Evaluation of the Nutritional Value of Early and Late Rice for Growing Rex Rabbits (Post-Print)

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Abstract

This experiment aimed to evaluate the nutritional value of early rice and late rice for growing rex rabbits through a digestion trial. Eighteen healthy white rex rabbits at 60 days of age with an average body weight of (1.50±0.20) kg were randomly allocated to three groups (six replicates per group, one rabbit per replicate) and fed a basal diet, an early rice diet (85% basal diet + 15% early rice), or a late rice diet (85% basal diet + 15% late rice). The preliminary and formal trial periods each lasted 7 days. The total feces collection method was employed to determine the apparent digestibility of main nutrients in early rice and late rice for growing rex rabbits. The results showed: 1) The contents of gross energy (GE), dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ash, calcium (Ca), phosphorus (P), and nitrogen-free extract (NFE) in early rice and late rice were 16.25 MJ/kg, 86.32%, 7.82%, 1.32%, 8.54%, 23.35%, 10.54%, 1.54%, 1.32%, 0.53%, 0.38%, 64.76% and 16.07 MJ/kg, 89.17%, 6.88%, 1.32%, 9.07%, 24.55%, 11.57%, 2.01%, 3.96%, 0.62%, 0.21%, 63.71%, respectively. 2) The apparent digestible energy of early rice and late rice in growing rex rabbits was 10.43 and 10.32 MJ/kg, respectively, and the apparent digestibility of GE, DM, CP, EE, CF, NDF, ADF, ash, Ca, P, and NFE in early rice and late rice for growing rex rabbits was 65.33%, 74.32%, 76.69%, 68.59%, 13.12%, 38.63%, 27.11%, 52.23%, 50.03%, 15.54%, 74.35% and 64.22%, 76.15%, 70.92%, 72.93%, 14.35%, 38.49%, 27.09%, 52.03%, 48.63%, 14.99%, 73.64%, respectively. It can be concluded that the difference in main nutrient contents between early rice and late rice was small, and the apparent digestibility of main nutrients in early rice and late rice for growing rex rabbits was basically comparable; both early rice and late rice can serve as energy feed sources for growing rex rabbits, and their nutritional values for growing rex rabbits were similar.

Full Text

Nutritional Value Evaluation of Early Rice and Late Rice for Growing Rex Rabbits

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Abstract: This study was conducted to evaluate the nutritional value of early rice and late rice for growing Rex rabbits through digestion trials. Eighteen healthy white Rex rabbits at 60 days of age with an average body weight of (1.50±0.20) kg were randomly divided into three groups (six replicates per group, one rabbit per replicate) and fed a basal diet, an early rice diet (85% basal diet + 15% early rice), or a late rice diet (85% basal diet + 15% late rice). Both the pre-trial and formal trial periods lasted seven days. The total feces collection method was used to determine the apparent digestibility of main nutrients in early rice and late rice for growing Rex rabbits. The results showed that: 1) The contents of gross energy (GE), dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), crude ash (Ash), calcium (Ca), phosphorus (P), and nitrogen-free extract (NFE) in early rice were 16.25 MJ/kg, 86.32%, 7.82%, 1.32%, 8.54%, 23.35%, 10.54%, 1.54%, 1.32%, 0.53%, 0.38%, and 64.76%, respectively, while those in late rice were 16.07 MJ/kg, 89.17%, 6.88%, 1.32%, 9.07%, 24.55%, 11.57%, 2.01%, 3.96%, 0.62%, 0.21%, and 63.71%, respectively. 2) The apparent digestible energy of early rice and late rice for growing Rex rabbits was 10.43 and 10.32 MJ/kg, respectively. The apparent digestibility of GE, DM, CP, EE, CF, NDF, ADF, Ash, Ca, P, and NFE in early rice was 65.33%, 74.32%, 76.69%, 68.59%, 13.12%, 38.63%, 27.11%, 52.23%, 50.03%, 15.54%, and 74.35%, respectively, while that in late rice was 64.22%, 76.15%, 70.92%, 72.93%, 14.35%, 38.49%, 27.09%, 52.03%, 48.63%, 14.99%, and 73.64%, respectively. In conclusion, the main nutrient contents showed little difference between early rice and late rice, and the apparent digestibility of main nutrients in early rice and late rice for growing Rex rabbits was essentially equivalent. Both early rice and late rice can serve as energy feed sources for growing Rex rabbits, with similar nutritional value.

Keywords: early rice; late rice; digestibility; nutrients; growing Rex rabbits

Most livestock and poultry diets in China are corn-soybean meal based. With the development of corn deep-processing technologies, the demand for corn in liquor brewing, bioethanol, amino acid, and xylitol industries has surged. Cou-

pled with the continuous expansion of domestic farming operations, corn supply cannot meet demand in many regions of China, forcing feed enterprises to allocate or purchase corn from other provinces. Developing new energy feed sources to partially replace corn provides a novel approach to addressing energy feed shortages. Rice is one of China' s major grain crops. In 2016, China' s total rice production was approximately 206.934 million tons, including 32.777 million tons of early rice and 174.157 million tons of medium and late rice. China' s annual rice output accounts for about 35% of the world' s total, ranking first globally [1-2]. Early rice has poor taste due to growth period and climate factors, resulting in low market prices and poor sales channels. Previous studies have reported on the use of early rice as feed for pigs, cattle, ducks, and other livestock [3-5], but its application in rabbit diets is rarely documented. This trial aimed to evaluate the nutritional value of early rice and late rice to provide data references for their application in Rex rabbit production.

1.1 Experimental Materials

The rice used in this trial was produced in Nanning, Guangxi Province, with early rice being the "Teyou 2258" variety and late rice being the "Jinyou 527" variety. The rice was naturally sun-dried, crushed, and stored in a shed. The experimental animals were 18 healthy white Rex rabbits at 60 days of age with an average body weight of (1.50±0.20) kg.

1.2 Experimental Diets

The basal diet was formulated according to the rabbit nutrient requirements recommended by NRC (1977) and the Rex rabbit diet nutrition standards recommended by Gu Zilin [6]. Its composition and nutrient levels are shown in Table 1 . The experimental diets consisted of an early rice diet and a late rice diet, designed using the substitution method and formulated with 85% basal diet and 15% test feed ingredient. Both the basal and experimental diets were pelleted with a diameter of 4 mm and length of 10 mm.

Table 1 Composition and nutrient levels of the basal diet (air-dry basis)

Items	Content
Ingredients	
Corn	
Wheat bran	
Soybean meal	
Barley	
Sesame meal	
Peanut meal	
Malt root	
Chrysanthemum powder	

Items	Content
Peanut hull	
Limestone	
Premix[1]	
NaCl	
Lys · HCl (98.5%)	
Met · HCl (99.0%)	
Total	
Nutrient levels[2]	
DE/(MJ/kg)	
CP	
CF	
EE	
TP	
TLys	
TMet+TCys	

[1]The premix provided per kg of the diet: Fe (as ferric sulfate) 70 mg, Cu (as copper sulfate) 20 mg, Zn (as zinc sulfate) 70 mg, Mn (as manganese sulfate) 10 mg, Co 0.15 mg, I 0.2 mg, Se (as sodium sulfate) 0.25 mg, VA 10 000 IU, VE 50 mg, VK 2 mg, thiamine 2 mg, riboflavin 6 mg, pantothenic acid 50 mg, pyridoxine 2 mg, VB12 0.02 mg, niacin 50 mg, choline 1,000 mg, biotin 0.2 mg.

[2]Nutrient levels were measured values.

1.3 Experimental Animals and Grouping

The digestion trial was conducted at the Experimental Rabbit Farm of Agricultural University of Hebei from May 1 to May 14, 2017. The 18 experimental Rex rabbits were randomly divided into three groups with six replicates per group and one rabbit per replicate. The three groups were fed the basal diet, early rice diet (85% basal diet + 15% early rice), and late rice diet (85% basal diet + 15% late rice), respectively.

1.4 Digestion Trial

The experimental rabbits were housed individually in digestion-metabolism cages and fed twice daily. Feed was provided ad libitum with slight leftovers, and water was freely available. Natural ventilation and lighting were maintained. The total feces collection method was used for the digestion trial, with both pre-trial and formal trial periods lasting seven days. During the pre-trial period, feed intake of each rabbit was observed. During the formal trial period, actual daily feed intake of each rabbit was recorded and weighed by replicate. All fresh feces were collected daily at 10:00, weighed after removing rabbit hair from fecal pellets, and divided into two portions. One portion was fixed with

10% hydrochloric acid solution for volatile nitrogen determination to measure crude protein content, while the other portion was left untreated for analysis of other conventional nutrients. After collection, feces were thoroughly mixed, dried in an oven at 65–70°C, weighed after 24-hour air moisture equilibration, and then ground. Partial samples were sealed in bottles for subsequent analysis.

1.5 Measurement Indicators and Methods

Samples of early rice, late rice, basal diet, experimental diets, and feces were collected to determine main nutrient contents. Gross energy (GE) was measured using a Changsha Youxin YX-ZR Tianying automatic calorimeter. Ether extract (EE) content was determined by Soxhlet extraction method (GB/T 6433-2006). Crude protein (CP) content was measured using a Foss Kjeltec 8400 automatic Kjeldahl nitrogen analyzer. Crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) contents were determined using an ANKOM A2000i automatic fiber analyzer. Crude ash (Ash) content was measured by 550°C incineration method (GB/T 6438-92). Calcium (Ca) content was determined by potassium permanganate titration (arbitration method) (GB/T 6436-2002). Phosphorus (P) content was measured by molybdic acid colorimetry (GB/T 6437-2002). Dry matter (DM) content was calculated after measuring moisture content (GB/T 6435-2014). Nitrogen-free extract (NFE) content was calculated using the formula: NFE = 100 - (moisture + crude ash + crude protein + ether extract + crude fiber).

1.6 Calculation Formulas

The apparent digestibility of main nutrients in diets was calculated as:

Apparent digestibility of a nutrient in diet (%) = 100 × (amount of nutrient intake - amount of nutrient in corresponding feces) / amount of nutrient intake.

The apparent digestibility of a nutrient in test feed was calculated as:

$D = 100 \times (A - B) / F + B$

$F = C \times f / [C \times f + C \times (1 - f)]$

Where: D is the apparent digestibility of a nutrient in test feed ingredient (%); A is the apparent digestibility of the nutrient in experimental diet (%); B is the apparent digestibility of the nutrient in basal diet (%); F is the proportion of the nutrient provided by test feed ingredient to total nutrient in experimental diet (%); f is the proportion of test feed ingredient substituted in experimental diet (%); C is the nutrient content in basal diet (%); C is the nutrient content in test feed ingredient (%).

1.7 Data Processing and Analysis

Experimental data were processed using Excel 2010, and results were expressed as mean ± standard deviation.

2.1 GE and Main Nutrient Contents in Diets and Tested Feed Ingredients for Growing Rex Rabbits

As shown in Table 2 , among the three diets, the basal diet had slightly lower GE than the early rice and late rice diets. Both experimental diets had lower CF content than the basal diet, with the early rice diet having the lowest CF content at 14.35%. The basal diet had the highest CP content at 17.12%, while the early rice and late rice diets had similar CP contents of 16.80% and 16.73%, respectively. Between the two test feed ingredients, early rice had GE and CP contents of 16.25 MJ/kg and 7.82%, respectively, which were higher than those of late rice at 16.07 MJ/kg and 6.88%. Early rice had a CF content of 8.54%, lower than late rice' s 9.07%. The NDF, ADF, and ADL contents in early rice were 23.35%, 10.54%, and 1.54%, respectively, all lower than those in late rice at 24.55%, 11.57%, and 2.01%.

Table 2 GE and major nutrient contents in diets and tested feed ingredients for growing Rex rabbits (air-dry basis)

Items	Basal diet	Early rice diet	Late rice diet	Early rice	Late rice
GE/(MJ/kg)	15.33±0.03	15.36±0.14	15.58±0.02	16.25±0.08	16.07±0.01
DM/%	86.73±0.04	87.36±1.35	88.40±0.05	86.32±0.17	89.17±0.10
CP/%	17.12±0.03	16.80±0.04	16.73±0.03	7.82±0.95	6.88±0.18
EE/%	2.64±0.03	2.33±0.03	2.27±0.07	1.32±0.03	1.32±0.04
Ash/%	11.53±0.06	12.16±1.27	10.98±0.05	3.58±0.10	3.96±0.00
Ca/%	0.87±0.04	0.61±0.03	0.78±0.02	0.53±0.53	0.62±0.01
P/%	0.49±0.05	0.42±0.01	0.44±0.03	0.38±0.04	0.21±0.06
CF/%	14.67±0.09	14.35±0.17	15.88±0.05	8.54±0.87	9.07±1.07
NDF/%	31.78±0.06	30.13±1.02	31.53±0.03	23.35±2.54	24.55±2.47
ADF/%	17.57±0.07	17.56±0.34	18.38±0.06	10.54±1.35	11.57±1.73
ADL/%	5.53±0.04	4.56±0.03	4.97±0.08	1.54±0.45	2.01±1.30
NFE/%	40.77±0.15	41.72±2.37	42.55±0.12	64.76±1.46	63.71±1.39

2.2 Apparent Digestible Energy and Apparent Digestibility of Energy and Main Nutrients in Diets and Tested Feed Ingredients for Growing Rex Rabbits

As shown in Table 3 , the early rice diet had slightly lower apparent digestible energy (10.35 MJ/kg) compared with the basal diet (10.52 MJ/kg) and late rice diet (10.56 MJ/kg). The basal diet had slightly higher energy apparent digestibility (68.64%) than the early rice diet (68.33%) and late rice diet (67.82%), though the differences were minimal. Early rice had slightly higher apparent digestible energy and energy apparent digestibility than late rice, exceeding them by 0.11 MJ/kg and 1.11 percentage points, respectively. Among the three diets, the basal diet showed the highest apparent digestibility of CP (80.65%) and CF (27.37%), while the late rice diet showed the lowest (79.92% and 25.40%, respectively). The late rice diet had the highest apparent digestibility of DM

(69.82%) and NFE (78.66%). The apparent digestibility of Ash, Ca, P, NDF, and ADF in the early rice diet was 52.43%, 53.45%, 19.87%, 39.42%, and 27.63%, respectively, which was essentially equivalent to that in the late rice diet at 51.84%, 53.25%, 19.93%, 38.36%, and 27.21%, respectively. For the test ingredients, early rice had higher CP apparent digestibility (76.69%) than late rice (70.92%), but lower CF apparent digestibility (13.12% vs. 14.35%). The DM apparent digestibility of early rice (74.32%) was slightly lower than that of late rice (76.15%). The apparent digestibility of Ash, P, Ca, NDF, and ADF was similar between early rice and late rice.

Table 3 Apparent digestible energy, apparent digestibility of energy and major nutrients in diets and tested feed ingredients for growing Rex rabbits

Items	Basal diet	Early rice diet	Late rice diet	Early rice	Late rice
Apparent digestible energy/(MJ/kg)	10.52±0.23	10.35±0.32	10.56±0.23	10.43±1.46	10.32±1.19
Apparent digestibility/%					
Energy	68.64±1.48	68.33±5.99	67.82±1.45	65.33±4.36	64.22±3.44
DM	68.83±1.44	69.73±4.33	69.82±3.72	74.32±3.05	76.15±10.75
CP	80.65±0.98	80.27±0.16	79.92±1.24	76.69±2.20	70.92±3.53
EE	83.95±1.38	82.63±0.14	82.98±0.21	68.59±1.65	72.93±2.60
Ash	52.08±2.17	52.43±0.79	51.84±0.57	52.23±3.17	52.03±10.03
Ca	53.52±5.66	53.45±3.87	53.25±0.05	50.03±4.32	48.63±6.88
P	20.70±5.83	19.87±2.13	19.93±0.17	15.54±1.78	14.99±2.45
CF	27.37±5.00	25.71±0.44	25.40±0.48	13.12±4.87	14.35±2.17
NDF	39.87±6.53	39.42±3.25	38.36±0.42	38.63±2.04	38.49±1.63
ADF	27.07±4.68	27.63±0.58	27.21±0.70	27.11±3.79	27.09±2.17
NFE	77.11±1.35	78.34±6.73	78.66±7.54	74.35±5.31	73.64±6.81

3.1 Main Nutrient Contents in Early Rice and Late Rice

Rice is divided into two subspecies: indica and japonica, corresponding to early-season and late-season rice. Early indica rice contains less amylopectin and more amylose (>25%), resulting in hard cooked rice grains with poor taste, low market price, and poor sales channels, making it primarily used for livestock feed. The content and ratio of amylose to amylopectin, along with feed retention time in the digestive tract, affect starch digestion and amylase activity, thereby influencing nutrient apparent digestibility [7]. This trial determined that early

rice and late rice contained 7.82% and 6.88% CP, respectively. The CP content in early rice was higher than the 7.27% reported by Yu et al. [8], lower than the 8.65%–12.52% reported by Zheng et al. [9] for early rice brown rice, but consistent with the 7.80% reported by Zhang et al. [10]. These differences may be related to varying degrees of dehulling, as CP content is directly related to dehulling extent. The GE of early rice measured in this trial was 16.25 MJ/kg, slightly higher than the 15.68 MJ/kg measured by He et al. [11] and the 15.83 MJ/kg measured by Tan et al. [12] for early indica rice, possibly due to varietal differences. The CF contents of early rice and late rice measured in this trial were 8.54% and 9.07%, respectively, both higher than the 8.2% reported by Zhang et al. [10]. The CF content in early rice was lower than the 12.7% reported by He et al. [13] but within the 0.93%–10.20% range reported by Zheng et al. [9]. The NDF and ADF contents of early rice and late rice measured in this trial were 23.35% and 10.54%, and 24.55% and 11.57%, respectively, both lower than the 27.4% and 28.7% reported by Xu [14].

Variations in rice variety, growing environment, harvest season, production processes, and dehulling degree can all lead to differences in nutrient contents, particularly CF content and digestibility. Since rice husk constitutes 20% of rice and its main component is lignin mixed with cellulose and hemicellulose, it serves as the main crude fiber component that is difficult to digest, resulting in particularly low CF digestibility in rice. Furthermore, CF content affects the utilization of CP, EE, and NFE in monogastric animals. The Ash contents of early rice and late rice measured in this trial were 3.58% and 3.96%, respectively, higher than the 1.59% reported by Yu et al. [8] and the 0.83%–1.30% reported by Zheng et al. [9], but lower than the 4.4% reported by Tan et al. [12] and the reference value of 4.6% in the *Feed Composition and Nutritional Value Table (28th Edition, 2017)* [15]. Ash is an important component of animal tissues, particularly abundant in bones and teeth, making it a crucial reference indicator in feed nutritional value evaluation.

3.2 Apparent Digestibility of Energy and Main Nutrients in Early Rice and Late Rice for Growing Rex Rabbits

This trial determined that the apparent digestible energy of early rice and late rice for growing Rex rabbits was 10.43 and 10.32 MJ/kg, respectively, slightly lower than the 10.61 MJ/kg reported by Gao et al. [16] for brown rice replacing corn, and lower than the values reported by Chen et al. [17] for corn, sorghum, and wheat (11.22, 11.18, and 11.19 MJ/kg, respectively). These values were also lower than the 12.58 MJ/kg apparent metabolizable energy reported by Yu et al. [18] for rice replacing corn in broiler chickens and the 11.62 MJ/kg apparent digestible energy reported by Xia and Zhao [19] for rice replacing corn in growing-finishing pigs. The lower digestible energy in rabbits compared with pigs and chickens may be related to diet composition, as rabbit diets contain higher CF levels (up to 14%) while growing pig diets generally do not exceed 7% CF, and CF content affects energy utilization. Additionally, digestive energy

varies among animal species. The energy digestibility of energy feedstuffs in rabbits ranges from 71% to 96% [20]. This trial measured energy apparent digestibility of 65.33% and 64.22% for early rice and late rice, respectively, lower than the 68.69%, 68.61%, and 68.63% reported by Chen et al. [17] for corn, sorghum, and wheat. Energy digestion and utilization in growing Rex rabbits are affected by dietary fiber levels, which in rice are largely influenced by dehulling degree. Chen et al. [17] reported CF apparent digestibility of 30.90% and 31.23% for sorghum and wheat, respectively, while this trial found only 13.12% and 14.35% for early rice and late rice. The low CF digestibility in rice may be due to the high lignin content from rice husks, which reduces digestive utilization.

This trial measured CP apparent digestibility of 76.69% and 70.92% for early rice and late rice, respectively, lower than the 80.65%, 80.45%, and 80.33% reported by Chen et al. [17] for corn, sorghum, and wheat. However, the CP apparent digestibility of early rice was higher than the 73.90% reported by Liu et al. [21] for pigs. Compared with corn, rice has lower effective energy (about 80%-85% of corn) but superior amino acid structure. However, rice contains anti-nutritional factors such as non-starch polysaccharides (NSP) including -glucan, xylan, and cellulose [22-23], which greatly limit its application effectiveness and result in limited direct use in feed. This trial measured EE apparent digestibility of 68.59% and 72.93% for early rice and late rice, respectively, lower than the 83.87%, 83.81%, and 83.08% reported by Chen et al. [17] for corn, sorghum, and wheat. The NFE apparent digestibility of early rice and late rice was 74.35% and 73.64%, respectively, lower than the 79.18% reported by Chen et al. [17] for sorghum and the 84.00% reported by Liu et al. [21] for early rice in pigs. The DM apparent digestibility of late rice and early rice was 76.15% and 74.32%, respectively, higher than the 68.93% and 69.02% reported by Chen et al. [17] for corn and wheat.

4 Conclusion

Considering the main nutrient contents in early rice and late rice and the differences in apparent digestibility of main nutrients for growing Rex rabbits, the nutritional value of the two rice types is similar and comparable to other cereal energy feedstuffs. Both early rice and late rice can be utilized as energy feed resources for growing Rex rabbits.

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