

Postprint: Effects of Fermented Wheat Alcohol Biogas Residue on Growth Performance, Serum Biochemical Indices, and Meat Quality in Growing-Finishing Pigs

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Abstract

This study was conducted to investigate the effects of fermented wheat distillers grains on growth performance, serum biochemical indices, and meat quality of growing-finishing pigs. One hundred twenty-eight “Duroc × Landrace × Yorkshire” crossbred pigs with an initial body weight of approximately 40 kg were randomly allocated into 4 groups according to sex, with 4 replicates per group and 8 pigs per replicate (half barrows and half gilts). The control group was fed a basal diet, while experimental groups 1, 2, and 3 were fed diets in which 5%, 10%, and 15% fermented wheat distillers grains replaced a portion of the soybean meal in the basal diet, respectively. The preliminary period lasted 7 days, and the experimental period lasted 60 days, divided into two phases: early phase (days 1-30) and late phase (days 31-60). The results showed: 1) During the early phase, no significant differences were observed in growth performance indices among all groups of growing-finishing pigs ($P>0.05$). During the late phase, the average daily gain (ADG) of experimental groups 1, 2, and 3 was significantly higher than that of the control group ($P<0.05$), increasing by 16.47%, 25.88%, and 20.00%, respectively, and the ADG of experimental group 2 was highly significantly higher than that of the control group ($P<0.01$); the average daily feed intake (ADFI) of experimental groups 1, 2, and 3 was significantly higher than that of the control group ($P<0.05$); while no significant differences were observed in feed conversion ratio (FCR) among all groups ($P>0.05$). During the entire experimental period, the ADG of experimental groups 2 and 3 was significantly higher than that of the control group ($P<0.05$). 2) Dietary supplementation with fermented wheat distillers grains had no significant effects on serum alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities, or total protein (TP) and urea nitrogen (UN) contents in

growing-finishing pigs ($P > 0.05$). 3) Dietary supplementation with fermented wheat distillers grains had no significant effects on pH1h, lightness (L), redness (a), yellowness (b*), drip loss, cooking loss, shear force, hardness, springiness, cohesiveness, resilience, or intramuscular fat content in the longissimus dorsi muscle of growing-finishing pigs ($P > 0.05$). The contents of threonine, lysine, proline, non-essential amino acids, and total amino acids in the longissimus dorsi muscle of experimental groups 1 and 2 were significantly higher than those of the control group and experimental group 3 ($P < 0.05$); the glutamic acid content of experimental group 2, the glycine content of experimental group 1, and the serine and alanine contents of experimental groups 1 and 2 were all significantly higher than those of the control group ($P < 0.05$). Dietary supplementation with fermented wheat distillers grains had no significant effects on fatty acid contents in the longissimus dorsi muscle of growing-finishing pigs ($P > 0.05$). These results suggest that dietary supplementation with 5% and 10% fermented wheat distillers grains can improve the ADG and ADFI of growing-finishing pigs, and increase the contents of certain umami amino acids, thereby improving meat flavor.

Full Text

Effects of Fermented Biogas Residue of Wheat after Alcohol Production on Growth Performance, Serum Biochemical Parameters, and Meat Quality of Growing-Finishing Pigs

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Abstract

This study investigated the effects of fermented biogas residue of wheat after alcohol production on growth performance, serum biochemical parameters, and meat quality of growing-finishing pigs. One hundred twenty-eight “Duroc × Landrace × Yorkshire” hybrid pigs weighing approximately 40 kg were randomly allocated into four groups by gender, with four replicates per group and eight pigs per replicate (half male and half female). The control group received a basal diet, while experimental groups 1, 2, and 3 received diets in which 5%, 10%, and 15% of the basal diet’s soybean meal was replaced with fermented biogas residue of wheat after alcohol production, respectively. The pre-test period lasted 7 days, followed by a 60-day experimental period divided into two stages: early period (days 1-30) and later period (days 31-60). The results showed: (1) During the early period, no significant differences were observed in growth performance indices among groups ($P > 0.05$). During the later period, average

daily gain (ADG) in experimental groups 1, 2, and 3 was significantly higher than in the control group ($P < 0.05$), increasing by 16.47%, 25.88%, and 20.00%, respectively, with ADG in experimental group 2 being extremely significantly higher than in the control group ($P < 0.01$). Average daily feed intake (ADFI) in experimental groups 1, 2, and 3 was significantly higher than in the control group ($P < 0.05$), while feed-to-gain ratio showed no significant differences among groups ($P > 0.05$). Over the entire experimental period, ADG in experimental groups 2 and 3 was significantly higher than in the control group ($P < 0.05$). (2) Dietary supplementation with fermented biogas residue of wheat after alcohol production had no significant effects on serum alanine aminotransferase (ALT), aspartate aminotransferase (AST) activities, or total protein (TP) and urea nitrogen (UN) contents ($P > 0.05$). (3) Dietary supplementation had no significant effects on pH_1 , lightness (L), redness (a), yellowness (b*), drip loss, cooking loss, shear force, hardness, elasticity, cohesiveness, resilience, or intramuscular fat content in the longissimus dorsi muscle ($P > 0.05$). However, threonine, lysine, proline, non-essential amino acids, and total amino acids in the longissimus dorsi muscle of experimental groups 1 and 2 were significantly higher than in the control group and experimental group 3 ($P < 0.05$). Glutamate content in experimental group 2, glycine content in experimental group 1, and serine and alanine contents in experimental groups 1 and 2 were significantly higher than in the control group ($P < 0.05$). Dietary supplementation had no significant effects on fatty acid contents in the longissimus dorsi muscle ($P > 0.05$). These results indicate that dietary supplementation with 5% and 10% fermented biogas residue of wheat after alcohol production can improve ADG and ADFI in growing-finishing pigs while enhancing certain umami amino acid contents, thereby improving meat flavor.

Keywords: fermented biogas residue of wheat after alcohol production; growing-finishing pigs; growth performance; serum biochemical parameters; meat quality

Wheat is processed into alcohol through crushing, washing, fermentation, and distillation, producing alcohol distiller's wastewater as a byproduct. After centrifugal separation, the lower sediment is dried to produce wheat dried distillers grains (DDG), while the supernatant is flocculated with flocculants to obtain floating residue. The filtrate then undergoes biogas production, yielding biogas residue. Direct disposal of this residue not only causes environmental pollution but also wastes protein resources. Studies have shown that the dry matter of wheat alcohol biogas residue contains approximately 35% crude protein and is safe and effective for feeding pigs and chickens. However, its high moisture content (80%) limits widespread application in feed industrialization. Mixing it with other feed ingredients for fermentation and drying effectively overcomes this limitation, though no studies have reported on feeding fermented wheat biogas residue to growing-finishing pigs. Therefore, this study aimed to investigate the effects of replacing partial soybean meal with fermented wheat biogas

residue on growth performance, serum biochemical parameters, and meat quality of growing-finishing pigs to provide a scientific basis for its rational utilization.

1. Materials and Methods

1.1 Experimental Material Preparation of fermented biogas residue of wheat after alcohol production: Using biogas residue from wheat alcohol wastewater after biogas production as raw material, supplemented with wheat bran, the moisture content was adjusted to 50%. The starter inoculation amount was 10%, followed by chain-type multi-layer aerobic fermentation with automatic layer-turning and ventilation every 12 hours for 48 hours, then drying and crushing. The final product contained: dry matter 92.01%, crude protein 21.87%, crude fat 6.35%, crude fiber 7.57%, crude ash 5.37%, calcium 0.24%, total phosphorus 0.48%, arginine 0.91%, histidine 0.73%, leucine 1.25%, isoleucine 0.73%, lysine 0.89%, methionine 0.32%, cystine 0.48%, tryptophan 0.42%, threonine 0.71%, phenylalanine 0.76%, tyrosine 0.52%, valine 1.05%, aspartic acid 1.57%, serine 0.80%, glutamic acid 3.53%, glycine 1.14%, alanine 1.04%, and proline 1.12%. The digestible energy for pigs was 13.85 MJ/kg, with apparent dry matter digestibility of 86%, apparent crude protein digestibility of 77.33%, and true crude protein digestibility of 82.98%.

1.2 Experimental Design One hundred twenty-eight “Duroc × Landrace × Yorkshire” hybrid pigs weighing approximately 40 kg were randomly allocated into four groups by gender, with four replicates per group and eight pigs per replicate (half male and half female). Replicate weights were not significantly different ($P > 0.05$). The control group received a basal diet, while experimental groups 1, 2, and 3 received diets in which 5%, 10%, and 15% of the basal diet’s soybean meal was replaced with fermented biogas residue of wheat after alcohol production, respectively. The pre-test period lasted 7 days, followed by a 60-day experimental period divided into early (days 1-30) and later (days 31-60) stages. Diet composition and nutrient levels are shown in Table 1. Management during the experimental period followed normal farm protocols.

1.3 Measurement Indicators and Methods 1.3.1 Growth Performance

Pigs in each replicate were weighed at the start, end of the early period, and end of the later period, with feed consumption and body weight gain recorded throughout. Feed was withheld (but not water) for 12 hours before weighing. Average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G) were calculated.

1.3.2 Serum Biochemical Parameters

After the experiment, two pigs (one male and one female) with similar body weight were randomly selected from each replicate. After 12 hours of fasting, 6 mL of blood was collected from the anterior vena cava. After natural coagulation at room temperature, serum was separated by centrifugation at 3,000

r/min for 10 minutes, aliquoted, and stored at -20°C for determination of total protein (TP), urea nitrogen (UN), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) using an automatic biochemical analyzer (Hitachi 7600-020).

1.3.3 Meat Quality

After the experiment, two pigs (one male and one female) with similar body weight were randomly selected from each replicate for slaughter. The left carcass' s longissimus dorsi muscle (from the fifth rib to the last portion) was sampled to determine pH_1 , lightness (L), redness (a), yellowness (b^*), drip loss, cooking loss, tenderness (expressed as shear force), hardness, elasticity, cohesiveness, resilience, intramuscular fat, inosine monophosphate, fatty acids, and amino acids using the methods of Yang et al. [6]. pH was measured using a Leici PHB-4 pH meter (Shanghai Yidian Scientific Instrument Co., Ltd.), meat color using an ADCI-WS1 colorimeter (Beijing Chentaike Instrument Technology Co., Ltd.), tenderness using a C-LM3 digital muscle tenderness meter (Northeast Agricultural University Engineering College), texture parameters using a TA.XT.PLUS texture analyzer (UK SMSTA Company), intramuscular fat using an S2F-200 automatic fat analyzer (Shanghai Xinjia Instrument Co., Ltd.), inosine monophosphate using an Agilent 1100 HPLC (USA Agilent Company), fatty acids using a Bruker Scion SQ GC-MS (USA Bruker Company), and amino acids using a Hitachi 835-50 automatic analyzer (Japan Hitachi Company).

1.4 Statistical Analysis Data are expressed as “mean \pm standard deviation.” One-way ANOVA was performed using SPSS 17.0 software. Differences were considered significant at $P < 0.05$ and extremely significant at $P < 0.01$. Duncan' s multiple comparison test was used for significant indicators.

2. Results

2.1 Effects on Growth Performance and Serum Biochemical Parameters As shown in Table 2, during the early period, no significant differences were observed in growth performance indices among groups ($P > 0.05$). During the later period, ADG in experimental groups 1 and 3 was significantly higher than in the control group ($P < 0.05$), increasing by 16.47% and 20.00%, respectively, while ADG in experimental group 2 was extremely significantly higher than in the control group ($P < 0.01$), increasing by 25.88%. ADFI in experimental groups 1, 2, and 3 was significantly higher than in the control group ($P < 0.05$), while F/G showed no significant differences among groups ($P > 0.05$). Over the entire experimental period, ADG in experimental groups 2 and 3 was significantly higher than in the control group ($P < 0.05$).

As shown in Table 3, dietary supplementation with fermented biogas residue of wheat after alcohol production had no significant effects on serum ALT and AST activities or TP and UN contents in growing-finishing pigs ($P > 0.05$).

2.2 Effects on Meat Quality As shown in Table 4 , dietary supplementation had no significant effects on pH_1 , L, a, b*, drip loss, cooking loss, shear force, hardness, elasticity, cohesiveness, resilience, or intramuscular fat content in the longissimus dorsi muscle ($P > 0.05$).

As shown in Table 5 , the contents of threonine, lysine, proline, non-essential amino acids, and total amino acids in the longissimus dorsi muscle of experimental groups 1 and 2 were significantly higher than in the control group and experimental group 3 ($P < 0.05$). Glutamate content in experimental group 2, glycine content in experimental group 1, and serine and alanine contents in experimental groups 1 and 2 were significantly higher than in the control group ($P < 0.05$).

As shown in Table 6 , dietary supplementation had no significant effects on fatty acid contents in the longissimus dorsi muscle ($P > 0.05$).

3. Discussion

3.1 Effects on Growth Performance The fermented biogas residue of wheat after alcohol production used in this study primarily consists of wheat protein remaining after alcohol production, mainly composed of gliadin and glutenin, both rich in glutamic acid and proline, which are beneficial for animal intestinal health. Wheat protein also contains high levels of glutamine, which can improve intestinal digestive function, enhance daily weight gain, and increase feed intake. Studies have shown that wheat protein can promote growth and immunity in weaned piglets (with effects superior to plasma protein and glutamine), increase ADG, and improve F/G. Additionally, research indicates that fermented protein diets can significantly improve growth performance in livestock and poultry compared to conventional protein diets. In this study, during the later period, ADFI in experimental groups 1, 2, and 3 increased with supplementation level and was significantly higher than in the control group, likely because microbial fermentation reduced pH and produced a rich acidic aroma, improving diet palatability and thus increasing feed intake. The increased ADG in experimental groups 1, 2, and 3 during the later period was probably due to increased feed intake, while the lack of significant difference in F/G suggests efficient nutrient utilization. These results indicate that dietary supplementation with 5%, 10%, and 15% fermented biogas residue during the later period significantly improved ADFI and ADG in growing-finishing pigs, while 10% and 15% supplementation significantly improved ADG over the entire period. However, the effects of higher supplementation levels require further investigation.

3.2 Effects on Serum Biochemical Parameters Changes in serum biochemical parameters reflect overall organ function and nutrient metabolism. Serum ALT and AST activities are important indicators of liver and heart function, participating in transamination and affecting metabolism of many substances. ALT primarily exists in hepatocyte cytoplasm, and its activity increases when hepatocyte membranes are damaged, while AST mainly exists in

cardiac muscle and hepatic mitochondria, with activity increasing significantly when hepatic mitochondrial membranes are damaged. In this study, ALT and AST activities in experimental groups 1, 2, and 3 were lower than in the control group, indicating no significant effects on transamination or liver function. TP content primarily reflects protein absorption and humoral immunity, while UN content reflects protein metabolism and kidney function, decreasing when amino acid balance is good. No significant differences in TP or UN contents among groups indicate that different supplementation levels had no significant effects on protein metabolism. In summary, dietary supplementation with up to 15% fermented biogas residue had no significant effects on protein metabolism in growing-finishing pigs.

3.3 Effects on Meat Quality pH, meat color, tenderness, drip loss, and cooking loss are common indicators for meat quality evaluation, reflecting pork's eating quality and palatability. After slaughter, muscle glycolysis produces lactic acid, causing pH decline. The pH at 45–60 minutes post-slaughter is a recognized indicator for distinguishing normal from defective meat; excessively rapid pH decline can cause pale color, increased water loss, protein denaturation, and reduced nutritional value. Intramuscular fat content is another important meat quality indicator, significantly affecting tenderness, juiciness, and flavor. In this study, no significant differences were observed among groups in pH_1 , L, a, b*, drip loss, cooking loss, shear force, hardness, elasticity, cohesiveness, resilience, or intramuscular fat content, and no significant differences in flavor-related fatty acid contents, indicating that dietary supplementation had no significant effects on pork appearance quality or fatty acid composition.

Amino acid types and contents are also important meat quality indicators. Alanine, glycine, glutamate, aspartate, and serine affect pork's umami taste, serving as essential precursors for meat flavor formation, particularly glutamate, the primary umami substance that buffers salty and sour tastes. This study found that threonine, lysine, proline, non-essential amino acids, and total amino acids in experimental groups 1 and 2 were significantly higher than in the control group and experimental group 3, while glutamate in experimental group 2, glycine in experimental group 1, and serine and alanine in experimental groups 1 and 2 were significantly higher than in the control group. This may be due to higher amino acid utilization from fermented biogas residue compared to soybean meal. Feng et al. and Wu et al. found that feeding fermented products effectively maintained intestinal villus integrity and improved digestive enzyme activity, thereby enhancing nutrient utilization efficiency. Therefore, the improved meat umami taste with 5% and 10% supplementation can be attributed to increased contents of certain umami amino acids.

Conclusion

Dietary supplementation with 5% and 10% fermented biogas residue of wheat after alcohol production can improve ADFI, ADG, and meat umami taste in

growing-finishing pigs without significantly affecting serum biochemical parameters or meat quality. Therefore, fermented biogas residue of wheat after alcohol production can be used as a high-quality protein feed ingredient in diets for growing-finishing pigs.

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