Evaluation of the Nutritional Value of Safflower Meal and Milk Thistle Meal for Growing Rex Rabbits (Post-Print)

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Abstract

This study was conducted to evaluate the nutritional value of safflower meal and milk thistle meal in growing rex rabbits through feeding and digestion trials. Eighteen healthy white rex rabbits, approximately 60 days of age with an average body weight of (1.73$±$0.21) kg, were selected and randomly allocated into 3 groups, with 6 replicates per group and 1 rabbit per replicate. The groups were fed the basal diet, safflower meal diet (85% basal diet + 15% safflower meal), and milk thistle meal diet (85% basal diet + 15% milk thistle meal), respectively. Both the pre-trial and formal trial periods lasted 5 days. Chemical analysis was employed to determine the gross energy (GE) and nutrient contents of safflower meal and milk thistle meal, while the total fecal collection method was used to determine the apparent digestibility of various nutrients in growing rex rabbits. The results showed that the contents of GE, dry matter (DM), crude protein (CP), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ether extract (EE), crude ash (Ash), calcium (Ca), phosphorus (P), and nitrogen-free extract (NFE) in safflower meal and milk thistle meal were 18.81 MJ/kg, 93.76%, 23.94%, 14.95%, 19.92%, 11.99%, 2.19%, 1.64%, 4.93%, 0.37%, 0.57%, 49.32% and 17.12 MJ/kg, 91.94%, 23.62%, 16.21%, 38.57%, 22.73%, 4.04%, 2.07%, 5.31%, 0.29%, 0.68%, 42.09%, respectively. The apparent digestibility of GE, DM, CP, CF, NDF, ADF, EE, Ash, Ca, P, and NFE in safflower meal and milk thistle meal by growing rex rabbits was 62.60%, 61.72%, 62.39%, 15.68%, 26.30%, 14.75%, 80.69%, 38.35%, 59.35%, 31.98%, 79.61% and 63.13%, 61.94%, 68.01%, 15.74%, 27.64%, 14.98%, 79.90%, 38.20%, 60.44%, 32.99%, 79.81%, respectively. These results indicate that there were certain differences in the apparent digestibility of different nutrients in safflower meal and milk thistle meal by growing rex rabbits. Based on the overall analysis of the nutrient contents of the two ingredients, both can be utilized as protein feed resources for rex rabbits, and their nutritional values for growing rex rabbits are similar.

Full Text

Nutritional Value Evaluation of Safflower Meal and Milk Thistle Meal for Growing Rex Rabbits

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Abstract

This study aimed to evaluate the nutritional values of safflower meal and milk thistle meal for growing Rex rabbits through feeding and digestion experiments. Eighteen healthy white Rex rabbits approximately 60 days old with an average body weight of (1.73$±$0.21) kg were randomly divided into three groups, with six replicates per group and one rabbit per replicate. Each group was fed either a basal diet, a safflower meal diet (85% basal diet + 15% safflower meal), or a milk thistle meal diet (85% basal diet + 15% milk thistle meal). Both the pre-trial and formal trial periods lasted for five days.

Chemical analysis was used to determine the gross energy (GE) and nutrient contents of safflower meal and milk thistle meal, while the total feces collection method was employed to measure the apparent digestibility of various nutrients in growing Rex rabbits. The results showed that safflower meal contained 18.81 MJ/kg GE, 93.76% dry matter (DM), 23.94% crude protein (CP), 14.95% crude fiber (CF), 19.92% neutral detergent fiber (NDF), 11.99% acid detergent fiber (ADF), 2.19% acid detergent lignin (ADL), 1.64% ether extract (EE), 4.93% crude ash (Ash), 0.37% calcium (Ca), 0.57% phosphorus (P), and 49.32% nitrogen-free extract (NFE). Milk thistle meal contained 17.12 MJ/kg GE, 91.94% DM, 23.62% CP, 16.21% CF, 38.57% NDF, 22.73% ADF, 4.04% ADL, 2.07% EE, 5.31% Ash, 0.29% Ca, 0.68% P, and 42.09% NFE.

The apparent digestibility coefficients of GE, DM, CP, CF, NDF, ADF, EE, Ash, Ca, P, and NFE for growing Rex rabbits were 62.60%, 61.72%, 62.39%, 15.68%, 26.30%, 14.75%, 80.69%, 38.35%, 59.35%, 31.98%, and 79.61% for safflower meal, respectively, and 63.13%, 61.94%, 68.01%, 15.74%, 27.64%, 14.98%, 79.90%, 38.20%, 60.44%, 32.99%, and 79.81% for milk thistle meal, respectively. These findings indicate that growing Rex rabbits exhibit different apparent digestibility rates for various nutrients in safflower meal and milk thistle meal. Based on comprehensive analysis of the nutrient composition of both ingredients and their digestibility, both can be utilized as protein feed resources for Rex rabbits, with similar nutritional values for growing animals.

Keywords: safflower meal; milk thistle meal; nutritional value; growing Rex rabbits

Introduction

The development and utilization of unconventional feed resources represent important measures for alleviating the shortage of conventional feed resources and reducing feed costs, while also promoting the scaled and intensive development of the rabbit industry and enhancing producers' capacity to withstand market risks. Safflower (*Carthamus tinctorius* L.) is a plant belonging to the Asteraceae family, and safflower meal is a byproduct of safflower oil extraction, available in both shelled and unshelled forms. Zheng Huiqin [1] reported that safflower seed meal is rich in edible protein, amino acids, and vitamins. Liu et al. [2] noted that safflower seed meal contains both unsaturated fatty acids and high-quality protein, making it an ideal energy and protein feed. Wang Weixian [3] found that safflower seed meal contains 5-hydroxytryptamine derivatives with strong antioxidant activity and DPPH free radical scavenging capacity. Although safflower is widely cultivated in China with substantial meal production, its efficient utilization remains limited, and research on its application as a feed resource for Rex rabbits is scarce.

Milk thistle (*Silybum marianum* L. Gaertn.) is another Asteraceae plant, and milk thistle meal is the byproduct remaining after oil (or silymarin) extraction from milk thistle seeds. Chen et al. [4] reported that milk thistle meal is rich in protein with a complete amino acid profile, representing a potential plant-based protein source. Hu and He [5] suggested that milk thistle meal can reduce production costs by partially replacing soybean meal and other feed ingredients, thereby mitigating feed resource shortages. With annual milk thistle production once reaching 100,000 tons, milk thistle meal is produced in considerable quantities. Although it has been applied in rabbit production, limited research has been reported, restricting its widespread use. This study aims to evaluate the nutritional values of safflower meal and milk thistle meal for growing Rex rabbits, providing a scientific basis for their further development and utilization.

Materials and Methods

1.1 Experimental Materials

The safflower meal used in this experiment was sourced from Qitai County, Changji Prefecture, Xinjiang, a major safflower-producing region. Milk thistle meal was obtained from Sunwu County, Heihe City, Heilongjiang Province. The experimental animals consisted of 18 healthy white Rex rabbits approximately 60 days old with an average body weight of (1.73$±$0.21) kg, selected at random.

1.2 Experimental Diets

The basal diet was formulated according to the nutritional requirements for Rex rabbits recommended by Gu Zilin [6], with composition and nutrient levels shown in Table 1 . Experimental diets were designed using the substitution method, comprising 85% basal diet and 15% test ingredient (safflower meal or milk thistle meal). Both basal and experimental diets were processed into pellet feed with a diameter of 4.5 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	
Barley	
Soybean meal	
Sesame meal	
Peanut meal	
Malt root	
Chrysanthemum powder	
Peanut hull	
Limestone	
Premix[1]	
NaCl	
Lys	
Met	
Total	
Nutrient levels[2]	
DE/(MJ/kg)	
CP	
CF	
NDF	
ADF	
ADL	
EE	
Ca	
TP	
Lys	
Met+Cys	

[1]The premix provided the following 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, VD 900 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]DE was a calculated value, while the others were measured values.

1.3 Experimental Period and Location

The digestion trial was conducted from April 1 to April 10, 2013, at the Experimental Rabbit Farm of Hebei Agricultural University. Sample analysis was performed from April to June 2014 at the Animal Nutrition Laboratory of Hebei Agricultural University.

1.4 Digestion Trial

Eighteen experimental 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, safflower meal diet (85% basal diet + 15% safflower meal), and milk thistle meal diet (85% basal diet + 15% milk thistle meal), respectively. Prior to the trial, all rabbit housing and cages were thoroughly cleaned and disinfected. Rabbits were individually housed in metabolic cages under conventional management. Feed was provided twice daily at 08:00 and 18:00, with ad libitum access to feed and water, natural ventilation, and lighting. Residual feed was collected and weighed each morning. The total feces collection method was used for the digestion trial, with a five-day pre-trial period and a five-day formal collection period. During the pre-trial period, feed intake of each rabbit was observed. During the formal period, actual daily feed intake was recorded and weighed for each replicate. Fresh feces were collected daily at 07:00, and after removing rabbit hair and debris, the feces were weighed and divided into two equal portions. One portion was treated with 10% hydrochloric acid for nitrogen fixation to measure crude protein content, while the other portion was collected directly for analysis of other nutrients. At the end of the collection period, the feces were thoroughly mixed, dried in an oven at 65–70 °C, weighed after 24 hours of air equilibration, and the initial moisture content was determined. The air-dried samples were then ground, and representative samples were collected using the quartering method, sealed in sample bottles, and stored for analysis.

1.5 Measurement Indicators and Methods

Samples of safflower meal, milk thistle meal, basal diet, experimental diets, and feces were collected to determine gross energy (GE) and contents of dry matter (DM), crude protein (CP), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), ether extract (EE), crude ash (Ash), calcium (Ca), phosphorus (P), and nitrogen-free extract (NFE). All conventional nutrient analyses were conducted according to the methods described in reference [7].

1.6 Calculation Formulas

The apparent digestibility of nutrients in the diet was calculated as:
Apparent digestibility of a nutrient in the diet (%) = 100 × [(amount of nutrient intake - amount of nutrient in corresponding feces) / amount of nutrient intake].

The apparent digestibility of a nutrient in the test feed was calculated as:
$D = 100 \times (A - B) / F + B$;
$F = C_1 \times f / [C_1 \times f + C_0 \times (1 - f)]$.

Where: D is the apparent digestibility of a nutrient in the test feed (%), A is the apparent digestibility of that nutrient in the experimental diet (%), B is the apparent digestibility of that nutrient in the basal diet (%), F is the proportion of that nutrient provided by the test feed to the total nutrient in the experimental diet (%), f is the proportion of test feed incorporated in the experimental diet (%), C_0 is the nutrient content in the basal diet (%), and C_1 is the nutrient content in the test feed (%).

1.7 Data Processing and Analysis

Data were processed and analyzed using Excel 2007 and SPSS 17.0 statistical software, with results expressed as means or means ± standard deviation.

Results

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

As shown in Table 2 , the CP contents of safflower meal and milk thistle meal were similar at 23.94% and 23.62%, respectively. The CF content of safflower meal (14.95%) was lower than that of milk thistle meal (16.21%), while safflower meal had higher GE (18.81 MJ/kg) compared to milk thistle meal (17.12 MJ/kg). Among the three diets, CP content was highest in the safflower meal diet (18.97%), followed by the milk thistle meal diet (18.81%), and lowest in the basal diet (18.06%). CF content was lowest in the basal diet (14.59%), intermediate in the safflower meal diet (14.67%), and highest in the milk thistle meal diet (14.82%). GE content was highest in the safflower meal diet (16.26 MJ/kg), with similar values for the milk thistle meal diet (16.07 MJ/kg) and basal diet (15.87 MJ/kg). Both EE and Ca contents were highest in the basal diet, while P content was highest in the milk thistle meal diet.

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

Items	GE (MJ/kg)	DM (%)	Ash (%)	CP (%)	CF (%)	NDF (%)	ADF (%)	ADL (%)	NFE (%)
Basal diet									

Items	GE (MJ/kg)	DM (%)	Ash (%)	CP (%)	CF (%)	NDF (%)	ADF (%)	ADL (%)	NFE (%)
Safflower meal diet									
Milk thistle meal diet									
Safflower meal									
Milk thistle meal									

2.2 Apparent Digestibility of Major Nutrients in Diets and Feed Ingredients for Growing Rex Rabbits

As shown in Table 3 , the apparent digestibility of DM and Ash in safflower meal and milk thistle meal were similar, at 61.72% and 38.35% for safflower meal, and 61.94% and 38.20% for milk thistle meal, respectively. The apparent digestibility of CP in milk thistle meal (68.01%) was superior to that in safflower meal (62.39%). The apparent digestibility of CF was low for both ingredients, at 15.68% for safflower meal and 15.74% for milk thistle meal. The apparent digestibility of EE was higher for safflower meal (80.69%) than for milk thistle meal (79.90%), while the apparent digestibility of Ca, P, and NFE were lower for safflower meal than for milk thistle meal.

Table 3 Apparent digestibility of major nutrients in diets and feed ingredients for growing Rex rabbit %

Items	Basal diet	Safflower meal diet	Milk thistle meal diet	Safflower meal	Milk thistle meal
DM					
Ash					
CP					
CF					
NDF					
ADF					
EE					
Ca					
P					

Items	Basal diet	Safflower meal diet	Milk thistle meal diet	Safflower meal	Milk thistle meal
NFE					

2.3 Apparent Digestible Energy and Energy Digestibility in Diets and Feed Ingredients for Growing Rex Rabbits

As shown in Table 4 , the apparent digestible energy of the basal diet was 10.09 MJ/kg, slightly lower than the designed value of 10.46 MJ/kg, but higher than that of the milk thistle meal diet (9.02 MJ/kg) and safflower meal diet (7.36 MJ/kg). In terms of energy digestibility, the basal diet was highest at 63.60%, followed by the milk thistle meal diet at 56.12%, and the safflower meal diet lowest at 54.27%. The apparent digestible energy and energy digestibility in milk thistle meal as a feed ingredient were 9.61 MJ/kg and 63.13%, respectively, both higher than those of safflower meal at 8.70 MJ/kg and 62.60%.

Table 4 Apparent digestible energy and apparent digestibility of energy in diets and feed ingredients for growing Rex rabbits

Items	Apparent digestible energy (MJ/kg)	Apparent digestibility of energy (%)
Basal diet	10.09 ± 0.08	63.60 ± 0.51
Safflower meal diet	7.36 ± 1.11	54.27 ± 6.95
Milk thistle meal diet	9.02 ± 1.34	56.12 ± 8.32
Safflower meal	8.70 ± 1.31	62.60 ± 0.40
Milk thistle meal	9.61 ± 1.42	63.13 ± 0.52

Discussion

3.1 Major Nutrient Contents of Safflower Meal and Milk Thistle Meal

Safflower meal is a byproduct of safflower seed pressing or solvent extraction. In this study, safflower meal contained 23.94% CP, which is higher than the 18–21% reported in *New Agriculture* [8] and the 19% reported by Lai Liang [9], but falls between the 19% CP content reported by Zhao et al. [10] for shelled safflower cake and the 38% for dehulled cake. This value aligns with the range of

20–60% CP in safflower meal reported by Sun Guojun [11], as CP content is directly related to the degree of dehulling. The CF content of 14.95% was slightly lower than the 15.1% reported for extracted safflower meal by Sun Guojun [11]. The Ash content of 4.93% was higher than the 3.2% reported by Gowda et al. [12]. Calcium and phosphorus contents were 0.37% and 0.57%, respectively, with the Ca content falling within the range of 0.23–0.40% reported by Sun Guojun [11] but higher than the 0.34% reported by Gowda et al. [12]. The P content was lower than the 0.83% reported by Gowda et al. [12] and slightly lower than the 0.61–1.65% range reported by Sun Guojun [11]. The EE content of 1.64% fell within the 1.3–6.6% range reported by Sun Guojun [11] but was lower than the 2.32% reported by Jiang et al. [13]. Variations in safflower variety, processing technology, and dehulling degree likely account for differences in nutrient contents reported across studies. Since safflower meal contains ugonin monoglucoside and 2-hydroxyarctigenin—compounds that impart bitterness and can cause diarrhea in growing Rex rabbits, respectively—these substances should be removed or the meal should be used at limited levels.

Milk thistle meal is a byproduct of milk thistle seed pressing and oil (silymarin) extraction. This study found that milk thistle meal contained 23.62% CP, which is higher than the 21.31% reported by Zhang Songbai [14] and the 22.10% reported by He et al. [15], but within the 20–47% range reported by Hu and He [5]. The CF content of 16.21% was lower than the 27.47% reported by Zhang Songbai [14] and the 37% reported by He et al. [15]. Ash, EE, and NFE contents were 5.31%, 2.07%, and 42.09%, respectively, with Ash and EE lower and NFE higher than the 9.87%, 2.17%, and 29.32% reported by Zhang Songbai [14]. Calcium and phosphorus contents were 0.29% and 0.68%, respectively, with Ca lower and P higher than the 0.34% and 0.62% values for soybean meal in the *Feed Composition and Nutritional Value Table* [16]. The small size of milk thistle seeds and the tight connection between hull and kernel make separation difficult, and the lack of standardized separation and extraction processes across different sources may contribute to variations in reported nutrient contents.

3.2 Apparent Digestibility of Energy and Nutrients in Safflower Meal and Milk Thistle Meal for Growing Rex Rabbits

This study determined that the apparent digestible energy of safflower meal and milk thistle meal for growing Rex rabbits was 8.70 and 9.61 MJ/kg, respectively, both lower than the 10.43 MJ/kg for soybean meal, 10.88 MJ/kg for sesame cake, and 11.53 MJ/kg for walnut meal reported by Wang Yuanyuan [17], and the 13.68 MJ/kg for peanut meal reported by Li Jinglin [18]. The apparent digestible energy of safflower meal was similar to the 8.79 MJ/kg for sunflower meal reported by Wang Yuanyuan [17]. The energy digestibility coefficients for safflower meal and milk thistle meal were 62.60% and 63.13%, respectively, lower than the 74.06% and 78.68% for soybean meal and peanut meal reported by Li Jinglin [18], similar to the 63.40% for soybean meal reported by Wang Yuanyuan [17], but higher than the 50.87% for sunflower seed meal reported

by Yang et al. [19]. The energy digestibility capacity of growing Rex rabbits is influenced by dietary fiber levels, which in safflower meal and milk thistle meal are largely affected by the degree of dehulling.

The apparent digestibility coefficients of DM and Ash for safflower meal and milk thistle meal were 61.72% and 38.35%, and 61.94% and 38.20%, respectively, similar to the 62.39% and 39.01% for soybean meal and 62.44% and 39.36% for walnut meal reported by Wang Yuanyuan [17], but lower than the 86.21% and 50.62% for peanut meal reported by Li Jinglin [18]. The CP digestibility coefficients were 62.39% for safflower meal and 68.01% for milk thistle meal, lower than the 82.37% for sunflower seed meal reported by He et al. [15] and the 86.91% for peanut meal reported by Li Jinglin [18], but similar to the 65.17% for sesame meal and 66.31% for soybean meal reported by Wang Yuanyuan [17]. The heating intensity and processing methods during safflower and milk thistle pressing can affect CP digestibility, as high temperatures may cause Maillard reactions between proteins and sugars, forming enzyme-resistant complexes that reduce protein utilization efficiency.

The CF digestibility coefficients were 15.68% for safflower meal and 15.74% for milk thistle meal, lower than the 23.60% for sunflower seed meal reported by He et al. [15] and the 19.79% for peanut meal reported by Li Jinglin [18], but similar to the 16.05% for sesame meal and 15.83% for walnut meal reported by Wang Yuanyuan [17], and slightly higher than the 14% CF digestibility for safflower meal in dairy cows reported by Pan Taojiang [20]. The slightly superior CF digestibility in Rex rabbits compared to dairy cows is likely due to rabbits' well-developed cecum, which enables better utilization of fibrous feeds. The EE digestibility coefficients were 80.69% for safflower meal and 79.90% for milk thistle meal, lower than the 87.89% for sunflower seed meal reported by He et al. [15], similar to the 81.64% for sesame meal reported by Wang Yuanyuan [17], but higher than the 45.88% for peanut meal reported by Li Jinglin [18]. The number of double bonds and chain length of fatty acids in the ingredients can affect fat utilization efficiency in growing Rex rabbits.

The Ca and P digestibility coefficients were 59.35% and 31.98% for safflower meal, and 60.44% and 32.99% for milk thistle meal, respectively, lower than the 72.56% and 49.50% for sunflower meal reported by He et al. [15], but similar to the 63.32% and 32.51% for soybean meal and 61.90% and 33.16% for walnut meal reported by Wang Yuanyuan [17]. The NDF, ADF, and NFE digestibility coefficients were 26.30%, 14.75%, and 79.61% for safflower meal, and 27.64%, 14.98%, and 79.81% for milk thistle meal, respectively, similar to the 25.31%, 14.04%, and 80.11% for soybean meal and the 29.09% and 80.79% for NDF and NFE in sunflower seed meal reported by Li Jinglin [18]. Considering the nutrient composition of both ingredients and the differences in nutrient digestibility for growing Rex rabbits, safflower meal and milk thistle meal have similar nutritional values and can both serve as protein feed resources for rabbits.

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