significant difference in FCR between the T2 and T3 groups ($P > 0.05$).

Table 4: Effect of ring die parameters and dietary DMX-7 supplementation on growth performance of weaned piglets.

Item	T1	T2	T3
Initial body weight/kg	8.57±0.88	8.89±1.67	8.25±1.71
Final body weight/kg	20.85±1.90	21.68±1.54	22.02±2.25
Average Daily Feed Intake (ADFI) /g·d ⁻¹	661.10±20.02	677.86±22.18	693.17±15.15
Average Daily Gain (ADG) /g·d ⁻¹	410.67±28.04	426.33±19.42	459.05±25.94
Feed Conversion Ratio (FCR)	1.62±0.08a	1.58±0.09ab	1.50±0.04b

Discussion

Effect of experimental treatment on the surface morphology and processing quality of pellet feed

Feed conditioning is a complex hydration process resulting from the combined effects of feed, moisture, heat, pressure and time. Among these factors, moisture is key; it enhances starch gelatinization and adhesion, with an ideal conditioning moisture content of 16-18%. Under the same feed formula and conditioning temperature, moisture content predominantly determines the degree of starch gelatinization during feed conditioning. If the moisture content of feed ingredients is too low, starch gelatinization becomes uneven or incomplete, especially under high-temperature and high-pressure conditioning. This also triggers a more severe Maillard reaction between free amino acids (such as lysine) and reducing sugars,

leading to nutrient loss and impeding the digestion and utilization of proteins and amino acids in animal feed [9-11]. Given the special physiological characteristics of weaned piglets and the specificity of their feed formulas, high-quality pellet feed processing requires high starch gelatinization, low nutrient loss, suitable pellet hardness and a low powder percentage. Previous studies indicate that appropriately increasing the length-to-diameter ratio of the die hole enhances the extrusion and friction effects within the ring die, raising the feed temperature during pelleting. Consequently, this significantly improves the starch gelatinization degree, compactness, hardness and surface smoothness of pellet feed, while reducing longitudinal cracks and powder percentage, thus enhancing feed palatability [12-15].

In the present study, a high die hole length-to-diameter ratio significantly improved the surface morphology (reduced cracks, higher compactness), starch gelatinization, hardness and PDI of pellet feed. However, it did not mitigate the Maillard reaction. Presumably, with the inherently low moisture content of feed ingredients, the high friction generated when mash feed passes through the ring die with a high L/D ratio result in incomplete feed hydration during conditioning, thereby intensifying the Maillard reaction in pellet feed. A previous study demonstrated that adding 0.5-1.5% water to mash feed in the mixer notably enhanced the appearance quality of pellet feed, increased starch gelatinization and PDI and reduced the powder percentage and nutrient loss [16]. While adding water to mash feed in the mixer can increase conditioning moisture, this approach is vulnerable to inconsistent addition ratios and methods, potentially causing quality risks such as mold growth and shortened shelf life. In this study, we utilized a novel mold inhibitor product (DMX-7). Based on a high die hole L/D ratio, a mixture of 0.15% DMX-7 and 1.3% water was added during the mixing stage. This intervention positively influenced pellet feed processing quality by improving appearance quality (smoothness, reduced Maillard reaction) and increasing final moisture content, starch gelatinization degree, hardness and PDI. DMX-7 contains hygroscopic substances like magnesium chloride and calcium chloride, which help stabilize water within the feed matrix, promoting water penetration and starch gelatinization, enhancing hydration and ultimately preventing the Maillard reaction during conditioning. Simultaneously, its efficient mold-inhibiting components extend the feed's shelf life [17]. This finding aligns with previous research reporting that water optimization combined with a liquid mold inhibitor system positively impacts pellet feed production [18-20].

Conclusion

In conclusion, this study clearly indicates that a high die hole length-to-diameter ratio significantly improves the surface morphology (reduced cracks, higher compactness), starch gelatinization, hardness and PDI of pellet feed. Furthermore, dietary DMX-7 supplementation can enhance the processing quality of pellet feed (surface smoothness, reduced Maillard reaction, higher moisture, starch gelatinization, PDI) and improve the growth performance (increased final BW, ADFI, ADG; improved FCR) of weaned piglets.

Moreover, the results suggest that water optimization combined with a liquid mold inhibitor system represents a potential technical strategy to improve the processing quality of pellet feed and the growth performance of pigs.

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Disclosure Statement

No potential conflict of interest was reported by the authors.

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