Effects of Different Dietary Levels of Daheishan Coix Straw Meal on Growth Performance, Nutrient Apparent Digestibility, and Slaughter Performance of Growing Meat Rabbits (Postprint)

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Date: 2018-12-24T00:00:00+00:00

Abstract

This experiment aimed to evaluate the effects of replacing different proportions of alfalfa meal with Dahheishan coix straw meal in diets on growth performance, health status, nutrient apparent digestibility, and slaughter performance of growing meat rabbits. A total of 150 weaned purebred New Zealand White rabbits at 35 days of age with similar body weight were used in two experiments as follows: 100 experimental rabbits weighing (1.00±0.09) kg were randomly allocated to 5 groups (10 replicates per group with 2 rabbits per replicate) for a 28-day feeding trial; 50 experimental rabbits weighing (1.12±0.05) kg were randomly allocated to 5 groups (10 replicates per group with 1 rabbit per replicate) for an 11-day digestibility trial (with a 4-day sample collection period). In both experiments, the 5 groups of experimental rabbits were randomly fed 5 isoenergetic, isonitrogenous, and isofibrous experimental diets, including one control diet (containing 16% alfalfa meal, group C) and four test diets in which 25% (group S25), 50% (group S50), 75% (group S75), and 100% (group S100) of the alfalfa meal in the control diet was replaced by Dahheishan coix straw meal. The results showed that: 1) There were no significant differences in average daily feed intake (ADFI), average daily gain (ADG), and feed to gain ratio (F/G) among groups at each period ($P>0.05$), but the overall ADG and F/G were better in group S50. No significant differences were observed among groups in overall morbidity rate, mortality rate, and health risk index, as well as hot carcass weight, commercial carcass weight, reference carcass weight, commercial dressing percentage, and drip loss at the end of the experiment ($P>0.05$), but most indices in group S50 were numerically higher than those in group C. 2) Replacing different proportions of alfalfa meal with Dahheishan coix straw meal in diets had significant or extremely significant effects on the apparent digestibility

of dietary dry matter (DM), crude protein (CP), ether extract (EE), ash (Ash), neutral detergent fiber (NDF), calcium (Ca), and phosphorus (P) ($P<0.05$ or $P<0.01$). All nutrient apparent digestibility in the four test groups (S25, S50, S75, and S100) were higher than those in group C to varying degrees [except that the EE apparent digestibility in group S100 was lower and the crude fiber (CF) apparent digestibility in the four test groups was comparable], especially in group S50. It can be concluded that under the conditions of this experiment, Dahheishan coix straw meal can completely replace alfalfa meal in commercial rabbit diets, but replacement at a proportion of 50% is optimal.

Full Text

Effects of Diets with Different Proportions of Coix lacryma-jobi cv. Daheishan Meal on Growth Performance, Nutrient Apparent Digestibility and Slaughter Performance of Growing Meat Rabbits

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Abstract: This study was conducted to evaluate the effects of substituting different proportions of alfalfa meal with Coix lacryma-jobi cv. Daheishan meal on growth performance, health status, nutrient apparent digestibility, and slaughter performance of growing meat rabbits. A total of 150 weaned New Zealand white rabbits aged 35 days with similar body weight were used in two experiments. In the 28-day feeding experiment, 100 rabbits with body weight of (1.00±0.09) kg were randomly divided into 5 groups (10 replicates per group, 2 rabbits per replicate). In the 11-day digestion experiment (with a 4-day sample collection period), 50 rabbits with body weight of (1.12±0.05) kg were randomly divided into 5 groups (10 replicates per group, 1 rabbit per replicate). In both experiments, the five groups were fed five isoenergetic, isonitrogenous, and isofibrous experimental diets: one control diet containing 16% alfalfa meal (group C) and four test diets where 25% (group S25), 50% (group S50), 75% (group S75), and 100% (group S100) of the alfalfa meal in the control diet was replaced by Coix lacryma-jobi cv. Daheishan meal.

The results showed: 1) There were no significant differences in average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio (F/G) among groups at any period ($P>0.05$), though the overall ADG and F/G were better in group S50. No significant differences were observed among groups in overall morbidity, mortality, health risk index, or in hot carcass weight, commercial carcass weight, reference carcass weight, commercial dressing percentage, and

drip loss at the end of the experiment (P>0.05), though most numerical values were higher in group S50 than in group C. 2) Replacing different proportions of alfalfa meal with Coix lacryma-jobi cv. Daheishan meal had significant or extremely significant effects on the apparent digestibility of dry matter (DM), crude protein (CP), ether extract (EE), ash, neutral detergent fiber (NDF), calcium (Ca), and phosphorus (P) (P<0.05 or P<0.01). All nutrient apparent digestibility values in the four test groups (S25, S50, S75, and S100) were higher than those in group C to varying degrees (except that EE apparent digestibility in group S100 was lower and CF apparent digestibility was similar), especially in group S50. These results indicate that under the conditions of this experiment, Coix lacryma-jobi cv. Daheishan meal can completely replace alfalfa meal in commercial rabbit diets, with 50% replacement being optimal.

Keywords: Coix lacryma-jobi cv. Daheishan meal; growth performance; nutrient apparent digestibility; slaughter performance; growing meat rabbits

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Rabbits have high dietary fiber requirements, with fiber content accounting for 15%–45% of complete diets depending on the measurement method, primarily provided by alfalfa meal and agricultural processing by-products [1]. However, as a major global rabbit producer and consumer, China faces a supply shortage of alfalfa with rising prices [2]. Therefore, identifying novel forage resources and systematically evaluating their nutritional and feeding value is of great practical significance for the sustainable development of China' s rabbit industry.

Coix lacryma-jobi, a annual or perennial herbaceous plant of the Poaceae family, has a long cultivation history. It offers numerous advantages including strong adaptability, high tillering capacity, large biomass, abundant stem and leaf yield, tender grass quality, and good palatability [3-4]. Moreover, all plant parts (roots, stems, leaves, and seeds) are rich in nutrients and active compounds [3-8], giving it high medicinal and food value [3-6] and making it a potential forage resource [3-6,9-12].

Extensive research has been conducted on the nutritional and medicinal value of Coix lacryma-jobi, particularly its seed [3-13], with limited reports on its use as feed [3-6,9-18]. Studies indicate that Coix seeds are excellent feed for poultry [4-6], pigs [5], and dairy cows [12], while processing by-products such as seed bran [4,15-16] and seed coat powder [17] can be used for poultry [4,15], meat rabbits [16-17], and growing pigs [16]. Fresh-cut Coix serves as high-quality green forage for herbivores, especially cattle, horses, and sheep [3-4,6,8,10-12], and can increase milk fat percentage in dairy cows [12] or be made into silage [4,11]. Coix straw can be used directly as roughage or as silage for ruminants [14,18], with the latter also suitable for pigs [18]. Additionally, Coix leaves are used as elephant feed in India [4].

Research shows that the chemical composition of Coix hay or meal is similar to other Poaceae crops [5], with quality comparable to China' s Grade 3 alfalfa meal [12]. However, no reports exist on Coix meal as rabbit feed. Building on

our previous research [13], this study further investigated the effects of replacing different proportions of alfalfa meal with Coix lacryma-jobi cv. Daheishan meal on growth performance, health status, nutrient apparent digestibility, and slaughter performance of growing meat rabbits, aiming to preliminarily evaluate its feeding value and provide reference materials for enriching China' s feed ingredient database.

1.1 Experimental Material

Coix lacryma-jobi cv. Daheishan meal was collected from the Yunnan Xishuangbanna base of Sichuan Agricultural University' s corn breeding program. The sample was harvested before flowering, naturally sun-dried, and ground. Its main chemical composition was: dry matter (DM) 88.46%, gross energy (GE) 16.94%, crude protein (CP) 13.46%, crude fiber (CF) 29.58%, ether extract (EE) 1.02%, ash 13.19%, calcium (Ca) 1.21%, and phosphorus (P) 0.20% [13].

1.2 Experimental Design

This study included a feeding experiment and a digestion experiment, both using a single-factor design. One hundred healthy 35-day-old weaned New Zealand white rabbits (gender not considered) with similar body weight [(1.00±0.09) kg] were randomly divided into 5 groups (10 replicates per group, 2 rabbits per replicate) for a 28-day feeding experiment. Additionally, 50 rabbits with body weight of (1.12±0.05) kg were selected and randomly divided into 5 groups (10 replicates per group, 1 rabbit per replicate) for an 11-day in vivo digestion experiment following the method of Pérez et al. [19], with a 4-day sample collection period.

In both experiments, rabbits in the 5 groups were randomly fed five isoenergetic, isonitrogenous, and isofibrous experimental diets: one control diet containing 16% alfalfa meal (group C) and four test diets where 25% (group S25), 50% (group S50), 75% (group S75), and 100% (group S100) of the alfalfa meal in the control diet was replaced by Coix lacryma-jobi cv. Daheishan meal.

1.3 Experimental Diets

Five isoenergetic, isonitrogenous, and isofibrous experimental diets were formulated according to experimental requirements and based on the nutrient requirements for growing rabbits recommended by De Blas et al. [20]. Diet composition and nutrient levels are shown in Table 1 . All diets were pelleted with a diameter of 2.50 mm.

Table 1 Composition and nutrient levels of experimental diets (DM basis)

Item	Groups
Ingredients	
Coix lacryma-jobi cv. Daheishan meal	
Alfalfa meal (CP 14%-15%)	
Corn	
Soybean meal	
Wheat bran	
Rice bran and hull	
Peanut hull	
Soybean oil	
CaHPO	
Limestone	
NaCl	
L-Lys · HCl (98.5%)	
DL-Met (98.5%)	
Premix[1])	
Total	
Nutrient levels[2])	
DE/(MJ/kg)	
CP	
CF	
NDF	
ADF	
ADL	
TP	
TLys	
TMet	

[1]) The premix provided the following per kilogram of diet: Fe 30 mg, Cu 6 mg, Zn 35 mg, Mn 8 mg, Se 0.05 mg, Co 0.3 mg, I 0.4 mg, VA 6,000 IU, VD 900 IU, VE 15 IU, VK 1 mg, biotin 100 g, choline 100 mg, pyridoxine 0.5 mg, riboflavin 3 mg, VB 9 g, niacin 35 mg, pantothenic acid 8 mg.

[2]) Values outside parentheses were calculated, while values inside parentheses were measured.

1.4 Animal Management

The experiment was conducted at the research base of the Animal Nutrition Institute of Sichuan Agricultural University. Experimental animals were housed in metabolism cages (60 cm × 60 cm × 45 cm) with automatic watering devices and separated feces/urine collection systems in a rabbit barn disinfected by formaldehyde and potassium permanganate (2:1) fumigation for 3 days. The barn temperature was (16.1±1.45)°C with relative humidity of (77.96±6.27)%,

under natural lighting and ventilation. Animals were fed twice daily (09:00 and 18:00) with ad libitum access to feed and water.

1.5.1 Growth Performance

On a replicate basis, daily feed provision, leftover feed, and wasted feed (e.g., feed scratched out by animals) were weighed and recorded to calculate average daily feed intake (ADFI) per animal. Individual body weight was measured at the start (day 1), middle (day 15), and end (day 29) of the experiment before morning feeding to calculate average daily gain (ADG) for different periods. Feed-to-gain ratio (F/G) was calculated based on feed intake and body weight gain. Feed intake of sick or dead animals was calculated according to Gidenne [21].

ADFI (g/d) = Total feed intake during experiment / Number of experimental days
ADG (g/d) = (Body weight at end - Body weight at start) / Number of experimental days
F/G = Total feed intake during experiment / (Body weight at end - Body weight at start)

1.5.2 Health Status

Animal health was observed and recorded daily. Morbidity, mortality, and health risk index were calculated according to Gidenne [22].

Morbidity (%) = 100 × Number of sick animals during experiment / Number of animals at start
Mortality (%) = 100 × Number of dead animals during experiment / Number of animals at start
Health risk index (%) = 100 × Number of sick and dead animals during experiment / Number of animals at start

1.5.3 Slaughter Performance

On the final day of the experiment (day 29), after weighing, 4 rabbits with body weight close to the group average were randomly selected from each group and slaughtered according to the method of Blasco et al. [23]. The following parameters were measured: hot carcass weight (carcass weight 15–30 min post-slaughter, g), commercial carcass weight (carcass weight after refrigeration for 24 h in a ventilated cold room (0–4°C) at approximately 1 h post-slaughter, g), reference carcass weight, commercial dressing percentage, and drip loss percentage.

Reference carcass weight (g) = Commercial carcass weight - (Head weight + Liver weight + Kidney weight + Chest and neck organ weight)
Commercial dressing percentage (%) = 100 × Commercial carcass weight / Live weight

Drip loss percentage (%) = 100 × (Hot carcass weight - Commercial carcass weight) / Hot carcass weight

1.5.4 Nutrient Apparent Digestibility

Fecal samples were collected and processed according to the method of Pérez et al. [19]. The contents of DM, GE, CP, CF, EE, ash, Ca, P, acid detergent fiber (ADF), neutral detergent fiber (NDF), and acid detergent lignin (ADL) in diets and feces were determined to calculate apparent digestibility.

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

1.6 Data Processing and Statistical Analysis

Data were processed using Excel 2013. Growth performance, slaughter performance, and nutrient apparent digestibility data were analyzed by one-way ANOVA and Duncan' s multiple comparison tests using SAS 9.2 statistical software. Morbidity, mortality, and health risk index were analyzed by chi-square test. Results are expressed as mean and standard error of the mean (SEM). $P<0.05$ and $P<0.01$ indicated significant and extremely significant differences, respectively, while $P>0.05$ indicated no significant difference.

2.1 Effects of Different Proportions of Coix lacryma-jobi cv. Daheishan Meal on Growth Performance and Health Status of Growing Meat Rabbits

As shown in Table 2 , there were no significant differences in ADFI, ADG, and F/G among groups at any period ($P>0.05$), though overall ADG and F/G were better in group S50. No animals died during the entire feeding experiment, and no significant differences were observed in morbidity or health risk index among groups ($P>0.05$). However, the four test groups (S25, S50, S75, and S100) showed a trend toward lower morbidity than the control group (C) (Table 3).

Table 2 Growth performance of growing meat rabbits fed diets with different proportions of Coix lacryma-jobi cv. Daheishan meal

Items	Groups	P-value
Average daily feed intake (ADFI), g		
Average daily gain (ADG), g		
Feed/gain ratio (F/G)		

In the same row, values with no letter or the same letter superscripts indicate no significant difference ($P>0.05$), different lowercase letters indicate significant difference ($P<0.05$), and different uppercase letters indicate extremely significant difference ($P<0.01$). The same applies below.

Table 3 Health status of growing meat rabbits fed diets with different proportions of Coix lacryma-jobi cv. Daheishan meal

Groups	Morbidity (%)	Mortality (%)	Health risk index (%)	^{2}-value	P-value

2.2 Effects of Different Proportions of Coix lacryma-jobi cv. Daheishan Meal on Nutrient Apparent Digestibility of Growing Meat Rabbits

As shown in Table 4 , replacing different proportions of alfalfa meal with Coix lacryma-jobi cv. Daheishan meal had no significant effects on apparent digestibility of gross energy, crude fiber, ADF, ADL, or digestible energy (P>0.05). However, significant (P<0.05) or extremely significant (P<0.01) effects were observed on apparent digestibility of DM, CP, EE, ash, NDF, Ca, and P. Except for EE apparent digestibility in group S100 being slightly lower than group C (P>0.05), all other nutrient apparent digestibility values in the four test groups were higher than those in group C to varying degrees (with CF apparent digestibility being similar). Among the four test groups, only EE and P apparent digestibility showed substantial differences.

Table 4 Nutrient apparent digestibility of growing meat rabbits fed diets with different proportions of Coix lacryma-jobi cv. Daheishan meal

Items	Groups	P-value
Digestible energy (DE), MJ/kg DM		
Apparent digestibility (%)		
Dry matter (DM)		
Gross energy (GE)		
Crude protein (CP)		
Crude fiber (CF)		
Acid detergent fiber (ADF)		
Neutral detergent fiber (NDF)		
Acid detergent lignin (ADL)		
Ether extract (EE)		
Ash		

2.3 Effects of Different Proportions of Coix lacryma-jobi cv. Daheishan Meal on Slaughter Performance of Growing Meat Rabbits

As shown in Table 5 , no significant differences were observed among groups in live weight, hot carcass weight, commercial carcass weight, reference carcass weight, commercial dressing percentage, or drip loss percentage (P>0.05). However, group S50 was generally slightly better than other groups.

Table 5 Slaughter performance of growing meat rabbits fed diets with different proportions of Coix lacryma-jobi cv. Daheishan meal

Items	Groups	P-value
Live weight, g		
Hot carcass weight, g		
Commercial carcass weight, g		
Reference carcass weight, g		
Commercial dressing percentage, %		
Drip loss percentage, %		

3.1 Effects on Growth Performance, Health Status, and Slaughter Performance

This study found that replacing different proportions of alfalfa meal with Coix lacryma-jobi cv. Daheishan meal not only caused no obvious adverse effects on growth performance, health status, and slaughter performance of growing meat rabbits, but the 50% replacement group (S50) also showed a trend toward improving some indicators. Regarding growth performance, these results are consistent with reports on feeding Coix seed powder to laying hens [5], fresh-cut Coix to dairy cows [12], seed coat powder to meat rabbits [17], seed bran to laying hens [4], broilers [15], meat rabbits [16], and growing pigs [16], and Coix straw bio-feed to cattle, sheep, and pigs [18]. These findings are also similar to applications of some Chinese herbal medicines in rabbits [24-25].

The possible reasons are: 1) Coix grass is tender and palatable [3-4,12], ensuring adequate feed intake in growing meat rabbits. 2) Coix meal contains various nutrients with high nutritional value [7-8,13], and in combination with other ingredients can meet animal growth requirements. Compared with alfalfa meal, Coix meal has fiber components closer to the nutritional and digestive physiology needs of rabbits, with crude protein content similar to China' s Grade 3 alfalfa meal but more balanced amino acids, and higher contents of copper, zinc, and manganese [8]. 3) Coix is a multi-functional traditional Chinese medicine. Its leaves have heat-clearing and dampness-removing effects, warm the middle-jiao to dispel cold, promote blood circulation, warm the stomach and replenish qi, strengthen the spleen, and kill parasites [26]. Its stems and leaves contain various active compounds including polysaccharides, organic acids, coixol, flavonoids, alkaloids, polyphenols, phytosterols, volatile oils, coumarins, triterpenoids, and glycosides [8,27], some of which have anti-cancer [4,26], anti-viral [4], antibacterial [27], anti-inflammatory [4], anti-allergic [4], anticonvulsant [4], antioxidant [4,28-29], immunomodulatory [30], metabolic syndrome-improving [4], gastrointestinal-protective [4], and gut microbiota-regulating effects [4], thus ensuring animal health and normal physiological function. The results for health status and slaughter performance may also be attributed to these factors, consistent with reports that some Chinese herbal medicines benefit rabbit health [25,31] without significantly affecting slaughter performance [25].

3.2 Effects on Nutrient Apparent Digestibility

In this experiment, except for EE apparent digestibility in the complete replacement group (S100) being slightly lower than the control group, all other nutrient apparent digestibility values (except CF) in the test groups were higher than those in group C, indicating that replacing alfalfa meal with Coix lacryma-jobi cv. Daheishan meal can improve digestive capacity and feed utilization efficiency in growing meat rabbits to some extent. The improved nutrient apparent digestibility may be related to: 1) the rich and well-balanced nutrient content of Coix meal [7-8,13], ensuring normal animal growth; 2) active compounds in Coix meal such as organic acids, polysaccharides, flavonoids, phenolic acids, alkaloids, and polyphenols, which ensure animal health, stimulate gastrointestinal development, promote gastrointestinal structural and functional integrity, and improve the intestinal microecosystem [4,8,27-30]. The reason for lower EE apparent digestibility in the complete replacement group remains unclear and warrants further investigation.

4 Conclusion

In conclusion, under the conditions of this experiment, Coix lacryma-jobi cv. Daheishan meal can completely replace alfalfa meal in diets for commercial rabbit production, with 50% replacement being optimal.

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