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Effects of different unconventional feed combinations on growth, digestion and rumen fermentation of dairy cows

Ming Chen[1], Mingan Dai[2*], Qingjiang Wang[1], Haonan Zhan[1], Zhoufu Bai[3]

[1] School of Animal Science and Technology, Jiangsu Agri-animal Husbandry Vocational College, Taizhou, 225300, China
[2] Jiangsu Guoqiao Biotechnology Co., Ltd., Changzhou, 213300, China
[3] Experimental Farm, Yangzhou University, Yangzhou, 225000, China

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ABSTRACT

To explore the effects of unconventional feed combinations on the growth and production, digestion and metabolism, and rumen fermentation of dairy cows, three different dairy cows were selected for the experiment. They are Holstein cows with permanent rumen fistula, 3 primiparous cows and 6 multiparous cows. The cow diet was prepared according to the ratio of 0% CGF, 7% CGF and 11% CGF. Part of alfalfa hay in the conventional diet was replaced by CGF and *Leymus chinensis*. The study analyzed the feed intake, digestibility, lactation performance, blood biochemical indicators, rumen degradation parameters, rumen microorganisms and other indicators of dairy cows. The nutritional composition, digestible nutrients and absorbable protein content of CGF, *L. chinensis* and alfalfa hay were verified. The feed economic benefits of different unconventional feed combinations were also investigated. The protein small intestine digestibility of CGF was higher than that of alfalfa hay. tdFA, NEm, NEg, and DEp were significantly higher than those of *L. chinensis* and alfalfa hay (P<0.05). Under the three CGF ratios, the nutrient intake and digestibility of the CGF-11% group were the highest (P<0.05). The S, Kd dry matter degradation rate and crude protein degradation rate of the CGF-11% group were significantly higher than those of the CGF-0% group and CGF-7% group (P<0.05). The CGF-11% group had the highest total output value and economic benefits, 119.057 ¥/d and 68.62 ¥/d respectively. To sum up, it was feasible to use the combination of CGF and *L. chinensis* to replace part of alfalfa hay in cow feed. This method could effectively promote rumen degradation and nutrient absorption in dairy cows. And it can improve the production and economic benefits of dairy farming. This is of great value for adjusting the structure of aquaculture feed in China.

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Introduction

Animal husbandry is an important industry in China's agricultural economic development, accounting for more than 1/3 of the total agricultural economic output value. Among them, dairy cattle breeding and the dairy product production industry are important development hotspots of animal husbandry in recent years (1). However, the development level of China's dairy farming and production industry still needs to be improved. There is a significant gap between China and the developed countries in animal husbandry in terms of breeding level and yield per unit area. The shortage of local feed is an important factor limiting the development of China's dairy farming industry. It is difficult to keep pace with the development of animal husbandry in China's forage and feed localization. There is a large gap between supply and demand in the development of the dairy cattle breeding industry (2). The lack of high-quality roughage resources makes it difficult to speed up the development of China's dairy cattle breeding industry. The supply of high-quality coarse fodder is in short supply, which cannot match the energy storage of China's dairy cows. High-quality roughage resources such as alfalfa hay are an important basis for improving the production efficiency of the dairy cattle breeding industry. And alfalfa hay has many advantages such as high protein content and good palatability. High-quality alfalfa hay can provide dairy cows with crude protein, trace elements and other nutrients. This is of great value to improve the cow's stomach health (3,4). Alfalfa hay is one of the main imported feed resources in China. China has implemented a number of policies and plans to plant alfalfa hay locally, hoping to solve the problem of the gap between the supply and demand of alfalfa hay. However, the quality and yield of alfalfa hay domesticated still cannot fill the production gap of dairy farming. It also needs to import a large amount of alfalfa hay from foreign countries for cow breeding (5,6). In addition, many pastures rely on imported alfalfa hay for breeding and use alfalfa hay feeding to improve the production capacity of dairy cows. However, a large number of alfalfa hay imports have led to a continuous increase in the cost of dairy farming. The economic benefits of raw and fresh milk in China have always been at a low level. And the competitiveness in the international market is not strong, forming a situation of high input and low output dairy farming. Therefore, it is required to actively adjust the feed structure of dairy farming, develop local low-cost feed resources, and reduce the dependence of dairy far-

* Corresponding author. Email: zzr13179361166@163.com

ming on imported feed resources (7,8). Therefore, corn fiber feed (CGF) and *L. chinensis* combination were used to replace alfalfa hay in the conventional diet to analyze the impact of unconventional feed on cow breeding. It is expected to provide a reference for the development of unconventional dairy cow diet combinations.

Materials and Methods

Test materials and animals

The main materials included corn fiber feed (CGF), *L. chinensis* and alfalfa hay. The raw materials of the test sample include soybean husk, soybean residue, beet meal, corn silage, crushed corn and other materials. All test materials were taken from pasture and feed companies. The material samples were collected by the quartering method. After the sample is prepared into the air-dried sample, use a 1mm sieve for crushing and sieving. Then put it into a sealed bag for storage at 4 ℃.

The 3 × 3 repeat the Latin square to design the experimental cow diet. The test period is 21 days, divided into 14 days of the adaptation period and 7 days of the sampling period. The proportion of concentrate and coarse in the experimental diet was 53:47, and the experimental diet was divided into three groups according to the proportion of coarse feed and CGF. The CGF-0% group contained 0% corn fiber feed. The CGF-7% group contained 7% corn fiber feed. The CGF-11% group contained 11% corn fiber feed. The composition of concentrated feed in each group is the same, and the feed in each group can meet the nutritional needs of dairy cows. Table 1 shows the feed composition and nutritional composition of the experimental diet.

The growth and production performance, digestion and metabolism and economic benefit analysis were selected as the test indexes. The experimental animals were 3 primiparous cows and 6 multiparous cows, with an average body weight of 589 ± 48.0 kg and average lactation days of 91 ± 22.8 days. According to the principle of similarity, the cows were randomly divided into three groups, with three cows in each group. They were raised in a single column, fed and drank freely, and were pushed six times a day.

The rumen fermentation test animals were 3 healthy Holstein cows. All three cows were equipped with permanent rumen fistula, and their weight was 600 ± 15kg. The experiment was carried out in a breeding experimental base, and the cows were all reared in separate pens. The ration was prepared according to the nutritional needs and feeding standards of dry dairy cows, which were all free drinking water.

Test measurement indexes and methods

Determination of nutrient composition

The nutritional components of CGF, *L. chinensis* and alfalfa hay were determined. The measurement indexes include dry matter (DM), ash powder, organic matter, crude extract (EE), carbohydrate composition and protein composition. The content of soluble carbohydrates and starch was determined by the enzyme method (9).

Nutritional value assessment based on the NRC model

The digestible nutrients and energy values of CGF, *L. chinensis* and alfalfa hay were calculated using the estimation model of cow nutritional requirements (NRC-2001). And the true absorbable protein content of three feed materials was predicted. The indexes for the determination of true digestible nutrients mainly included the four indexes of total digestible nutrients (TDN), production level digestible energy, metabolic energy and lactation performance. It covered indexes such as digestible crude protein (tdCP), digestible neutral detergent fiber (tdNDF), net energy

Table 1. Feed composition and nutrient composition of experimental diet.

Items	CGF-0%	CGF-7%	CGF-11%
CGF (%)	0	7.00	11.00
Chinese Ley mus (%)	0	3.55	6.53
Alfalfa hay (%)	23.41	13.00	5.92
Corn silage (%)	23.42	23.42	23.42
Ground con (%)	23.34	23.34	23.34
Cottonseed meal (%)	7.75	7.75	7.75
Soybean meal (%)	11.53	11.53	11.53
Beet pulp (%)	4.28	4.28	4.28
DDGS (%)	4.56	4.56	4.56
Sodium bicarbonate (%)	0.51	0.51	0.51
Fat peak[2] (%)	1.43	1.43	1.43
Salt (%)	0.14	0.14	0.14
Limestone (%)	0.39	0.39	0.39
Premix[3] (%)	0.52	0.52	0.52
ADF (% of DM)	20.2	19.4	18.5
NDF (% of DM)	32.4	33.8	34.5
CP (% of DM)	18.1	17.9	17.8
Starch (% of DM)	21.1	21.5	21.6
NFC4 (% of DM)	36.4	37.2	35.4
NE_L[3] (MJ/kg of DM)	7.02	7.12	7.03

maintenance, net energy gain and so on. The net energy of maintenance and weight gain was predicted by the beef cattle estimation model (10).

The NFC model is used to predict the true absorbable protein content of CGF, *L. chinensis* and alfalfa hay. In Formula 1, the formula for calculating the absorbable microbial protein content in the small intestine is shown.

$$AMCP = 0.80 \times 0.80 \times MCP \quad [1]$$

In formula 1, *MCP* represents microbial protein synthesized in the rumen, of which 80% is microbial protein and 20% is nucleic acid protein.

In formula 2, the formula for calculating the content of small intestinal absorbable rumen protein is shown.

$$ARUP = RUP \times dIDP \quad [2]$$

In formula 2, *RUP* represents the rumen non-degradable protein, and *dIDP* represents the intestinal digestibility of rumen protein.

Determination of small intestine digestion characteristics of protein

The digestibility of rumen-passing protein was determined by a three-step in vitro method. Take 5g of the residue from the nylon bag in the rumen of the cow after 16 hours of culture and put it into a 50 mL centrifuge tube. Add 10mL pepsin buffer solution, 0.5mL NaOH solution and 13.5mL trypsin. The culture was carried out in a 38 ℃ water bath shaker environment, and vortex oscillation was conducted every 8 hours. After culture, add 3mL 100% trichloroacetic acid into the culture medium, mix the culture medium evenly, and conduct 10000 for 15 minutes × G Centrifuge. The content of crude protein in the culture solution was determined by the Kjeldahl method. The small intestine digestibility of rumen-passing protein is the ratio of the crude protein content in the culture medium to the crude protein content in the degradation residue.

Growth, production, digestion and metabolism performance analysis

Record the feeding amount and the remaining amount of the test cows on the 15th to 17th days of each test cycle. The study recorded the average dry matter intake of the experimental cows in three consecutive days and the milk production of the cows. Six consecutive milk samples were collected every day. The morning and evening milk samples of each cow were mixed in the proportion of 50:50 (V: V) and divided into three parts. The milk composition, the number of somatic cells and the urea nitrogen of the milk samples were determined respectively.

Fecal samples were collected on the 19th to 21st days of each test cycle. The rectal fecal collection method was used for collection. The single sampling volume is 200g (11). The fecal samples of each cow were collected twice a day and mixed. The apparent digestibility of nutrient components in the experimental diet was determined by the endogenous indicator method. Formula 3 is the calculation formula of apparent digestibility.

$$L = 100 \times \left[1 - \left(B_1 \times F_2\right) / \left(B_2 \times F_1\right)\right] \quad [3]$$

In formula 3, B_1 and B_2 respectively represent the content of non-degradable neutral detergent fiber in feed and fecal samples. F_1 and F_2 respectively represent the content of nutrient components in feed and fecal samples.

The blood samples of test cows were collected on the 18th day of each test cycle. Blood samples were collected 3 hours after morning feeding. A 10 mL blood sample was collected from the milk vein of the cow, placed in a heparin sodium tube, and passed through 3000 for 15 minutes × G Centrifuge for plasma separation. The blood biochemical indicators are measured by an automatic biochemical analyzer, including total protein, blood sugar, triglyceride, cholesterol, etc.

Rumen fermentation test

7g feed samples were placed in nylon bags. According to the principle of gradual insertion, culture in the rumen at 0, 4, 8, 12, 24, 36, 48 and 72 hours. After incubation, the nylon bag and the 0-hour nylon bag were washed with cold water. After washing, dry it at 65 ℃ for 48 hours, and fully regain moisture and weigh it. Use a 40-mesh sieve to crush and sift before testing. The rumen kinetic index model was used to calculate the rumen degradation parameters. Formula 4 is the calculation formula for the effective rumen degradation rate.

$$ED = S + D + k_d / \left(k_p + k_d\right) \quad [4]$$

In formula 4, *S* represents the proportion of the soluble part. *D* represents the proportion of potentially soluble parts. k_d represents the degradation rate. k_p represents the rumen pass rate.

On the 19th to 21st days of each test cycle, 300 mL of rumen fluid from the test cows was collected by the oral sampler. To avoid the interference of saliva, the first 100 mL of rumen fluid was discarded. Use 4 layers of gauze to filter the rumen fluid and divide it into two parts. The rumen degradation characteristics and microbial quantity were analyzed respectively.

Data statistics and analysis

The test data are statistically processed with SAS 9.2 software. The mixed model is used for data analysis. Duncan's method is used to compare the multiple differences between the average values, and structural equation modeling (SEM) is used for data analysis and causal test. $P<0.05$ indicates that the difference is significant, $P<0.01$ indicates that the difference is extremely significant, and $0.05 \le P<0.10$ indicates that there is a trend. Formula 5 shows the rumen degradation data processing model.

$$Y_{ijk} = \mu + trt_i + r_j + e_{ijk} \quad [5]$$

In formula 5, Y_{ijk} is the dependent variable of independent variable *i, j, k*. μ is the average value of the variable. trt_i is the fixed effect of feed. r_j is the random effect of different cows, and e_{ijk} is the random error.

Results

Comparison results of nutritional components

The comparison results of nutrient components of CGF, *L. chinensis* and alfalfa hay were shown in Table 2. There were significant differences in dry matter, ash, organic matter and crude fat content among the three raw materials

(*P*<0.05). The organic content of CGF and *L. chinensis* was significantly higher than that of alfalfa hay. The levels of ADF and ADL in CGF were the lowest, and there was a significant difference between CGF and *L. chinensis* and alfalfa hay (*P*<0.05).

Analysis of nutrient metabolism performance

The comparison results of protein-small intestine digestibility of three feed materials are shown in Table 3. The dIDP of CGF was higher than that of *L. chinensis* (*P*<0.05), but there was no significant difference between CGF and alfalfa hay (*P*>0.05). CGF has the highest IDP and TDP. The next is alfalfa hay, with the lowest IDP and TDP of *L. chinensis*.

The comparison results of digestible nutrient content and energy value of three feed materials are shown in Table 4. There were significant differences in tdFA, NEm, NEg and DEp among the three raw materials (*P*<0.001). The tdFA, NEm, NEg and DEp of CGF were significantly higher than those of *L. chinensis* and alfalfa hay. The highest TDNm of CGF was 685.67g/kg DM, followed by alfalfa hay, and the lowest TDNm of *L. chinensis*. The difference was statistically significant (*P*<0.05).

The comparison results of the content of true absorbable protein of three feed raw materials are shown in Table 5. The MCP predicted value of CGF is 89.47g/kg DM. The predicted value of AMCP is 56.82g/kg DM, which is higher than that of *L. chinensis* and alfalfa hay (*P*<0.05). The difference in MP and MCPRDP between CGF and alfalfa hay was not statistically significant, but significantly higher than that of *L. chinensis*.

Growth, production and digestion and metabolism performance analysis

The comparison results of nutrient intake and apparent digestibility of the diet under three CGF ratios are shown

Table 2. Comparative results of nutritional components of CGF, *L. chinensis* and alfalfa hay.

Items	CGF	Chinese Ley mus	Alfalfa hay	SEM	*P*
DM (g/kg ADM)	942.38	942.86	925.63	5.896	0.025
Ash (g/kg DM)	60.53*	60.58*	115.37**	1.185	0.027
OM (g/kg DM)	939.56*	936.48*	884.79**	1.248	0.015
EE (g/kg DM)	28.06*	11.96**	13.15**	0.896	0.028
CHO (g/kg DM)	706.48*	856.93**	659.37***	1.689	0.008
NDF (g/kg DM)	519.28*	685.39**	418.06***	2.897	0.014
ADF (g/kg DM)	145.93*	404.25	308.59***	1.875	0.006
Starch (g/kg DM)	106.89*	11.83**	17.26**	2.49	<0.001
CP (g/kg DM)	205.79*	75.03**	213.59***	1.038	<0.001
SCP (g/kg CP)	643.09*	289.26**	425.86***	3.182	0.017
NPN (g/kg SCP)	930.25*	812.59**	617.26***	13.589	0.027
ADICP (g/kg CP)	15.23*	55.96**	37.58***	3.057	0.005
NDICP (g/kg CP)	154.29*	389.29**	117.53***	4.26	0.017

Note: *, ** and *** indicate statistical differences (*P*<0.05).

Table 3. Intestinal digestibility of protein in three feed materials.

Items	dIDP	IDP		TDP	
	%RUP	% CP	g/kg DM	% CP	g/kg DM
CGF	62.67*	23.81*	48.89*	87.63*	179.83*
Chinese Ley mus	52.57**	28.45**	28.43***	74.21**	62.85***
Alfalfa hay	69.25*	27.93**	59.58**	87.85*	186.97**
SEM	1.71	0.69	1.18	0.81	1.15
P	0.003	<0.001	<0.001	<0.001	<0.001

Note: *, ** and *** indicate statistical differences (*P*<0.05).

Table 4. Comparison results of digestible nutrient content and energy value of three feed materials.

Items	CGF	Chinese Ley mus	Alfalfa hay	SEM	*P*
tdCP (g/kg DM)	199.35*	71.75**	204.01*	1.96	0.005
tdNDF (g/kg DM)	301.48*	242.25**	137.75***	2.25	0.015
tdNFC (g/kg DM)	212.45*	188.21**	258.96***	1.75	0.028
tdFA (g/kg DM)	42.45*	4.06**	6.78**	1.79	<0.001
TDNm (g/kg DM)	685.67*	435.88**	538.48***	1.98	0.002
NEm (MJ/kg DM)	6.91*	3.05**	4.83***	0.142	<0.001
NEg (MJ/kg DM)	4.36*	0.72**	2.79***	0.071	<0.001
DEp (MJ/kg DM)	12.28*	8.09**	10.56***	0.068	<0.001
MEp (MJ/kg DM)	1078*	6.07**	8.06***	0.063	<0.001

Note: *, ** and *** indicate statistical differences (*P*<0.05).

in Table 6. The NDF intake, DM digestibility, NDF digestibility and ADF digestibility were the highest in the CGF-11% group. The difference was statistically significant (P<0.05). The NDF intake of CGF-7% was significantly different from that of CGF-0% (P<0.05). There was no significant difference in other indicators between the CGF-0% group and the CGF-7% group.

The effects of diets with three CGF ratios on the lactation performance of dairy cows are shown in Table 7. The dry matter intake of the CGF-11% group was higher, and the difference was statistically significant (P<0.05). There was no significant difference in milk production among the three groups (P>0.05). There were differences in milk protein composition among the three groups. The proportion of milk protein in CGF-0% was the highest, which was significantly different from that of *L. chinensis* and alfalfa hay (P<0.05).

Analysis of blood biochemical indicators

The effects of diets with three CGF ratios on the blood biochemical indexes of dairy cows are shown in Table 8. Compared with the CGF-0% group, the CGF-7% group and CGF-11% group added with CGF had higher blood glucose (GLU) index. The difference was statistically significant (P<0.05). There was no significant difference in other blood biochemical indexes.

Rumen degradation analysis

The comparison results of the rumen degradation rate of diets with three CGF ratios are shown in Figure 1. In

Table 5. Comparative results of the true absorbable protein content of three feed materials.

Items	CGF	Chinese Ley mus	Alfalfa hay	SEM	*P*
AMCP (g/kg DM)	56.82*	36.12**	43.25***	0.793	<0.001
MCP (g/kg DM)	89.47*	55.87**	69.86***	0.615	<0.001
ECP (g/kg DM)	11.78	11.59	10.82	0.538	0.082
AECP (g/kg DM)	4.53	4.28	5.11	0.286	0.105
ARUP (g/kg DM)	48.58*	28.49**	59.58***	1.185	<0.001
MP (g/kg DM)	110.21*	69.58**	106.79*	1.145	<0.001
MCP_{TDNm} (g/kg DM2)	88.96*	56.47**	69.83***	0.358	0.011
MCP_{RDP} (g/kg DM^2)	117.89*	31.06**	114.59*	1.59	0.003
RENB (g/kg DM2)	-28.93	25.41	-44.76	1.134	/

Note: *, ** and *** indicate statistical differences (P<0.05).

Table 6. Comparative results of nutrient intake and apparent digestibility of diets with three CGF ratios.

Items		CGF-0%	CGF-7%	CGF-11%	SEM	*P*
Nutrient intake (kg/d)	CP	3.75	3.79	3.91	0.112	0.384
	NDF	6.77*	7.14**	7.53***	0.175	0.042
	ADF	4.22	4.09	4.05	0.072	0.396
Apparent digestibility of nutrients (%)	DM	59.61*	62.59**	63.12**	1.167	0.251
	CP	64.63	63.89	65.93	1.154	0.268
	NDF	42.36*	45.67**	48.06**	1.065	0.014
	ADF	27.96*	34.15**	34.83**	1.157	0.006

Note: *, ** and *** indicate statistical differences (P<0.05).

Table 7. Effects of three CGF ratios on lactation performance of dairy cows.

Items		CGF-0%	CGF-7%	CGF-11%	SEM	*P*
	Dry matter intake (kg/d)	20.71*	21.13*	21.98**	0.286	0.001
	Milk yield	32.89	33.87	34.21	0.597	0.082
	ECM	35.96	36.34	37.29	0.758	0.158
Milk fat	Yield (kg/d)	1.295	1.329	1.351	0.054	0.268
	Milk compositions (%)	3.938	3.864	3.918	0.093	0.152
Lactose	Yield (kg/d)	1.658	1.675	1.729	0.054	0.759
	Milk compositions (%)	4.98	4.96	5.03	0.053	0.489
Protein	Yield (kg/d)	0.983*	1.058**	1.061**	0.052	0.043
	Milk compositions (%)	2.97	3.09	3.11	1.057	0.121
Total solids	Yield (kg/d)	3.736	3.926	3.864	0.089	0.367
	Milk compositions (%)	11.43	11.61	11.39	0.182	0.348
	Feed efficiency (%)	1.59	1.61	1.58	0.036	0.794
	Fat/Protein (%)	1.32*	1.24**	1.26**	0.018	0.042
	SCC ($\times10^3$)	328	364	302	41.053	0.298

Note: *, ** and *** indicate statistical differences (P<0.05).

terms of dry matter degradation rate, the degradation rates of S, Kd and EDDM in the CGF-11% group were higher than those in the CGF-0% group and CGF-7% group, with statistically significant difference (P<0.05). The D degradation rate of the CGF-11% group was significantly lower than that of the CGF-0% group (P<0.05), and there was no significant difference between the CGF-11% group and the CGF-7% group (P>0.05). In terms of crude protein degradation, the degradation rates of S, Kd and EDCP in the CGF-11% group were significantly higher than those in the CGF-0% group and CGF-7% group (P<0.05). The degradation rate of RUP was 50.61% CP, lower than that of the CGF-0% group and CGF-7% group, and the difference was statistically significant (P<0.05).

The effects of diets with three CGF ratios on the rumen microorganisms of dairy cows are shown in Table 9. The relative bacteria expression of *Ruminococcus flavefaciens*, *Fibrobacter succinogenes*, *P. bryanti*, *Butyrivibrio fibrisolvens* and *Selenomonas ruminantium* in CGF-11% cows was significantly higher than that in CGF-0% and CGF-7% groups (P<0.05). There was no significant difference in the expression of *Ruminococcus albus*, *Ruminobacter amylophilus* and *Streptomonospora amylolytica* among the three groups (P>0.05). The expression of *S. ruminantium* in the CGF-0% group and CGF-7% group was significantly different (P<0.05).

The differences in rumen microbial protein synthesis and nitrogen conversion rate of diets with three CGF ratios are shown in Table 10. The UA and MCP indexes of the CGF-11% group were significantly higher than those of the other two groups (P<0.05). The second was the CGF-7% group, and the lowest was the CGF-0% group. There was no significant difference in UA indexes between the CGF-11% group and the CGF-7% group (P>0.05). The difference in creatinine and allantoin indexes among the three groups was small, and the difference was not statistically significant (P>0.05). The ratio of CGF in the diet had no significant effect on the nitrogen conversion rate of plasma and milk (P>0.05). The urine nitrogen conversion rate of the CGF-11% group was significantly higher than that of the CGF-0% group (P<0.05). And there was no statistically significant difference between the CGF-11% group and the CGF-7% group (P>0.05).

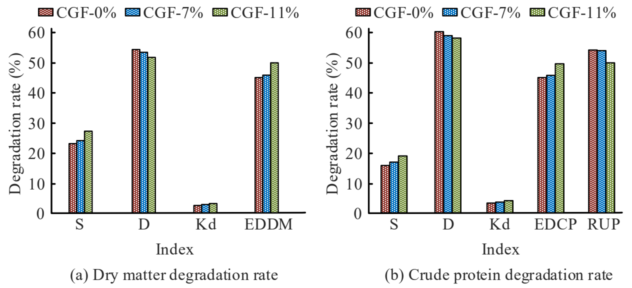

Figure 1. Comparative results of the rumen degradation rate of diets with three CGF ratios.

Economic benefit analysis

Table 11 shows the difference in economic benefits of diets with three CGF ratios. The total output value of the CGF-0% group is 112.67 ¥/d, the total output value of the CGF-7% group is 118.19 ¥/d, and the total output value of the CGF-11% group is 119.057 ¥/d. Among them, the CGF-11% group has the highest economic benefit, which is 68.62 ¥/d. The next is the CGF-7% group, and the CGF-0% group has the lowest benefit. The economic benefits of the CGF-7% group and CGF-0% group were 66.41 ¥/d and 59.87 ¥/d respectively.

Table 8. Effects of three CGF ratios on plasma biochemical indexes of dairy cows.

Items	CGF-0%	CGF-7%	CGF-11%	SEM	P
TP (g/L)	75.49	73.48	71.25	3.065	0.278
ALB (g/L)	28.38	30.15	31.39	1.268	0.122
GLB (g/L)	43.39	43.05	41.08	2.168	0.258
TG (mmol/L)	0.14	0.14	0.14	0.008	0.439
CHOL (mmol/L)	5.29	5.38	5.24	0.347	0.697
HDL (mmol/L)	1.35	1.47	1.49	0.251	0.204
LDL (mmol/L)	1.42	1.48	1.39	0.087	0.638
GLU (mmol/L)	2.89*	3.05**	3.72**	0.204	0.005

Note: *, ** and *** indicate statistical differences (P<0.05).

Table 9. Effects of diets with three CGF ratios on rumen microorganisms in dairy cows.

Items	CGF-0%	CGF-7%	CGF-11%	SEM	P
R. flavefaciens	3.42**	3.51**	4.01*	0.111	<0.001
R. albus	0.65	0.65	0.67	0.031	0.684
F. succinogenes	1.43**	1.48**	1.58*	0.0.24	<0.001
P. bryanti	2.01**	2.13**	2.41*	0.048	<0.001
B. fibrisolvens	12.57**	13.76**	15.88*	0.229	<0.001
R. amylophilus	0.02	0.02	0.01	0.001	0.469
S. amylolytica	0.070	0.081	0.078	0.006	0.293
S. ruminantium	4.20***	4.17**	4.44*	0.063	<0.001
Eubacterium	0.050	0.062	0.057	0.001	0.114

Note: *, ** and *** indicate statistical differences (P<0.05).

Table 10. Differences in rumen microbial protein synthesis and nitrogen conversion rate of diets with three CGF ratios.

Items		CGF-0%	CGF-7%	CGF-11%	SEM	*P*
Cr (mmol/d)		157.41	153.97	160.28	4.731	0.348
PD(mmol/d)	ALL	352.61	370.26	390.24	16.014	0.245
	UA	77.69**	89.13*	92.86*	2.815	<0.001
	EPD	46.34	46.51	46.12	0.784	0.438
MCP (g/d)		1745.03**	1843.87***	1985.16*	75.056	0.086
IDP (%)		49.68	49.07	51.58	1.013	0.348
IADP (g/d)		1075.87	1013.41	967.04	45.413	0.309
N conversion		0.27	0.29	0.28	0.012	0.215
Urea N concentration (mg/dL)	Blood	7.01	6.80	7.19	0.207	0.294
	Urine	801.34**	819.76***	866.95*	34.467	0.106
	Milk	15.31	14.17	14.38	0.463	0.548

Note: *, ** and *** indicate statistical differences ($P<0.05$).

Table 11. The difference in economic benefits of diets under three CGF ratios.

Items	CGF-0%	CGF-7%	CGF-11%	SEM	*P*
DMI (kg/d)	20.73	21.14	21.91	2.115	0.263
Diet cost (¥/d)	53.79**	51.04*	50.11*	0.794	0.307
Milk yield (kg/d)	32.75	33.86	34.18	27.643	0.109
Feed cost (¥/kg)	1.68	1.53	1.46	0.089	0.097
Milk price (¥/kg)	3.49	3.49	3.49	0.146	0.243
Production value (¥/d)	112.67	118.19	119.05	5.762	0.144
Benefit (¥/d)	59.87	66.41	68.62	1.697	0.126

Note: *, ** and *** indicate statistical differences ($P<0.05$).

Discussion

The nutritional components of CGF, *L. chinensis* and alfalfa hay were determined and analyzed. The content of CP and NDF in CGF is high, while the content of ADL and ADF is low. This is consistent with previous research results (12,13). Compared with alfalfa hay, CGF has higher NDF and starch content, and CP level is close to that of alfalfa hay. This proves that CGF has the basic nutritional characteristics of a high-quality feed and can replace the nutritional function of alfalfa hay. CGF contains highly digestible NDF, which can provide a high-quality fiber source for dairy cows. Because CGF is the product of mature corn, it has a lower degree of cell wall lignification. Therefore, the ADL and ADF levels of CGF are low (14). CGF takes into account the characteristics of fiber feed and protein feed and can provide high-quality fiber and protein nutrition for dairy cows. CGF can effectively reduce the feeding cost of dairy cows while ensuring the high caloric and nutritional levels of dairy cows. And it can alleviate the shortage of raw materials for other dairy cows.

Feed intake and digestibility indicators represent the necessary nutritional basis for dairy production. The study showed that the CGF-11% group had the highest NDF intake, DM digestibility, NDF digestibility and ADF digestibility. The difference was statistically significant (P<0.05), consistent with previous research results (15). In the CGF-11% group, corn fiber is easy to digest, which could effectively improve the digestibility of the diet and replace the function of alfalfa hay fiber. The long fiber characteristics of *L. chinensis* could also help to prolong the digestion time of NDF in the rumen of dairy cows. The dry matter intake of dairy cows was related to the production capacity of dairy cows. In this study, CGF was used to replace alfalfa hay in conventional feed, which effectively increased the dry matter intake of dairy cows. It could achieve the effect of improving the nutrient intake of dairy cows, which was similar to previous research results (16). The improvement of dry matter intake also promoted the growth of the lactation performance of dairy cows. The use of CGF instead of alfalfa hay in dairy cow diets effectively increased the energy correction milk yield of dairy cows. This also effectively promoted the improvement of the milk protein content of dairy cows, consistent with previous research results (17). The content of digestible nutrients in CGF was significantly higher than that in conventional cow feed. After using CGF to replace part of the alfalfa hay in the diet, the digestible energy and net milk yield of the diet were higher, and the digestible NDF content was also increased. This effectively promoted the synthesis of MCP in the rumen of dairy cows, thus improving the milk protein rate of dairy cows.

The blood biochemical indexes of cows before and after replacing alfalfa hay with CGF and *L. chinensis* were compared. The results showed that the addition of CGF increased the plasma glucose level of dairy cows. This effectively promoted the energy metabolism of dairy cows, consistent with previous research results (18). After adding CGF, the dry matter intake of dairy cows increased. Thus, starch intake and digestible starch content in the small intestine also increased. Therefore, the plasma glucose concentration of dairy cows after consuming CGF was significantly increased. The rumen degradation characteristics of nutrient components in cow feed directly affect its nutritional value. The rumen degradation characteristics of feed with different CGF ratios were analyzed.

The results showed that the dry matter solubility of CGF was higher than that of *L. chinensis* and alfalfa hay, which was consistent with previous research results (19). The nutrients of CGF are more easily degraded by the rumen microorganisms of dairy cows. Most fibers of CGF will be degraded into VFA in the rumen of dairy cows, thus promoting the growth and metabolic activities of rumen microorganisms. This plays an important role in promoting the nutritional value of feed. CGF belongs to cereal fiber, and its semi-fiber content is higher than that of conventional roughage. The content of ADL and ADF fibers that are not easy to digest is lower. Therefore, CGF has a highly effective fiber degradation rate, which can replace part of the forage fiber in the conventional diet and provide a new feed basis for dairy cows.

The economic benefits of dairy farming are mainly affected by the output, cost and milk price. The feed cost of dairy cows accounts for about 70% of the breeding cost. In recent years, with the rise of commodity and labor costs, the cost of dairy farming has been increasing. The price of high-quality coarse fodder commonly used in dairy cow diets is also rising. The gap of forage such as alfalfa hay continues to expand, which is difficult to meet the production demand of China's dairy farming industry. Corn fiber feed is a by-product of corn starch production, which has the advantages of a large yield and low price. The CGF-11% group has the highest economic benefit of 68.62 ¥/d. The economic benefit of the CGF-0% group without CGF is 59.87 ¥/d, which is similar to previous research results (20). After replacing part of alfalfa hay in the cow diet with CGF and forage, the cost of cow feed decreased significantly, thus improving the economic profit efficiency of cow breeding. This is of great value for improving the economic benefits of dairy farming.

In conclusion, the combination of CGF and *L. chinensis* can replace some alfalfa hay in the feed. The combination of CGF and *L. chinensis* can effectively promote the digestion and metabolism of dairy cows. This can improve the digestible nutrient and protein content of feed and promote rumen degradation and nutrient absorption. This method can reduce the cost of breeding feed and improve the production and economic benefits of dairy farming.

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