Effects of Fermented Distiller's Grains on Growth Performance, Digestion and Metabolism, and Nitrogen Emissions in Weaned Piglets (Postprint)

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Abstract

To investigate the effects of fermented distiller' s grains on growth performance, digestion and metabolism, and nitrogen emission in weaned piglets, twenty-four 21-day-old weaned castrated Duroc × Landrace × Large Yorkshire barrows were selected and randomly allocated to 4 groups with 6 replicates per group and 1 pig per replicate. The control group was fed a basal diet, while the experimental groups were fed diets in which 2%, 4%, and 6% fermented distiller' s grains were used to equally replace the basal diet, respectively. When the average body weight reached approximately 10 kg and 25 kg, the experimental pigs were transferred to metabolism cages for digestion and metabolism trials. Each trial period lasted for 1 week, with the first 4 days as an adaptation period and the last 3 days as a fecal and urinary collection period. Daily feed intake of the piglets was recorded, and fasting body weight was measured at the beginning and end of each trial. The total fecal collection method was employed to determine the apparent digestibility of conventional nutrients and amino acids, as well as nitrogen excretion, in weaned piglets. The results showed that, compared with the control group, in the 10 kg weaned piglet trial, the 2% fermented distiller' s grains group exhibited significantly lower apparent digestible energy and urinary nitrogen ($P<0.05$), with no significant differences in the apparent digestibility of other nutrients ($P>0.05$); the 4% and 6% fermented distiller' s grains groups showed significantly reduced apparent digestibility of gross energy, lysine, methionine, and proline, as well as apparent metabolizable energy and apparent digestible energy ($P<0.05$). In the 25 kg weaned piglet trial, the 2% fermented distiller' s grains group showed no significant differences in the apparent digestibility of dry matter, crude ash, and crude fat ($P>0.05$), but exhibited a significant increase in average daily gain ($P<0.05$); the 6% fermented distiller' s grains group displayed a significant decrease in methionine apparent digestibility ($P<0.05$); the 2%, 4%, and 6% fermented distiller' s grains groups all showed significant reductions in nitrogen intake, nitrogen absorption, nitrogen retention,

apparent digestibility of crude protein and gross energy, apparent nitrogen digestibility, apparent metabolizable energy, and digestible energy (P<0.05), with a significant increase in fecal nitrogen (P<0.05). These results indicate that dietary supplementation with 2% fermented distiller' s grains does not affect the apparent digestibility of dry matter in weaned piglets and can improve their growth performance; long-term high-dose supplementation with fermented distiller' s grains reduces the digestion and metabolism of conventional nutrients in weaned piglets to a certain extent.

Full Text

Effects of Fermented Distiller' s Grains on Growth Performance, Digestibility and Metabolism, and Nitrogen Excretion of Weaned Piglets

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Abstract

This study was conducted to investigate the effects of fermented distiller's grains (FDG) on growth performance, digestibility and metabolism, and nitrogen excretion in weaned piglets. Twenty-four 21-day-old weaned Duroc × Landrace × Yorkshire barrows were randomly allocated into four groups with six replicates per group and one pig per replicate. The control group was fed a basal diet, while the experimental groups were fed the basal diet with 2%, 4%, or 6% FDG substituted at equal proportions. Digestion and metabolism trials were performed when the average body weight reached approximately 10 kg and 25 kg, respectively, after transferring the pigs to metabolic cages. Each trial lasted for one week, consisting of a 4-day adaptation period followed by a 3-day collection period for feces and urine. Daily feed intake was recorded, and fasting body weight was measured at the beginning and end of each trial. The apparent digestibility of routine nutrients and amino acids, as well as nitrogen excretion, were determined using the total feces collection method.

The results showed that in the 10 kg trial, compared with the control group, the 2% FDG group exhibited significantly lower apparent digestible energy (ADE) and urinary nitrogen ($P < 0.05$), with no significant differences in other nutrient digestibility rates ($P > 0.05$). The 4% and 6% FDG groups showed significantly reduced apparent digestibility of gross energy, lysine, methionine, and proline,

as well as lower apparent metabolizable energy (AME) and ADE ($P < 0.05$). In the 25 kg trial, the 2% FDG group showed no significant differences in apparent digestibility of dry matter, crude ash, and ether extract ($P > 0.05$), but average daily gain increased significantly ($P < 0.05$). The 6% FDG group exhibited significantly decreased methionine digestibility ($P < 0.05$). Across all FDG-supplemented groups (2%, 4%, and 6%), nitrogen intake, absorbed nitrogen, retained nitrogen, and nitrogen apparent digestibility were significantly reduced ($P < 0.05$), as were the apparent digestibility of crude protein and gross energy, AME, and ADE ($P < 0.05$), while fecal nitrogen increased significantly ($P < 0.05$).

These findings indicate that dietary supplementation with 2% FDG does not affect the apparent digestibility of dry matter and can improve growth performance in weaned piglets, whereas long-term supplementation with high doses of FDG reduces the digestion and metabolism of routine nutrients to some extent.

Keywords: fermented distiller' s grains; weaned piglets; growth performance; digestibility; nitrogen excretion

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Introduction

Distiller' s grains are a major byproduct of the liquor industry, characterized by large production volumes and concentrated sources. They are rich in conventional nutrients such as crude protein, crude starch, crude fiber, and ether extract, as well as abundant amino acids, vitamins, minerals, and various bioactive substances produced by microbial autolysis. However, distiller' s grains have high moisture content, strong acidity, high viscosity, and are prone to spoilage, which can cause environmental pollution if not processed promptly. Additionally, their high crude fiber content substantially reduces their feeding value. Microbial fermentation can degrade starch, cellulose, and hemicellulose in distiller' s grains, fully utilizing carbon and nitrogen sources and significantly increasing the true protein content of the fermented product. Therefore, distiller' s grains can serve as a new protein feed resource to alleviate the shortage of protein feed resources in animal husbandry.

Previous studies have demonstrated that dietary supplementation with 9.25% fermented distiller's grains can improve production performance and nutrient digestibility in yaks, while replacing 17% of concentrate with fermented distiller' s grains significantly increased daily gain, reduced feed-to-gain ratio, and improved apparent nutrient digestibility and economic benefits in Tibetan sheep. Wet fermented distiller' s grains protein feed has been shown to increase egg production rate and reduce ammonia concentration in chicken houses. Although the digestible and metabolizable energy of distiller' s grains for growing pigs is lower than that of soybean meal, they still possess considerable feeding value. Weaned piglets are susceptible to digestive and metabolic disturbances due to weaning stress and environmental changes, and the nutrients, microorganisms,

and their metabolites in fermented distiller' s grains may benefit their growth and development. While some reports on the utilization of fermented distiller' s grains exist, few have focused on weaned piglets. Therefore, this study aimed to investigate the effects of different inclusion levels of fermented distiller' s grains on growth performance, digestibility and metabolism, and nitrogen excretion in weaned piglets, providing a scientific basis for their development and utilization as a protein feed ingredient.

Materials and Methods

1.1 Fermented Distiller' s Grains The fermented distiller' s grains were obtained from a company in Sichuan Province. Analysis showed that they contained 92.97% dry matter, 9.28% crude ash, 23.96% crude protein, 5.39% ether extract, 17.67% crude fiber, and 18.29 MJ/kg gross energy.

1.2 Experimental Animals, Grouping, and Management The animal feeding trial was conducted from March to April 2016 at the Xinfengfeng Yong' an Experimental Base of the Institute of Subtropical Agriculture, Chinese Academy of Sciences. Twenty-four 21-day-old weaned Duroc × Landrace × Yorkshire barrows were randomly divided into four groups with six replicates per group and one pig per replicate. The control group was fed a basal diet in powder form, while the experimental groups were fed the basal diet with 2%, 4%, or 6% fermented distiller' s grains substituted at equal proportions. When the average body weight reached approximately 10 kg and 25 kg, the pigs were transferred to metabolic cages for digestion and metabolism trials. Each trial period lasted for one week, with the first four days as an adaptation period (to determine daily feed and water intake for each pig) and the last three days for total collection of feces and urine samples. Body weight was measured at the beginning and end of each trial, and daily feed intake was recorded for each pig. The daily cutoff point for feed intake recording and sample collection was 09:00. The basal diet was formulated according to NRC (2012) standards, with composition and nutrient levels shown in Table 1 . The measured routine nutrient contents of the experimental diets are presented in Table 2 .

1.3 Sample Collection and Processing Fecal samples were collected using the total collection method. All feces were collected daily in sealed bags and stored at -20°C. After the 3-day collection period, the fecal samples were thawed and mixed thoroughly. Subsamples representing 10% of the fresh weight were taken in duplicate. One subsample received 10 mL of 6 mol/L hydrochloric acid per 100 g of feces to fix ammonia nitrogen for crude protein determination, while the other was used for analysis of other nutrients. Both subsamples were stored at -20°C. Prior to analysis, samples were thawed, and approximately 70 g of feces was weighed accurately and dried at 65°C for 72 hours. After recording

the initial moisture content, samples were equilibrated for 24 hours to constant weight, ground, placed in sealed bags, and stored at -20°C.

Urine was collected daily, with volumes measured at 08:30 and 21:00, filtered through gauze, and subsampled at 10% of the total volume. Ten milliliters of 6 mol/L hydrochloric acid was added per 100 mL of urine for nitrogen fixation. Samples were stored at -20°C, and after the 3-day collection period, the urine samples were thawed, mixed thoroughly, and 10% of the total volume was used for analysis.

1.4 Measurements and Calculations The contents of dry matter, crude ash, ether extract, crude protein, hydrolyzed amino acids, and gross energy were determined in diets and feces, and gross energy was measured in urine samples. Gross energy was determined using a precision rapid automatic calorimeter (Changsha Kaiyuan Instrument Factory). Hydrolyzed amino acid content was measured using hydrochloric acid hydrolysis. Apparent digestible energy and metabolizable energy of fermented distiller' s grains and nitrogen metabolism status were calculated on a replicate basis using the following formulas:

- Dietary apparent digestible energy = (gross energy intake - gross energy in feces) / dry matter intake
- Dietary apparent metabolizable energy = (gross energy intake - gross energy in feces - gross energy in urine) / dry matter intake
- Apparent digestibility of routine nutrients = 100 × (nutrient content in diet - nutrient content in feces) / nutrient content in diet
- Absorbed nitrogen = nitrogen intake - fecal nitrogen
- Retained nitrogen = nitrogen intake - fecal nitrogen - urinary nitrogen
- Nitrogen apparent digestibility = 100 × absorbed nitrogen / nitrogen intake
- Nitrogen apparent biological value = 100 × retained nitrogen / absorbed nitrogen
- Net protein utilization = 100 × (nitrogen intake - fecal nitrogen - urinary nitrogen) / nitrogen intake
- Total nitrogen emission rate = 100 × (fecal nitrogen + urinary nitrogen) / nitrogen intake

1.5 Statistical Analysis Data were analyzed using one-way ANOVA with SAS 9.2 software. Duncan' s multiple range test was used for post-hoc comparisons, and results were expressed as least squares means. Differences were considered significant at $P < 0.05$ and trends at $0.05 \leq P < 0.10$.

Results

2.1 Effects of Fermented Distiller' s Grains on Growth Performance of Weaned Piglets As shown in Table 3 , in the 10 kg digestion and metabolism

trial, there were no significant differences in initial body weight, final body weight, average daily feed intake, average daily gain, or feed-to-gain ratio among all groups ($P > 0.05$). In the 25 kg trial, compared with the control group, the 2% FDG group showed significantly increased average daily gain ($P < 0.05$) and a trend toward reduced feed-to-gain ratio ($P = 0.09$).

2.2 Effects of Fermented Distiller' s Grains on Apparent Digestibility of Routine Nutrients in Weaned Piglets Table 4 shows that in the 10 kg trial, compared with the control group, the 2% FDG group exhibited significantly lower apparent digestible energy ($P < 0.05$) but no significant differences in other measured parameters ($P > 0.05$). The 4% FDG group showed significantly reduced apparent digestibility of gross energy, apparent digestible energy, and apparent metabolizable energy ($P < 0.05$). The 6% FDG group demonstrated significantly lower values for all measured parameters except apparent digestibility of ether extract and crude protein ($P < 0.05$). In the 25 kg trial, there were no significant differences in apparent digestibility of crude ash and ether extract among the four groups ($P > 0.05$). Compared with the control group, the 4% and 6% FDG groups showed significantly reduced apparent digestibility of dry matter ($P < 0.05$), while the 2%, 4%, and 6% FDG groups exhibited significantly lower apparent digestibility of crude protein and gross energy, as well as reduced apparent metabolizable energy and apparent digestible energy ($P < 0.05$).

2.3 Effects of Fermented Distiller' s Grains on Apparent Digestibility of Amino Acids in Weaned Piglets As shown in Table 5 , in the 10 kg trial, the 4% and 6% FDG groups showed significantly decreased apparent digestibility of lysine, methionine, and proline compared with the control group ($P < 0.05$). In the 25 kg trial, the 6% FDG group exhibited significantly reduced methionine digestibility ($P < 0.05$). No significant differences were observed in the apparent digestibility of other amino acids among groups ($P > 0.05$).

2.4 Effects of Fermented Distiller' s Grains on Nitrogen Excretion in Weaned Piglets Table 6 presents the nitrogen excretion results. In the 10 kg trial, compared with the control group, the 4% FDG group showed significantly reduced absorbed nitrogen, retained nitrogen, and nitrogen apparent biological value ($P < 0.05$). The 2% and 6% FDG groups exhibited significantly lower urinary nitrogen and higher nitrogen apparent biological value ($P < 0.05$). No significant differences were observed in nitrogen intake, fecal nitrogen, nitrogen apparent digestibility, net protein utilization rate, or total nitrogen emission rate among the FDG groups ($P > 0.05$). In the 25 kg trial, the 2%, 4%, and 6% FDG groups all showed significantly reduced nitrogen intake, absorbed nitrogen, retained nitrogen, and nitrogen apparent digestibility ($P < 0.05$), with significantly increased fecal nitrogen ($P < 0.05$). The 2% and 6% FDG groups also demonstrated significantly reduced net protein utilization rate and increased total nitrogen emission rate ($P < 0.05$), while no significant differences were

found in urinary nitrogen or nitrogen apparent biological value among groups ($P > 0.05$).

Discussion

Growth performance in weaned piglets directly impacts farm economic efficiency, making improvements in daily gain and feed efficiency particularly important. The current results indicate that dietary supplementation with 2% fermented distiller' s grains significantly increased average daily gain in 25 kg piglets. This improvement may be attributed to the antioxidant phenolic compounds present in sorghum distiller' s grains, as well as the production of microbial protein, digestive enzymes, and B vitamins during fermentation, which can enhance diet palatability and improve intestinal microecological balance, thereby promoting animal growth. Emiola et al. also reported that adding 30% fermented distiller' s grains to basal diets improved growth performance in growing pigs. However, the lack of significant effects on growth performance in 10 kg piglets may be due to the shorter feeding duration. Additionally, fermented distiller' s grains are more cost-effective than conventional feed ingredients, offering potential for reducing production costs.

In this study, 2% dietary supplementation with fermented distiller' s grains did not affect apparent digestibility of dry matter, crude ash, or ether extract in weaned piglets, while 6% supplementation reduced dry matter digestibility. This reduction may be explained by the higher crude fiber level increasing endogenous secretions in the intestine and accelerating digesta passage rate, preventing complete digestion and absorption of nutrients. Although the crude fiber content of the fermented distiller' s grains used in this study had been reduced to 17.67%, it remained substantially higher than conventional feed ingredients such as soybean meal and corn. Combined with the underdeveloped intestinal function of weaned piglets, this led to reduced digestibility. Furthermore, as the inclusion level of fermented distiller' s grains increased, apparent digestible and metabolizable energy, as well as apparent digestibility of lysine, methionine, and proline, decreased, though ether extract and most amino acid digestibility remained unaffected. Previous studies have found that fermented distiller's grains can improve nutrient digestibility in lactating dairy cows, and dried distiller' s grains can enhance production performance. Partial replacement of corn starch with distiller' s grains in dairy cow diets did not significantly affect milk yield or composition. After microbial fermentation, distiller' s grains quality improves substantially, producing abundant beneficial microorganisms and a characteristic aroma. These microorganisms can improve rumen microbial balance and fermentation patterns, thereby increasing feed intake and digestibility in dairy cows.

Nitrogen metabolism trials are primarily used to study animal protein requirements, dietary protein utilization efficiency, and dietary protein quality. Nitro-

gen excreted by animals is the main pollutant in their waste, and its content is related to dietary nitrogen content and nitrogen digestion and absorption. In the 25 kg trial, fecal nitrogen increased significantly in all FDG groups, showing an upward trend with increasing inclusion levels. Research indicates that reduced nitrogen retention may be associated with amino acid imbalance, low levels of digestible amino acids, or low amino acid utilization efficiency. The minimal changes in urinary nitrogen observed in this study suggest an inverse relationship between fecal nitrogen and nitrogen retention, consistent with previous findings. This may be explained by three mechanisms: first, feeding fiber-rich diets can increase loss of intestinal epithelial cells or mucus secretion, leading to increased endogenous nitrogen excretion; second, fermented distiller' s grains may convert urinary nitrogen to fecal nitrogen, increasing microbial protein synthesis in the intestine; and third, proteins in distiller' s grains are rich in prolamins that are difficult to digest. The significantly lower nitrogen intake in the 4% FDG group may be attributed to reduced feed intake. In the 10 kg trial, 2% and 4% FDG supplementation reduced retained nitrogen and nitrogen apparent biological value, with the 4% group showing significant differences, possibly related to decreased digestibility of lysine, methionine, and proline. However, 6% FDG did not affect retained nitrogen or nitrogen apparent biological value, and the specific reasons require further investigation. The reduction in urinary nitrogen with 2% and 6% FDG supplementation may be due to microbial utilization of nitrogen in the intestine, reducing its entry into the bloodstream, and increased short-chain fatty acids from fiber reducing urinary nitrogen production. Additionally, the different nitrogen excretion patterns between the 10 kg and 25 kg trials suggest that the effects of fermented distiller's grains on nitrogen excretion may be influenced by the physiological stage of the piglets. Pigs at 10 kg and 25 kg represent the weaned piglet and early growing pig stages, respectively, with small intestine development being essentially complete at 20 kg body weight. The developmental status of the small intestine in piglets of different weights may affect nitrogen absorption and excretion.

Conclusion

Dietary supplementation with 2% fermented distiller' s grains does not affect apparent digestibility of dry matter, crude ash, ether extract, or most amino acids in weaned piglets and can promote their growth. However, long-term supplementation with high doses of fermented distiller's grains reduces apparent digestible and metabolizable energy of nutrients to some extent.

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Note: Figure translations are in progress. See original paper for figures.