Effects of Diets Containing Palm Kernel Meal, Camellia Seed Meal, or Tea Seed Meal on Digestion, Metabolism, and Serum Biochemical Indices in Weaned Calves: Postprint

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Abstract

This experiment aimed to investigate the differences in growth performance, digestion and metabolism, and serum biochemical indices of weaned summer crossbred bull calves fed diets containing palm kernel meal, camellia seed meal, or tea seed meal. Forty-eight healthy weaned summer crossbred bull calves at 46 days of age with an average body weight of (79.5$±$0.79) kg were selected and randomly allocated to 4 groups (n=12 per group), and fed four types of total mixed rations. Groups A, B, C, and D were fed isoenergetic and isonitrogenous total mixed rations containing soybean meal, soybean meal + palm kernel meal, soybean meal + camellia seed meal, and soybean meal + tea seed meal, respectively, with the inclusion level of palm kernel meal, camellia seed meal, and tea seed meal in the diets all at 5%. The experimental period lasted 104 days, including a 14-day pre-trial period and a 90-day formal trial period. Daily feed intake was recorded, and body weight of the calves was measured every 30 days; digestion and metabolism trials were conducted using the total collection of feces and urine method at calf ages of 90 and 150 days to determine nutrient digestion and metabolism rates; jugular blood samples were collected every 30 days for determination of serum biochemical indices. The results showed: 1) During the entire experimental period, the average daily gain and dry matter intake of Group B were significantly higher than those of Groups C and D ($P<0.05$), with no significant difference from Group A ($P>0.05$); the feed conversion ratio of Group D was significantly higher than that of the other three groups ($P<0.05$). 2) At 150 days of age, the apparent digestibility of dry matter in Groups A and B was significantly higher than that in Group D ($P<0.05$); the apparent digestibility of neutral detergent fiber in Group A was significantly higher than that in the other three groups ($P<0.05$); the apparent digestibility of acid detergent fiber in Group A was significantly higher than that in Groups B and D (P<0.05); the metabolic efficiency of digestible energy in Groups A, B, and C was significantly higher than that in Group D (P<0.05); the apparent nitrogen digestibility and nitrogen retention rate in Group B were significantly higher than those in Group D (P<0.05), with no significant difference from Group A (P>0.05). 3) During the period of 61-150 days of age, the serum glucose concentration in Group B was significantly higher than that in Groups A and C (P<0.05), the serum triglyceride concentration in Group A was significantly lower than that in Group D (P<0.05), and the serum urea nitrogen concentration in Group C was significantly higher than that in Groups A, B, and D (P<0.05); at 90 days of age, the serum total protein concentration in Groups B and C was significantly higher than that in Group A (P<0.05); at 150 days of age, the serum globulin concentration in Group A was significantly higher than that in Group C (P<0.05). In conclusion, dietary supplementation with 5% palm kernel meal can achieve the same growth-promoting effect in summer crossbred bull calves as feeding soybean meal alone, and this diet is readily digestible and utilizable, with related serum biochemical indices remaining within normal ranges after feeding, without affecting calf health; dietary supplementation with 5% tea seed meal or camellia seed meal reduced feed intake, digestible nitrogen, and apparent nitrogen digestibility, thereby affecting the growth and development of the calves.

Full Text

Effects of Diets Containing Palm Kernel Meal, Oil Tea Seed Meal, or Tea Seed Meal on Digestion, Metabolism, and Serum Biochemical Indices of Weaned Calves

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Abstract

This experiment aimed to investigate the effects of diets containing palm kernel meal, oil tea seed meal, or tea seed meal on growth performance, digestion, metabolism, and serum biochemical indices of weaned Charolais crossbred male calves. Forty-eight healthy weaned calves at 46 days of age, with an average body weight of (79.5$±$0.79) kg, were randomly divided into four groups of twelve calves each. The calves were fed four isocaloric and isonitrogenous total mixed rations: Group A received a soybean meal-based diet (control), while Groups B, C, and D received diets containing 5% palm kernel meal, 5% oil tea seed meal, and 5% tea seed meal, respectively, with adjustments made through varying amounts of dried distillers grains with solubles, wheat bran, and soybean meal to maintain equal energy and protein levels. The experiment lasted 104 days, including a 14-day adaptation period and a 90-day formal experimental period. Daily feed intake was measured, body weight was recorded every 30 days, digestion and metabolism trials were conducted at 90 and 150 days of age using total fecal and urinary collection methods to determine nutrient digestibility and metabolic rates, and jugular blood samples were collected every 30 days for serum biochemical analysis.

The results showed: (1) Throughout the entire experimental period, average daily gain (ADG) and dry matter intake (DMI) in Group B were significantly higher than those in Groups C and D ($P<0.05$), with no significant difference from Group A ($P>0.05$). Feed conversion ratio (F/G) in Group D was significantly higher than in the other three groups ($P<0.05$). (2) At 150 days of age, the apparent digestibility of dry matter in Groups A and B was significantly higher than in Group D ($P<0.05$). The apparent digestibility of neutral detergent fiber (NDF) in Group A was significantly higher than in the other three groups ($P<0.05$). The apparent digestibility of acid detergent fiber (ADF) in Group A was significantly higher than in Groups B and D ($P<0.05$). The metabolic rate of digestive energy in Groups A, B, and C was significantly higher than in Group D ($P<0.05$). The apparent digestibility and deposition rate of nitrogen in Group B were significantly higher than in Group D ($P<0.05$), with no significant difference from Group A ($P>0.05$). (3) From 61 to 150 days of age, serum glucose concentration in Group B was significantly higher than in Groups A and C ($P<0.05$), serum triglyceride concentration in Group A was significantly lower than in Group D ($P<0.05$), and serum urea nitrogen concentration in Group C was significantly higher than in Groups A, B, and D ($P<0.05$). At 90 days of age, serum total protein concentration in Groups B and C was significantly higher than in Group A ($P<0.05$). At 150 days of age, serum globulin concentration in Group A was significantly higher than in Group C ($P<0.05$).

In conclusion, supplementation of 5% palm kernel meal in the diet can achieve growth-promoting effects equivalent to a soybean meal-based diet in weaned Charolais crossbred calves. This diet is readily digestible and utilizable, with associated serum biochemical indices remaining within normal ranges without compromising calf health. In contrast, supplementation with 5% tea seed meal or oil tea seed meal reduces feed intake, digestible nitrogen, and nitrogen apparent digestibility, thereby negatively affecting calf growth and development.

Keywords: Charolais crossbred calves; palm kernel meal; oil tea seed meal; tea seed meal; serum biochemical indices; digestion and metabolism

Introduction

The utilization of unconventional feed resources has garnered widespread attention. Reports indicate that China produces over one billion tons of unconventional feed resources annually, with various oilseed meals exceeding 15 million tons per year, yet only approximately 30% is utilized for feed [1]. This falls short of meeting the development needs of animal husbandry production, while the contradiction between large-scale livestock production and environmental pollution has become increasingly prominent. Therefore, resolving the challenge of promoting animal husbandry development while protecting the ecological environment through rational resource utilization has become urgent. Unconventional feeds have made significant contributions to addressing this dilemma. Most of these meal-based feed ingredients are by-products of industrial and agricultural processing. Materials such as palm kernel meal, oil tea seed meal, and tea seed meal, due to their low cost and rich nutritional composition, can not only serve as ruminant feed but also help factories reduce processing costs and minimize environmental pollution [2]. However, oil tea seed meal and tea seed meal contain high concentrations of tea saponins, tannins, alkaloids, and flavonoids, with tea saponins and tannins being the primary anti-nutritional factors. Tea saponins also impart a bitter taste that can negatively affect palatability [3-5], making the effects of dietary supplementation unpredictable.

Previous research has extensively investigated the nutritional composition of palm kernel meal, oil tea seed meal, and tea seed meal and their effects on animal production performance. However, most studies on digestibility have been based on in vitro or semi-in vivo methods, with limited reports on in vivo digestibility and serum biochemical indices. Therefore, this experiment was conducted to examine the effects of adding palm kernel meal, oil tea seed meal, or tea seed meal on growth performance, digestion, metabolism, and serum biochemical indices of post-weaning calves, providing a scientific basis for the utilization of unconventional feeds in animal production.

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1. Materials and Methods

1.1 Experimental Time and Location The experiment was conducted from October 2016 to January 2017 at the Xuchang Animal Science and Veterinary Medicine Practice Teaching Base of Henan Agricultural University.

1.2 Experimental Materials and Design A single-factor experimental design was employed. Forty-eight Charolais crossbred (Charolais × Nanyang Yellow Cattle) male calves weaned at 46 days of age, with an average body weight of (79.5$±$0.79) kg, were randomly divided into four groups of twelve calves each. Groups A, B, C, and D were fed four total mixed rations containing soybean meal, soybean meal + palm kernel meal, soybean meal + oil tea seed meal, and soybean meal + tea seed meal, respectively. Group A served as the control, while Groups B, C, and D achieved isocaloric and isonitrogenous levels with Group A through adjustments in dried distillers grains with solubles, wheat bran, and soybean meal content. The experimental period lasted 104 days, including a 14-day adaptation period and a 90-day formal period. Basal diet nutrient levels were established according to Li Lanjie et al. [6]. Diet composition and nutrient levels are presented in Table 1 .

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

Items	Groups
Ingredients	
Alfalfa	
Corn	
DDGS	
Wheat bran	
Soybean meal	
Molasses	
Tea seed meal	
Oil tea seed meal	
Palm kernel meal	
Limestone	
$CaHPO_4$	
NaCl	
Premix[1]	
Total	
Nutrient levels[2]	
DM	
CP	
EE	
Ash	
NDF	
ADF	
TP	
ME/(MJ/kg)	

[1]The premix provided the following per kg of diets: VA 15,000 IU, VD 5,000 IU, VE 50 mg, Fe 90 mg, Cu 12.5 mg, Mn 60 mg, Zn 100 mg, Se 0.3 mg, I 1.0 mg, Co 0.5 mg.

[2]ME was a calculated value, and ME=GE-FE-UE-CH_4E (CH_4E in the equation was 8% of GE) [7]; the other nutrient levels were measured values.

1.3 Animal Management Upon arrival, calves were weighed on an empty stomach in the morning, ear-tagged, and dewormed before being housed individually in calf hutches (4.5 m × 1.5 m). Each calf was provided with separate water and feed troughs. Feed was offered twice daily at 08:00 and 16:00, with free access to water. Pens were cleaned and disinfected weekly. Diets were provided at 3.5% of body weight on a dry matter basis.

1.4 Sample Collection and Analysis

1.4.1 Growth Performance Measurement Residual feed was collected daily before morning feeding to calculate dry matter intake (DMI). Body weight of each calf was measured individually before morning feeding at 60, 90, 120, and 150 days of age to calculate average daily gain (ADG) for each group. Diet and residual feed samples were analyzed for dry matter (DM), crude protein (CP), ether extract (EE), ash, calcium (Ca), and phosphorus (P) content according to Zhang Liying [8].

1.4.2 Fecal and Urine Sample Collection and Analysis Digestion and metabolism trials were conducted at 90 and 150 days of age using total fecal and urinary collection in metabolism crates for 6 days (2-day adaptation and 4-day collection period). Six calves per group were selected, and daily feed intake, total fecal output, and total urinary output were recorded. Daily fecal samples (100 g) were mixed with 50 mL of 10% sulfuric acid for nitrogen fixation, while daily urine samples (100 mL) were mixed with 10 mL of 10% sulfuric acid for nitrogen fixation. All samples were stored at -20°C for subsequent analysis.

Fecal samples: CP content was determined using a Kjeldahl nitrogen analyzer, NDF and ADF contents were measured using an ANKOM 200 Fiber Analyzer, gross energy (GE) was determined using a PARR-6400 automatic oxygen bomb calorimeter, and DM and ash contents were measured to calculate organic matter (OM) content [8].

Urine samples: Urinary nitrogen was determined using a Kjeldahl nitrogen analyzer, and urine energy was measured using a PARR-6400 automatic oxygen bomb calorimeter. Energy utilization rates were calculated using the following formulas:

- Gross energy digestibility (%) = 100 × digestible energy / gross energy
- Gross energy metabolic rate (%) = 100 × metabolic energy / gross energy
- Digestible energy metabolic rate (%) = 100 × metabolic energy / digestible energy

1.4.3 Serum Sample Collection and Analysis At the start of the experiment and every 30 days thereafter, six calves per group were selected based on body weight close to the group mean. Blood samples were collected via jugular venipuncture into 10 mL vacuum tubes (without anticoagulant), centrifuged at 4,000 r/min for 30 minutes, and the serum was collected into two 1.5 mL tubes and stored at -20°C for analysis.

Serum biochemical indices were determined using standard kits (Beijing Jinhai Keyu Biotechnology Development Co., Ltd.). Glucose (GLU), albumin (ALB), globulin (GLB), total protein (TP), urea nitrogen (UN), and triglyceride (TG) concentrations were measured using colorimetric methods (Kehua ZY KHB-1280 automatic biochemical analyzer). Growth hormone (GH), leptin (LEP), insulin-like growth factor-1 (IGF-1), and β-hydroxybutyric acid (β-HB) concentrations were determined using enzyme-linked immunosorbent assay (ST-360 automatic microplate reader).

1.5 Statistical Analysis Experimental data were processed using SAS 9.2 statistical software with MIXED and GLM procedures. When significant differences were detected, multiple comparison tests were performed using LSD and Duncan' s methods. Differences were considered significant at P<0.05 and marginally significant at 0.05≤P<0.10.

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2. Results

2.1 Growth Performance As shown in Table 2 , throughout the entire experimental period (61-150 days of age), ADG and DMI in Group B were significantly higher than those in Groups C and D (P<0.05), with no significant difference from Group A (P>0.05). Feed conversion ratio in Group D was significantly higher than in the other three groups (P<0.05). Group B showed significantly higher ADG (during 61-90, 91-120, and 121-150 days) and DMI (during 61-90 and 91-120 days) compared to Groups C and D (P<0.05), with no significant difference from Group A (P>0.05). DMI in Group B during 121-150 days was significantly higher than in the other three groups (P<0.05). Feed conversion ratio in Group D (during all periods) was significantly higher than in Groups A and B (P<0.05), with no significant difference from Group C (P>0.05).

Both ADG, DMI, and feed conversion ratio were significantly affected by age (P<0.05). ADG was not affected by the group × age interaction (P>0.05), while DMI and feed conversion ratio were significantly affected by the group × age interaction (P<0.05).

Table 2 Effects of diets containing palm kernel meal, oil tea seed meal, and tea seed meal on growth performance of weaned calves

Items	Groups	P-value of fixed effects			
	A	B	C	D	Age
ADG (kg/d)					
61-150 days	1.05a	1.21a	0.71b	0.70b	<0.0001
61-90 days	1.05a	1.24ab	0.86bc	0.79c	<0.0001
91-120 days	0.92a	1.49a	0.83b	0.69c	<0.0001
121-150 days	1.21a	1.18a	0.45b	0.61b	<0.0001

Items	Groups	P-value of fixed effects			
DMI (kg/d)					
61-150 days	4.46a	4.78a	3.56b	3.40b	<0.0001
61-90 days	3.78ab	4.00a	3.20b	2.49c	<0.0001
91-120 days	4.21a	4.36a	3.32b	3.02b	<0.0001
121-150 days	5.38b	5.98a	4.87c	3.96d	<0.0001
F/G					
61-150 days	3.40c	3.46b	5.41b	5.92a	<0.0001
61-90 days	2.89d	3.16b	3.59b	6.18a	<0.0001
91-120 days	5.41b	3.15b	5.92a	7.27a	<0.0001
121-150 days	5.93a	4.12a	5.97a	4.55a	<0.0001

In the same row, values with different small letter superscripts indicate significant differences (P<0.05). The same applies below.

2.2 Nutrient Apparent Digestibility As shown in Table 3 , at 90 days of age, there were no significant differences in apparent digestibility of any nutrients among groups (P>0.05). At 150 days of age, intake in Groups A, B, and C was significantly higher than in Group D (P<0.05). Fecal output in Groups A and B was significantly higher than in Group D (P<0.05), with no significant difference from Group C (P>0.05). Apparent digestibility of dry matter in Group A was significantly higher than in Groups C and D (P<0.05), with no significant difference from Group B (P>0.05). Apparent digestibility of neutral detergent fiber in Group A was significantly higher than in Groups B, C, and D (P<0.05). Apparent digestibility of acid detergent fiber in Group A was significantly higher than in Groups B and D (P<0.05), with no significant difference from Group C (P>0.05), while Group C was significantly higher than Group D (P<0.05). There were no significant differences among groups in metabolic body weight, intake/metabolic body weight, or organic matter apparent digestibility at either 90 or 150 days of age (P>0.05).

Table 3 Effects of diets containing palm kernel meal, oil tea seed meal, and tea seed meal on nutrient intake and apparent digestibility of weaned calves

Items	Groups	P-value
	A	B
150 days of age		
Metabolic weight $W^{0 \cdot 75}$ (kg)	67.90a	65.32ab
Intake (kg/d)	4.37a	4.39a
Intake/$W^{0 \cdot 75}$	1.59a	1.53a
Fecal output (kg/d)	1.44a	1.45a
DM apparent digestibility (%)	69.42b	67.18b
OM apparent digestibility (%)	72.24ab	76.06a
NDF apparent digestibility (%)	49.50a	40.24bc

Items	Groups	P-value
ADF apparent digestibility (%)	38.37ab	50.29a

2.3 Energy Utilization Rate As shown in Table 4 , at 90 days of age, there were no significant differences in any energy indices among groups (P>0.05). At 150 days of age, gross energy intake (GEI) in Groups A, B, and C was 36.14%, 35.54%, and 25.30% higher than in Group D, respectively (P<0.05). Fecal energy (FE) in Groups A and C was 27.08% and 29.17% higher than in Group D, respectively (P<0.05), with no significant difference from Group B (P>0.05). Methane energy (CH_4E) in Groups A, B, and C was 38.46%, 20.08%, and 38.46% higher than in Group D, respectively (P<0.05). Gross energy metabolic rate in Groups A, B, and C was 9.25%, 12.89%, and 7.20% higher than in Group D, respectively (P<0.05). Digestible energy metabolic rate in Groups A, B, and C was 5.44%, 8.18%, and 6.57% higher than in Group D, respectively (P<0.05). There were no significant differences in urinary energy or gross energy digestibility among groups (P>0.05).

Table 4 Effects of diets containing palm kernel meal, oil tea seed meal, and tea seed meal on energy utilization rate of weaned calves

Items	Groups	P-value
	A	B
150 days of age		
GEI [MJ/(kg $W^{0 \cdot 75}$ · d)]	2.26a	2.25a
FE [MJ/(kg $W^{0 \cdot 75}$ · d)]	0.61a	0.54ab
UE [MJ/(kg $W^{0 \cdot 75}$ · d)]	0.18a	0.16a
CH_4E [MJ/(kg $W^{0 \cdot 75}$ · d)]	0.55ab	0.72a
GE digestibility (%)	58.13a	60.07a
GE metabolic rate (%)	79.29a	81.35a
DE metabolic rate (%)	38.37ab	50.29a

2.4 Nitrogen Metabolism As shown in Table 5 , at 90 days of age, there were no significant differences in nitrogen metabolism indices among groups (P>0.05). At 150 days of age, nitrogen intake in Groups A and B was significantly higher than in Groups C and D (P<0.05), with Group C being significantly higher than Group D (P<0.05). Fecal nitrogen in Groups A and C was significantly higher than in Group D (P<0.05), with no significant difference from Group B (P>0.05). Nitrogen retention in Group B was significantly higher than in Groups C and D (P<0.05), with no significant difference from Group A (P>0.05). Nitrogen deposition rate in Group B was significantly higher than in Group D (P<0.05), with no significant difference from Groups A and C (P>0.05). Digestible nitrogen in Groups A and B was significantly higher than in Groups C and D (P<0.05), with Group C being significantly higher than Group D (P<0.05). Nitrogen apparent digestibility in Group B was significantly higher than in Groups C and D (P<0.05), with no significant difference from Group A (P>0.05). There were no significant differences in urinary nitrogen among groups (P>0.05).

Table 5 Effects of diets containing palm kernel meal, oil tea seed meal, and tea seed meal on nitrogen metabolism of weaned calves

Items	Groups	P-value
	A	B
150 days of age		
N intake [g/(kg $W^{0\cdot75}\cdot$ d)]	1.44a	1.45a
Fecal N [g/(kg $W^{0\cdot75}\cdot$ d)]	0.40a	0.35ab
Urine N [g/(kg $W^{0\cdot75}\cdot$ d)]	0.55ab	0.72a
Retained N [g/(kg $W^{0\cdot75}\cdot$ d)]	0.49a	0.38a
N deposition rate (%)	38.37ab	50.29a
Digestible N [g/(kg $W^{0\cdot75}\cdot$ d)]	1.04a	1.10a
N apparent digestibility (%)	72.24ab	76.06a

2.5 Serum Biochemical Indices As shown in Table 6 , there were no significant differences among groups in serum concentrations of ALB, GLB, β-HB, GH, LEP, and IGF- (P>0.05). Mean serum GLU concentration in Group B was significantly higher than in Groups A and C (P<0.05), with no significant difference from Group D (P>0.05). Serum TG concentration in Group A was significantly lower than in Group D (P<0.05), with no significant differences from other groups (P>0.05). Serum UN concentration in Group C was significantly higher than in Groups A, B, and D (P<0.05).

At both 90 and 150 days of age, serum GLU concentration in Group B was significantly higher than in Groups A and C (P<0.05), with no significant difference from Group D (P>0.05). At 90 days of age, serum TP concentration in Groups B and C was significantly higher than in Group A (P<0.05), with no significant difference from Group D (P>0.05). At 90 days of age, serum UN concentration in Group A was significantly lower than in Groups B, C, and D (P<0.05), with no significant differences among Groups B, C, and D (P>0.05). At 120 days of age, serum TG concentration in Group C was significantly lower than in Group D (P<0.05), with no significant differences from other groups (P>0.05). At 150 days of age, serum GLB concentration in Group A was significantly higher than in Group C (P<0.05), with no significant difference from Groups B and D (P>0.05).

Serum GLU and UN concentrations were significantly affected by age (P<0.05), while age had no significant effect on serum TG, TP, ALB, GLB, β-HB, GH, LEP, and IGF- concentrations (P>0.05). Serum GLU, TP, GLB, and UN concentrations were significantly affected by the group $\times$ age interaction (P<0.05), whereas serum TG, ALB, β-HB, GH, LEP, and IGF- were not affected by the group × age interaction (P>0.05).

Table 6 Effects of diets containing palm kernel meal, oil tea seed meal, and tea seed meal on serum biochemical indexes of weaned calves

Items	Groups	P-value of fixed effects			
	A	B	C	D	Age
GLU (mmol/L)					
Mean	3.44b	4.68a	3.71b	4.34ab	<0.0001
150 days	2.39b	3.97a	2.67b	3.73a	
TG (mmol/L)					
Mean	4.04b	5.45a	5.53a	4.80ab	0.10
150 days	0.10b	0.15ab	0.14ab	0.17a	
TP (g/L)					
Mean	53.80b	61.62a	59.91a	56.34ab	0.15
150 days	0.12ab	0.15ab	0.09b	0.18a	
ALB (g/L)					
Mean	32.46a	28.03ab	26.59b	27.95ab	0.09
150 days	4.73c	3.30b	5.96bc	5.47a	
GLB (g/L)					
Mean	57.88b	62.37a	56.81b	57.72b	0.18
150 days	6.82a	6.15a	6.63b	6.98a	
UN (mmol/L)					
Mean	4.73c	3.30b	5.96bc	5.47a	<0.0001
150 days	6.82a	6.15a	6.63b	6.98a	
β-HB (mmol/L)					
Mean	0.55ab	0.72a	0.49bc	0.31c	0.18
150 days	0.49a	0.38a	0.41ab	0.39b	
GH (ng/mL)					
Mean	38.37ab	50.29a	38.07ab	33.05b	0.18
150 days	1.04a	1.10a	0.90b	0.70c	
LEP (ng/mL)					
Mean	72.24ab	76.06a	70.39b	70.62b	0.18
150 days	0.55ab	0.72a	0.49bc	0.31c	
IGF- (ng/mL)					
Mean	4.73c	3.30b	5.96bc	5.47a	0.18
150 days	6.82a	6.15a	6.63b	6.98a	

3. Discussion

3.1 Effects of Diets Containing Palm Kernel Meal, Oil Tea Seed Meal, or Tea Seed Meal on Calf Growth Performance In production practice, animal performance is a crucial indicator reflecting growth status. Studies have shown that when palm kernel meal was added at 1.5, 2.5, and 3.5 kg/d to diets of Swiss castrated calves, no significant differences in ADG or DMI were observed among different supplementation levels, though both were higher than in the pure forage control group [9]. In this experiment, DMI in the palm kernel meal group was significantly higher than in the oil tea seed meal and tea seed meal groups. The increased intake with palm kernel meal supplementation may be attributed to its higher digestion rate compared to oil tea seed meal and tea seed meal. Research indicates that in ruminants, feed intake correlates more strongly with digestion rate than with digestibility itself [10]. Additionally, palm kernel meal is non-toxic, has a chocolate-like flavor, and exhibits good palatability, which may contribute to increased intake [11]. DMI is closely related to ADG in calves, and in this study, the palm kernel meal group achieved the highest ADG at 1.21 kg/d. The higher organic matter and nutrient digestibility in the palm kernel meal group compared to the oil tea seed meal and tea seed meal groups also contributed to the highest ADG. These growth-promoting results are consistent with Lai Jingtao et al. [12] but differ somewhat from Carvalho et al. [13], possibly due to variations in diet composition, nutrient levels, palm kernel meal origin and nutritional content, as well as differences in animal breed, sex, and age.

3.2 Effects of Diets Containing Palm Kernel Meal, Oil Tea Seed Meal, or Tea Seed Meal on Calf Digestion and Metabolism The intake and digestion of DM and OM can reflect animal health status, feed utilization efficiency, and gastrointestinal development [14-15]. In this study, DM apparent digestibility did not differ significantly between the soybean meal-based diet and the palm kernel meal diet, and both were significantly higher than the other two groups. Although OM apparent digestibility showed only a trend toward significance, the soybean meal and palm kernel meal groups had higher values than the other groups, indicating that palm kernel meal can partially replace soybean meal in beef calf diets. The higher crude fiber content in palm kernel meal may alter microbial flora, stimulate gastrointestinal motility and fecal excretion, increase metabolic rate, and enhance nutrient demand, thereby improving DM apparent digestibility. NDF and ADF serve as substrates for rumen fiber-degrading bacteria, and the volatile fatty acids produced through fermentation provide substantial energy for calves. Therefore, the digestion extent of NDF and ADF can reflect rumen digestive function development [16-17]. In this experiment, calves fed the soybean meal-based diet showed significantly higher NDF and ADF apparent digestibility than the other three groups. This may be because palm kernel meal, oil tea seed meal, and tea seed meal contain anti-nutritional factors. Palm kernel meal primarily contains mannan and other non-starch polysaccharides [18], while oil tea seed meal contains high concentrations of saponins and tannins that affect palatability [4]. Tea seed meal contains bitter-tasting tea saponins that reduce palatability and can be toxic at excessive levels, affecting feed intake and performance [19]. These anti-nutritional factors reduce NDF and ADF intake, accelerate gastrointestinal passage rate, shorten contact time between fiber and degrading bacteria, lower dietary energy concentration, slow metabolic rate, reduce volatile fatty acid absorption, and decrease fiber degradation rates, ultimately reducing digestibility [20].

3.3 Effects of Diets Containing Palm Kernel Meal, Oil Tea Seed Meal, or Tea Seed Meal on Calf Energy Utilization Rate Energy provided by the diet beyond maintenance requirements is utilized for various forms of production. Young growing animals primarily store energy in newly synthesized tissue protein, while adult animals accumulate more energy as fat, and lactating animals convert dietary energy into milk components [20]. In this experimental stage, calves focused energy utilization on growth. Research indicates that improving energy metabolic rate is key to enhancing energy utilization efficiency [21]. In this study, gross energy digestibility across all four groups remained around 72% and was minimally affected by diet, similar to the 71.7% reported by Khan et al. [22]. Energy lost through feces, urine, and methane accounted for approximately 41% of intake, with average gross energy metabolic rate and digestible energy metabolic rate of 57.11% and 78.99%, respectively. The patterns of digestible and metabolic energy mirrored gross energy intake, possibly because after 90 days of feeding, calves' gastrointestinal tracts had adapted to different diets, thereby affecting energy utilization efficiency.

3.4 Effects of Diets Containing Palm Kernel Meal, Oil Tea Seed Meal, or Tea Seed Meal on Calf Nitrogen Metabolism While energy maintains vital activities, protein constitutes important body components, and both interact to promote growth and development. Ruminants primarily utilize nitrogen through nitrogen metabolic pathways [14], with nitrogen sources mainly from undigested dietary protein, shed intestinal mucosal cells, and intestinal bacteria. In this experiment, dietary protein levels were similar across groups. However, at 150 days of age, nitrogen intake, digestible nitrogen, and nitrogen apparent digestibility were significantly higher in the soybean meal and palm kernel meal groups than in the oil tea seed meal and tea seed meal groups. This may be because tea saponins and tannins in oil tea seed meal and tea seed meal reduce palatability, decrease nitrogen intake, limit nitrogen availability for rumen microbes, reduce microbial populations, decrease protein flow to the small intestine, and consequently lower nitrogen apparent digestibility. Additionally, appropriate energy-to-protein ratios are essential for optimal nutrient utilization, and improper ratios can reduce efficiency [23]. In this study, the palm kernel meal group showed the highest nitrogen retention and deposition rate, with no significant difference from the soybean meal group. Partial replacement of soybean meal with palm kernel meal, with its higher fiber and sugar content and slightly lower protein content, may have balanced dietary nutrients more appropriately for rumen and microbial development in this growth stage, increasing protein flow to the small intestine and improving nitrogen deposition rate for body protein synthesis, corresponding to the higher ADG observed from 61-150 days of age.

3.5 Effects of Diets Containing Palm Kernel Meal, Oil Tea Seed Meal, or Tea Seed Meal on Calf Serum Biochemical Indices Serum biochemical indices comprehensively reflect livestock nutritional status, metabolism, internal and external environmental balance, health, and production performance [24]. Serum urea nitrogen concentration accurately reflects dietary amino acid balance and protein metabolism, representing short-term protein nutritional status [25] and generally showing a significant negative correlation with nitrogen deposition and protein or amino acid utilization [26]. For ruminants, when rumen ammonia nitrogen concentration reaches equilibrium between ammonia release rate, dietary nitrogen degradation rate, and microbial protein synthesis rate, blood ammonia concentration decreases, leading to reduced serum urea nitrogen concentration [27]. In this study, serum UN concentration was significantly lower in the palm kernel meal and soybean meal groups, indicating superior amino acid balance or nitrogen deposition and higher protein utilization compared to the other two groups, consistent with nitrogen apparent digestibility, deposition rate, and weight gain trends.

Glucose is an important indicator of energy balance, reflecting glucose absorption, transport, and metabolism, with elevated blood glucose indicating enhanced fat deposition and protein synthesis [28-29]. Total protein (TP) comprises albumin (ALB) and globulin (GLB), where TP reflects protein absorption and metabolism, ALB functions as a nutrient carrier and maintains plasma osmotic pressure, and GLB concentration reflects immune capacity [30]. Triglycerides (TG) reflect fat deposition, with decreased serum cholesterol and TG indicating poor lipid digestion and absorption. The results showed that the palm kernel meal group significantly increased serum GLU and TP concentrations compared to the other three groups, consistent with digestion, metabolism, and weight gain trends. This may be because palm kernel meal lacks toxic anti-nutritional factors, promotes intake, provides higher digestible nutrients, enhances GLU and TP production, and promotes fat deposition and protein synthesis, benefiting calf growth.

IGF- is secreted by the liver into the bloodstream, binds to carrier proteins, and is transported to target organs (e.g., muscle, bone) to exert its effects. GH and IGF- form the GH-IGF- axis that regulates growth and development, with GH stimulating hepatic IGF- production while IGF- exerts negative feedback on GH secretion [31]. However, this study did not show the expected reciprocal relationship between GH and IGF- , and no significant differences were observed among groups. Breier [32] and Louveau [33] reported that nutritional status plays an important role in regulating GH and IGF- circulation, with serum GH pulse frequency increasing as dietary protein intake increases. The lack of significant differences in serum GH and IGF- concentrations among groups in this study suggests that feeding these four meal-based diets did not significantly affect GH secretion, which contradicts the improved growth performance in the palm kernel meal group and warrants further investigation. Leptin, a protein secreted by adipocytes, primarily regulates energy balance [34], participates in glucose, fat, and energy metabolism after entering the bloodstream, and influences other hormone secretion. No significant differences in serum leptin concentration were observed among groups in this study. The difficulty in establishing clear patterns and the lack of significant differences in multiple hormone indices may be related to environmental factors, animal age, and temporary stress states, and the effects of different meal-based diets on calf hormone levels require further research.

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4. Conclusion

A diet supplemented with 5% palm kernel meal can meet the nutrient requirements of weaned Charolais crossbred calves. This diet not only maintains high ADG but also is readily digestible and utilizable, with associated serum biochemical indices remaining within normal ranges without compromising calf health. In contrast, supplementation with 5% tea seed meal or oil tea seed meal reduces feed intake, digestible nitrogen, and nitrogen apparent digestibility, negatively affecting calf growth and development.

References

[1] Diao Qiyu, Zhang Naifeng. Development and application evaluation of unconventional feed resources[J]. Feed and Husbandry: New Feed, 2010(10): 8-12.

[2] Shi Fenghua. Effects of unconventional feeds replacing corn on rumen fermentation, nutrient digestibility, production performance, and carcass quality in beef cattle[D]. PhD Thesis. Beijing: China Agricultural University, 2014.

[3] Ueda H, Shigemizu G. Effects of tea saponin, cholesterol and oils on the growth and feed passage rates in chicks[J]. Nihon Chikusan Gakkaiho, 1998, 69(1): 14-21.

[4] Wang Y F, Sun D, Chen H, et al. Fatty acid composition and antioxidant activity of tea (Camellia sinensis L.) seed oil extracted by optimized supercritical carbon dioxide[J]. International Journal of Molecular Sciences, 2011, 12(11): 7708-7719.

[5] Xiong Daoling, Zhang Tuanjie, Chen Jinzhou, et al. Research progress on extraction and application of tea saponin[J]. Chemical Industry Progress, 2015, 34(4): 1080-1087.

[6] Li Lanjie, Cheng Shuru, Diao Qiyu, et al. Effects of dietary non-fibrous carbohydrate/neutral detergent fiber ratio on growth performance and nutrient digestibility in beef calves[J]. Chinese Journal of Animal Nutrition, 2017, 29(6): 2143-2152.

[7] Xu Guishan, Diao Qiyu, Ji Shoukun, et al. Effects of different feeding levels on energy and protein digestion and metabolism in mutton sheep[J]. Chinese

Journal of Animal Science, 2012, 48(17): 40-44.

[8] Zhang Liying. Feed Analysis and Feed Quality Detection Technology[M]. 3rd ed. Beijing: China Agricultural University Press, 2007: 49-151.

[9] Avellaneda-Cevallos J H, Cedeno-Cedeno T A, Suarez-Chiquito A, et al. Effect of palm kernel meal plus urea on finishing of Brown Swiss young bulls[J]. Journal of Dairy Science, 2007, 90: 96-96.

[10] McDonald P, Edwards A, Greenhalgh J F D, et al. Food additives[M]//McDonald P, Edwards R A, Greenhalgh J F D, et al. Animal Nutrition. 7th ed. Harlow: Pearson Education Ltd., 2011: 594-607.

[11] Tang Maoyan, Chen Xudong, He Xiaoming. Research on application of palm kernel meal in animal feed[J]. Feed Industry, 2013(20): 45-48.

[12] Lai Jingtao, Li Xiuliang, Liu Ruixin. Effects of replacing corn with equal amounts of palm kernel meal on lactating and dry cows[J]. Guangxi Animal Husbandry and Veterinary Medicine, 2010, 26(6): 329-331.

[13] Carvalho L P F, Melo D S P, Pereira C R M, et al. Chemical composition, in vivo digestibility, N degradability and enzymatic intestinal digestibility of protein supplements[J]. Animal Feed Science and Technology, 2005, 119(1/2): 171-178.

[14] Zhang Weibing, Diao Qiyu, Zhang Naifeng, et al. Effects of dietary protein to energy ratio on growth performance and nutrient digestion in 8-10 month-old dairy heifers[J]. Scientia Agricultura Sinica, 2010, 43(12): 2541-2547.

[15] Lou Can, Jiang Chenggang, Ma Tao, et al. Effects of feeding level on digestion and metabolism in pregnant sheep[J]. Chinese Journal of Animal Nutrition, 2014, 26(1): 134-143.

[16] Gouet P, Nebout J M, Fonty G, et al. Cellulolytic bacteria establishment and rumen digestion in lambs isolated after birth[J]. Canadian Journal of Animal Science, 1984, 64(5): 163-164.

[17] Li Hui, Diao Qiyu, Zhang Naifeng, et al. Effects of different protein levels on digestion, metabolism and serum biochemical indices in calves[J]. Scientia Agricultura Sinica, 2008, 41(4): 1219-1226.

[18] Knudsen K E B. Carbohydrate and lignin contents of plant materials used in animal feeding[J]. Animal Feed Science and Technology, 1997, 67(4): 319-338.

[19] Zhang Min, Sun Yanfa, Li Yan, et al. Effects of dietary tea seed cake meal on slaughter performance, blood biochemical indices, and duodenal mucosal immune function in broilers[J]. China Poultry, 2016, 38(3): 24-29.

[20] Cui Xiang, Diao Qiyu, Zhang Naifeng, et al. Effects of dietary energy level on growth performance and nutrient digestion and metabolism in weaned calves[J]. Acta Veterinaria et Zootechnica Sinica, 2014, 45(11): 1815-1823.

[21] Mu Ali, Wu Naike, Liu Faxiao, et al. Study on energy requirement and metabolic patterns in 4-6 month-old crossbred calves[J]. Journal of Domestic Animal Ecology, 2007, 28(1): 23-26.

[22] Khan M A, Lee H J, Lee W S, et al. Starch source evaluation in calf starter: . Ruminal parameters, rumen development, nutrient digestibilities, and nitrogen utilization in Holstein calves[J]. Journal of Dairy Science, 2008, 91(3): 1140-1149.

[23] Zhang Rong. Study on effects of energy level and source on digestion and metabolism in early-weaned calves[D]. Master' s Thesis. Beijing: Chinese Academy of Agricultural Sciences, 2008.

[24] Sudre K, Cassar-Malek I, Listrat A, et al. Biochemical and transcriptomic analyses of two bovine skeletal muscles in Charolais bulls divergently selected for muscle growth[J]. Meat Science, 2005, 70(2): 267-277.

[25] Lapierre H, Lobley G E. Nitrogen recycling in the ruminant: a review[J]. Journal of Dairy Science, 2001, 84(S1): E223-E236.

[26] Ponnampalam E N, Egan A R, Sinclair A J, et al. Feed intake, growth, plasma glucose and urea nitrogen concentration, and carcass traits of lambs fed isoenergetic amounts of canola meal, soybean meal, and fish meal forage based diet[J]. Small Ruminant Research, 2005, 58(3): 245-252.

[27] Li Jianguo, Li Ying, Cao Yufeng, et al. Effects of protein supplements replacing cottonseed cake on performance and blood biochemical indices in beef cattle[J]. Chinese Journal of Animal Nutrition, 2001, 13(4): 50-53.

[28] An Jiaoyang, Lü Qiufeng, Cao Shuang, et al. Effects of different cellulase levels on slaughter performance, immune organ indices, and serum biochemical indices in broilers[J]. Modern Animal Husbandry and Veterinary Medicine, 2011(12): 56-61.

[29] Gong Feifei, Hu Denglin, Zhao Zhengjian, et al. Effects of nutritional regulator supplementation on growth and biochemical indices of grazing lambs in warm season[J]. China Herbivore Science, 2011, 31(4): 26-29.

[30] Yang Chuntao, Si Bingwen, Siqinbateer, et al. Effects of supplementing concentrate with different energy to nitrogen ratios on growth performance and blood indices of pastoral lambs in winter and spring[J]. Chinese Journal of Animal Nutrition, 2015, 27(1): 289-297.

[31] Yan Yunfeng, Yang Hua, Yang Yonglin, et al. Effects of different dietary protein levels on IGF-1 and GH secretion and gene expression in sheep[J]. Acta Veterinaria et Zootechnica Sinica, 2015, 46(1): 85-95.

[32] Breier B H. Regulation of protein and energy metabolism by the somatotropic axis[J]. Domestic Animal Endocrinology, 1999, 17(2/3): 209-208.

[33] Louveau I, Bonneau M. Biological actions of somatotropin in pigs[M]//Renaville R, Burny A. Biotechnology in Animal Husbandry. Dordrecht: Springer, 2001,

5: 111-131.

[34] Wang Chunyan, Du Ruiping, Zhang Xingfu, et al. Overview of leptin and its physiological functions[J]. Chinese Journal of Animal Nutrition, 2012, 24(3): 423-427.

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