Effects of Different Processing Techniques on the Nutritional Value of Corn Fiber Feed Postprint

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Abstract

This experiment utilized dry corn gluten feed (DCGF) and wet corn gluten feed (WCGF) as raw materials to analyze the effects of processing technology on the nutritional value of corn gluten feed. Three dry-period Holstein dairy cows fitted with permanent rumen fistulas were selected as experimental animals. Conventional methods were employed to determine the nutrient composition of DCGF and WCGF, the nylon bag technique was used to measure rumen degradation characteristics, a three-step in vitro method was applied to determine the intestinal digestibility of rumen undegradable protein (RUP), and the NRC model was utilized to predict the supply of metabolizable protein and essential amino acids. The results showed: 1) Among the conventional nutrients of DCGF, except for the contents of neutral detergent fiber (NDF), neutral detergent insoluble crude protein (NDICP), and acid detergent insoluble crude protein (ADICP), which were significantly higher than those of WCGF ($P<0.05$), the contents of other nutrients showed no significant differences ($P>0.05$); 2) The rumen NDF degradability of DCGF and WCGF showed no significant difference ($P>0.05$), whereas the rumen dry matter (4, 24, 48 h) and crude protein (CP) degradability (12, 24, 48, and 72 h) and effective degradability of DCGF were significantly lower than those of WCGF ($P<0.05$); 3) The RUP content of DCGF was significantly higher than that of WCGF ($P<0.05$), while the contents of total digestible nutrients, microbial protein, and metabolizable protein in WCGF showed no significant difference from those in DCGF ($P>0.05$); 4) The intestinal digestibility of RUP of DCGF was significantly lower than that of WCGF ($P<0.05$), but the total digestible protein content showed no significant difference between the two feeds ($P>0.05$); 5) Among the essential amino acids provided by feed RUP, the contents of histidine (His), phenylalanine (Phe), isoleucine (Ile), and total essential amino acids provided by RUP of DCGF were significantly higher than those of WCGF ($P<0.05$). In conclusion, both DCGF and WCGF contain high contents of utilizable fiber and protein and can serve as good fiber and protein

source feeds for dairy cows; however, the lower rumen CP degradability and intestinal digestibility of RUP of DCGF may affect its protein and amino acid nutritional value.

Full Text

Effects of Different Processing Techniques on Nutritional Value of Corn Gluten Feed

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Abstract

This trial was conducted to evaluate the effects of processing technology on the nutritional value of corn gluten feed using wet corn gluten feed (WCGF) and dry corn gluten feed (DCGF) as ingredients. Three ruminally cannulated Holstein cows in dry period were selected as experimental animals. Nutrient composition contents of DCGF and WCGF were determined by conventional methods, nylon-bag technique was used to evaluate rumen degradation characteristics, intestinal digestibility of rumen undegraded protein (RUP) was determined using an in vitro three-step method, and the NRC model was used to determine supplemental amounts of metabolizable protein and essential amino acids. The results showed as follows: 1) Except for contents of neutral detergent fiber (NDF), neutral detergent insoluble crude protein (NDICP), and acid detergent insoluble crude protein (ADICP), which were significantly higher in DCGF than in WCGF ($P<0.05$), other nutrient contents showed no significant differences ($P>0.05$). 2) Rumen NDF degradability was not significantly different between DCGF and WCGF ($P>0.05$), while rumen dry matter (DM) degradability (at 4, 24, and 48 h) and crude protein (CP) degradability (at 12, 24, 48, and 72 h) of DCGF were significantly lower than those of WCGF ($P<0.05$). 3) RUP content of DCGF was significantly higher than that of WCGF ($P<0.05$), while total digestible nutrients, microbial protein, and metabolizable protein contents showed no significant differences ($P>0.05$). 4) Intestinal digestibility of RUP of DCGF was significantly lower than that of WCGF ($P<0.05$), but total digestible protein content showed no significant difference ($P>0.05$). 5) Among essential amino acids provided by feed RUP, contents of histidine (His), phenylalanine (Phe), isoleucine (Ile), and total essential amino acids provided by RUP of DCGF were significantly higher than those of WCGF ($P<0.05$). In conclusion, both DCGF and WCGF contain high contents of available fiber and protein, and can serve as good fiber and protein sources for dairy cows. However, the lower rumen CP degradability and intestinal digestibility of RUP of DCGF may affect its protein and amino acid nutritional value.

Keywords: corn gluten feed; rumen degradability; intestinal digestibility; amino acid

Introduction

In recent years, China’ s corn deep-processing industry has developed rapidly, with corn being primarily used for producing alcohol and starch. Approximately 30% byproducts are generated during corn deep processing, mainly including corn gluten meal, corn gluten feed, germ cake/meal, and distillers grains. These byproducts are rich in nutrients and represent good feed resources for livestock and poultry [1].

The processing flow for corn starch production via wet milling can be broadly divided into three basic stages: soaking, grinding, and separation. Corn soaking involves immersing cleaned corn in a 0.2% sulfurous acid solution at approximately 50°C for 60-70 h [2]. The primary purposes are to soften the corn and reduce its mechanical strength for grinding, and to disrupt protein structures in endosperm cells to release free starch for easier separation. The resulting soaking liquid, known as dilute corn steep liquor, contains 7-9% dry matter (DM) with a pH of 3.9-4.1. This liquid is concentrated through a three-effect falling film evaporation system to produce concentrated corn steep liquor with approximately 40% DM content [2]. After soaking, corn moisture content is about 45%. Following three grinding steps, germ, starch, and seed coat are separated. Starch milk undergoes sedimentation, washing, defibering, and drying to produce starch products. Germ is processed through washing, dehydration, and drying for corn oil and corn germ meal production. The separated corn fiber (corn seed coat, germ root, and root cap) is washed countercurrently and dehydrated to about 40% DM content [3]. Corn fiber is mixed with concentrated corn steep liquor at a specific ratio (related to final crude protein content), thoroughly blended in a large mixer to produce wet corn gluten feed (WCGF) with about 40% DM content for direct use as animal feed. Alternatively, WCGF is dried in a tube-bundle dryer to approximately 12% moisture content to produce dry corn gluten feed (DCGF) [4]. Internationally, most corn gluten feed is utilized by dairy farms in WCGF form with good feeding results [5-6]. However, due to storage and transportation limitations, many domestic manufacturers produce DCGF instead.

Different processing techniques may affect feed nutritional value, yet comparative studies on the nutritional value of WCGF and DCGF are lacking. Therefore, this trial compared differences in nutritional value between WCGF and DCGF from perspectives of nutrient composition, rumen degradation characteristics, and metabolizable protein and amino acid supply, to investigate the effects of heat drying on corn gluten feed nutritional value and provide a theoretical basis for scientific and rational utilization.

1. Materials and Methods

1.1 Experimental Animals and Materials Three healthy dry-period Holstein cows weighing approximately 600 kg and fitted with permanent rumen cannulas were selected as experimental animals. DCGF and WCGF were collected from two batches each at Cargill Biochemical Co., Ltd. in Songyuan City, Jilin Province, and Feihe Original Ecology Ranch (four feed samples total). WCGF was dried at 65°C for 48 h, and air-dried samples were ground through a 1 mm sieve for analysis.

1.2 Basal Diet and Management The basal diet for experimental cows was formulated according to NRC (2001) [7] dairy cattle nutrient requirements, with composition and nutrient levels shown in Table 1 . Cows were fed twice daily (06:00 and 18:00) with free access to water.

Table 1 Composition and nutrient levels of the basal diet (%)

Item	Content
Ingredients (air-dry basis)	
Corn silage	
Chinensis wildrye	
Alfalfa	
Corn	
Wheat bran	
Soybean meal	
Cottonseed meal	
DDGS	
Limestone	
CaHPO4	
NaCl	
Premix1)	
Total	
Nutrient levels (DM basis)2)	
DM	
CP	
NDF	
ADF	
Ca	
NEL/(MJ/kg)	

1) The premix provided the following per kg of diet: Mixed vitamins 600,000 IU, Cu 800 mg, Zn 11,000 mg, Mn 3,000 mg, Se 60 mg, I 220 mg, Co 55 mg.

2) NEL was a calculated value, while the others were measured values. NEL (MJ/kg) = 9.62 × digestible energy (MJ/kg) - 0.3960 [8].

1.3 Experimental Methods

1.3.1 Nutrient Composition Analysis DM, crude ash, CP, ether extract (EE), and other routine nutrient components of DCGF and WCGF were determined according to AOAC (1997) [9]. Starch content was determined using the enzymatic method of Zhang et al. [10] with reagent kits purchased from Shanghai Rongsheng Biopharmaceutical Company. Contents of neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), neutral detergent insoluble crude protein (NDICP), and acid detergent insoluble crude protein (ADICP) were determined according to Van Soest et al. [11]. Non-protein nitrogen (NPN) and soluble protein (SP) contents were determined using the Cornell Net Carbohydrate and Protein System (CNCPS) method [12]. Each sample was analyzed in triplicate for each indicator.

1.3.2 Rumen Degradability Determination by Nylon Bag Technique The nylon bag procedure followed the steps described by Nuez-Ortín et al. [13]. Approximately 7 g of sample (precise to 0.0001 g) was placed in nylon bags (10 cm × 20 cm, 50 m pore size), with a sample weight to surface area ratio of 17.5 mg/cm^2. Bags were incubated in the rumen of three experimental cows for 0, 4, 8, 12, 24, 36, 48, and 72 h. Upon removal, bags were immediately rinsed with cold tap water to remove surface chyme and residues, terminating microbial fermentation. Bags were washed with cold tap water until the rinse water was clear and odorless, then dried at 65°C for 48 h without wringing. Residues were ground for nutrient content analysis. Three replicate bags were used for each time point from 0-12 h, and four replicates for 16-48 h, with no more than 30 bags in the rumen simultaneously. Rumen dynamic degradation parameters were calculated using the nonlinear model of Ørskov et al. [14]:

$$P = a + b[1 - \exp(-ct)]$$

where:
P = nutrient degradability at each time point (%);
a = rapidly degradable (soluble) fraction content (%);
b = slowly degradable fraction content (%);
c = degradation rate of slowly degradable fraction (%/h) ($c > 0$);
$a + b$ = potentially degradable fraction (%).

Effective degradability was calculated as:

$$ED = a + bc/(c + Kp) \quad [13]$$

where:
ED = effective degradability (%);
Kp = rumen outflow rate of feed, valued at 4.6%/h [7].

1.3.3 Intestinal Digestibility of Rumen Undegraded Protein (RUP) by Three-Step In Vitro Method Intestinal digestibility of RUP was determined using a modified three-step in vitro method [15-16]. Five grams of residue from nylon bags after 16 h rumen incubation were placed in 50 mL centrifuge tubes, and 10 mL pepsin solution (Sigma P-7012, Sigma-Aldrich, USA) (pH = 1.9) was added. Tubes were incubated in a 37°C water bath shaker for 60 min. Then, 13.5 mL trypsin solution (Sigma P-7545, Sigma-Aldrich, USA) and 0.5 mL of 1 mol/L NaOH solution were added to adjust the pH to 7.9. Tubes were further incubated in a 38°C water bath shaker for 24 h with vortexing every 8 h. After incubation, 3 mL of 100% trichloroacetic acid (TCA) was added, vortexed, and centrifuged at 10,000 × g for 15 min. CP content in the supernatant was determined by the Kjeldahl method. The ratio of CP content in the supernatant to CP content in the 16 h rumen residue represented intestinal digestibility of RUP.

$$IDP = RUP \times dIDP$$

$$TDP = IDP + RDP$$

where:
IDP = intestinally digestible protein;
$dIDP$ = intestinal digestibility of RUP (%);
TDP = total digestible protein;
RDP = rumen degradable protein.

1.3.4 Prediction of Metabolizable Protein Supply by NRC Model The NRC (2001) [7] model was used to estimate potential nutrient supply of the two feeds, including total digestible nutrients, microbial protein, intestinally absorbable microbial protein, intestinally absorbable RUP, endogenous true protein, intestinally absorbable endogenous true protein, and metabolizable protein. According to the NRC model, feed nutrient supply formulas [7] were:

$$TDN = dNFC + dCP + (dFA \times 2.25) + dNDF - 7$$

$$MCP = 0.13 \times TDN$$

$$AMCP = 0.80 \times 0.80 \times MCP$$

$$ARUP = RUP \times dIDP$$

$$ECP = 6.25 \times 1.9 \times DM$$

$$AECP = 0.50 \times 0.80 \times ECP$$

$$MP = ARUP + AMCP + AECP$$

where:
TDN = total digestible nutrients (g/kg DM);

$dNFC$ = digestible non-fibrous carbohydrate (NFC) (%);
dCP = digestible CP (%);
dFA = digestible fatty acid (FA) (%);
$dNDF$ = digestible NDF (%);
MCP = microbial protein (g/kg DM);
$AMCP$ = intestinally absorbable microbial protein (g/kg DM);
$ARUP$ = intestinally absorbable RUP (g/kg DM);
ECP = endogenous true protein (g/kg DM);
$AECP$ = intestinally absorbable endogenous true protein (g/kg DM);
MP = metabolizable protein (g/kg DM).

1.3.5 Prediction of Amino Acid Supply by NRC Model Amino acid content was determined by acid hydrolysis [17], and the hydrolysate was analyzed on a Hitachi L-8800 automatic amino acid analyzer. Detection wavelengths: 440 and 570 nm; column temperature: 57°C; reaction column temperature: 135°C; flow rate: 0.400 mL/min; post-column derivatization reagent flow rate: 0.350 mL/min; injection volume: 20 L.

According to the NRC (2001) [7] prediction model, essential amino acid content provided by RUP was calculated:

$$EAAiRUP = CP \times RUP \times EAAi \times 0.001$$
$$TEAARUP = \sum EAAiRUP$$

where:
$EAAiRUP$ = content of a specific essential amino acid provided by feed RUP (g/kg DM);
$EAAi$ = content of a specific essential amino acid (% CP);
$TEAARUP$ = total essential amino acid content provided by feed RUP (g/kg DM).

1.4 Statistical Analysis Data were processed using SAS 9.2 NLIN procedure to calculate rumen dynamic degradation parameters, and MIXED model was used for statistical analysis.

2. Results

2.1 Nutrient Composition of WCGF and DCGF Nutrient composition of DCGF and WCGF is shown in Table 2 . Crude ash and EE contents were not significantly different between the two feeds (P>0.05). For carbohydrates, DCGF contained higher NDF content, significantly greater than WCGF (P<0.05, 520.9 vs. 490.8 g/kg DM), while starch, ADF, and ADL contents showed no significant differences (P>0.05). For protein components, CP content was not significantly different between the two feeds (P>0.05), but NDICP, ADICP, and NPN contents of DCGF were significantly higher than those of WCGF (P<0.05).

Table 2 Nutrient composition contents of DCGF and WCGF (n=4, g/kg DM)

<table>
<tr><th>Item</th><th>DCGF</th><th>WCGF</th></tr>
<tr><td>DM (g/kg)</td><td colspan="2">938.8$±9.1|363.5±4.1||Ash|59.3±4.3|43.7±6.2||EE|27.2±3.1|23.5±2.9||Starch|105.</td></tr>
</table>

In the same row, values with different letter superscripts mean significant difference (P<0.05), while values with no letter superscripts mean no significant difference (P>0.05). The same applies to Table 5 , Table 6 , and Table 7 .

2.2 Rumen Degradation Characteristics of DM, CP, and NDF in WCGF and DCGF Rumen degradation rates of DM, CP, and NDF in DCGF and WCGF at different time points are shown in Table 3 . As rumen degradation time increased, degradation rates of DM, CP, and NDF gradually increased. DM degradability of DCGF was significantly lower than that of WCGF at 4, 24, and 48 h (P<0.05), with no significant differences at other time points (P>0.05). CP degradability was not significantly different between the two feeds before 8 h (P>0.05), but WCGF showed higher CP degradability after 12 h, significantly greater than DCGF (P<0.05), reaching 91.51% at 72 h. NDF degradability was not significantly different between the two feeds at any time point (P>0.05), indicating similar rumen degradation characteristics.

Rumen dynamic degradation parameters of DM, CP, and NDF for DCGF and WCGF were analyzed using nonlinear fitting in SAS 9.2 software and are presented in Table 4 . The rapidly degradable fraction of DM was not significantly different between the two feeds (P>0.05), while the slowly degradable fraction of DM in DCGF was significantly higher than in WCGF (P<0.05), but its degradation rate and effective degradability were significantly lower (P<0.05). WCGF had significantly higher slowly degradable and potentially degradable fractions of CP than DCGF (P<0.05), with no significant difference in rapidly degradable fraction (P>0.05). Effective degradability of CP in WCGF was significantly higher than in DCGF (67.01% vs. 64.08% CP, P<0.05). No significant differences were observed in any rumen degradation parameters for NDF between the two feeds (P>0.05).

Table 3 DM, CP, and NDF degradability of DCGF and WCGF in rumen at different time points (n=4, %)

<table>
<tr><th>Sampling time (h)</th><th>DM degradability</th><th></th><th>CP degradability</th><th></th><th>NDF degradability</th><th></th></tr>
<tr><td></td><td>DCGF</td><td>WCGF</td><td>DCGF</td><td>WCGF</td><td>DCGF</td><td>WCGF</td></tr>
<tr><td>4</td><td colspan="6">38.03$±0.78|40.98±0.74|48.16±1.12|50.43±0.76|11.53±0.62|12.72±0.43||8|44.94±0.78|31.55</td></tr>
</table>

In the same column, values of the same item with different letter superscripts mean significant difference (P<0.05), while values with no letter superscripts mean no significant difference (P>0.05). The same applies to Table 4.

Table 4 Ruminal dynamic degradation parameters of DM, CP, and NDF of DCGF and WCGF (n=4)

Item	Rapidly degraded fraction (%)	Slowly degraded fraction (%)	Potentially degraded fraction (%)	Degradation speed of slowly degraded fraction (%/h)	Effective degradability (%)
DM					
DCGF	24.54±0.56	57.32±0.25	81.86±1.06	3.48±0.17	49.22±0.12
WCGF	26.14±0.93	53.39±1.56	79.62±0.61	4.5	
CP					
DCGF	43.41±0.18	40.92±1.09	84.33±1.27	3.55±0.19	64.18±0.23
WCGF	42.34±0.56	48.07±0.16	91		
NDF					
DCGF	1.37±0.52	84.97±0.35	84.75±0.50	3.47±0.09	40.76±0.81
WCGF	1.78±1.05	92.97±0.69	84.7		

2.3 Comparison of Intestinal Protein Digestion Characteristics between DCGF and WCGF Comparison of intestinal protein digestion characteristics between DCGF and WCGF is shown in Table 5. Intestinal digestibility of RUP in DCGF was significantly lower than in WCGF (P<0.05, 65.31% vs. 71.49%). No significant differences were observed in intestinal digestible protein and total digestible protein contents between the two feeds (P>0.05).

Table 5 Comparison of intestinal digestion characteristics of protein of DCGF and WCGF (n=4)

Item	DCGF	WCGF
Intestinal degradability of RUP (%)	65.31±0.97	71.49±1.24
Intestinal digestible protein (	±0.77	23.60±0.68
Intestinal		

2.4 Metabolizable Protein Supply of DCGF and WCGF Predicted by NRC Model Results of metabolizable protein supply prediction for DCGF and WCGF by NRC model are shown in Table 6. No significant differences were observed in total digestible nutrients content between the two feeds (P>0.05), and correspondingly, microbial protein and intestinally absorbable microbial protein contents also showed no significant differences (P>0.05). The two feeds had different protein degradation characteristics in the rumen. RUP content of DCGF was significantly higher than that of WCGF (P<0.05, 75.30 vs. 66.80 g/kg DM). Due to differences in intestinal digestibility of RUP, intestinally absorbable RUP content was not significantly different between the two feeds (P>0.05). Ultimately, metabolizable protein content showed no significant difference between DCGF and WCGF (P>0.05), at 110.90 and 108.42 g/kg DM, respectively.

Table 6 Supplemental amount of metabolizable protein of DCGF and WCGF predicted by NRC model (n=4)

Item	DCGF	WCGF
Total digestible nutrients (g/kg DM)	688.91$±5.23|708.23±3.71||RUP(g/kgDM)|75.30±1.41|66.80±1.27||Microbialprot	

2.5 Essential Amino Acid Nutritional Value of DCGF and WCGF Essential amino acid nutritional value of DCGF and WCGF is shown in Table 7. Except for isoleucine (Ile), threonine (Thr), and total essential amino acids (TEAA) in feed essential amino acids, other individual essential amino acid contents showed no significant differences ($P>0.05$). Among essential amino acids provided by RUP, contents of histidine (His), phenylalanine (Phe), and Ile provided by RUP of DCGF were significantly higher than those of WCGF ($P<0.05$), while other essential amino acids provided by RUP showed no significant differences ($P>0.05$). However, TEAA content provided by RUP of DCGF was significantly higher than that of WCGF (26.33 vs. 24.43 g/kg DM). Lysine and methionine contents provided by RUP in DCGF were 2.72 and 1.06 g/kg DM, respectively, compared to 2.57 and 1.01 g/kg DM in WCGF. Lys:Met ratios were 2.56 and 2.54, respectively, indicating lysine as the first limiting amino acid with relatively balanced amino acid profiles.

Table 7 The nutritional value of amino acids for DCGF and WCGF (n=4)

Item	DCGF	WCGF
Feed EAA (% CP)		
Lys	3.61$±0.05|3.84±0.08||Met|1.41±0.04|1.51±0.04||His|3.25±0.09|3.43±0.10||Arg|4. ∗EAAprovidedbyRUP(g/kgDM)∗ ∗||||Lys|2.72±0.04|2.57±0.05||Met|1.06±0.03|1.01±0.03||His|2.45±0.04|2.29±0.03|	

3. Discussion

3.1 Nutrient Composition of WCGF and DCGF This trial comprehensively analyzed and compared nutrient composition differences between WCGF and DCGF. From routine nutrient analysis, both feeds contained high levels of NDF, CP, and starch, making them good fiber and protein sources for dairy cows. DCGF had significantly higher NDF content than WCGF, while ADF, ADL, and starch contents were not significantly different, potentially giving DCGF an advantage in energy supply. Compared with results reported by Pan [3], WCGF nutrient composition in this trial was basically similar except for slightly lower NDICP content. However, differences existed compared with DCGF and WCGF nutrient composition reported by foreign scholars, possibly due to variations in corn varieties and quality used for starch processing [18-19]. DM, CP, NDF, and ADF contents of DCGF in this trial were comparable to results from Lin et al. [1], but EE and crude ash contents were higher, likely due to differences in origin and processing procedures. Significantly higher NDICP and ADICP contents in DCGF indicated lower protein degradability compared with WCGF, possibly caused by increased proportions of heat-denatured proteins (Maillard reaction products) during the drying process after corn husk spraying [12]. Different feed protein processing methods can create differences in three-dimensional structures and chemical bonds (such as cross-linking bonds) within and between protein molecules and between proteins and carbohydrates [20].

3.2 Rumen Degradation Characteristics of DM, CP, and NDF in WCGF and DCGF Currently, limited research data are available on rumen degradation patterns of corn gluten feed for comparison. Rumen degradation characteristics of WCGF in this trial were similar to results reported by Li [21]. Rumen degradation of feed depends primarily on fermentation difficulty and retention time in the rumen [22], with passage rate largely determined by feed specific gravity and particle size [23]. Small particles can fully contact the rumen and ferment adequately, promoting feed degradation. In this trial, within 72 h of rumen incubation, DM degradability of DCGF was lower than WCGF at 4, 24, and 48 h, with no significant differences at other time points, indicating WCGF was more easily degradable than DCGF. DM degradability of both feeds was high initially (4 h) and plateaued after 24 h, suggesting DM degradation occurred mainly within 24 h. DCGF had higher slowly degradable DM fraction content but significantly lower degradation rate and effective degradability than WCGF. WCGF had faster CP degradation, with significantly higher slowly degradable fraction content and degradation rate than DCGF, likely because protein denaturation during heat drying altered degradation characteristics. NRC (2001) [7] stated that heat treatment reduces CP availability, so differences in RUP content were likely caused by heat treatment. Both feeds showed slow NDF degradation within 24 h, with extensive degradation after 24 h and no significant difference in effective degradability, indicating the drying process did not affect fiber availability. Hristov et al. [24] reported that high specific gravity of WCGF results in short rumen retention time and higher dietary rumen passage rate. Since it provides non-forage short fiber with relatively high specific gravity and short rumen retention time, Allen et al. [25] suggested adding appropriate alfalfa hay to diets containing corn gluten feed to increase dietary rumen retention time and NDF degradability.

3.3 Intestinal Protein Digestion Characteristics of DCGF and WCGF After entering the small intestine, RUP and microbial protein are digested similarly to monogastric animals, forming free amino acids through hydrolysis by pancreatic proteases and being absorbed by small intestinal epithelial cells. These two components constitute total digestible protein. In this trial, intestinal digestibility of RUP in DCGF was significantly lower than in WCGF, possibly because protein structure changes during DCGF processing altered protein content bound to cellulose, thereby affecting protein digestibility. Lower protein digestibility resulted in similar intestinally absorbable RUP and metabolizable protein contents between DCGF and WCGF. Nutritional value of feed protein depends on metabolizable protein content [15].

3.4 Prediction of Truly Absorbable Protein Supply from DCGF and WCGF According to the NRC model, total digestible nutrients are determined by digestible CP, digestible NDF, digestible NFC, and digestible FA contents. DCGF had higher NDF content while WCGF contained more NFC, resulting in no significant difference in total digestible nutrients content between the two feeds, indicating similar nutritional value in energy supply. Although RUP contents differed between the two feeds, differences in intestinal digestibility of RUP led to no significant difference in intestinally absorbable RUP content. In the NRC model, microbial protein content positively correlates with total digestible nutrients content, and no significant difference was observed in microbial protein content between DCGF and WCGF in this trial. Eighty percent of microbial protein is true protein with approximately 80% intestinal absorption rate. Rumen endogenous nitrogen (containing 80% true protein) content positively correlates with feed DM content, and 50% of endogenous true protein can reach the duodenum for absorption. Therefore, endogenous true protein and intestinally absorbable endogenous true protein contents of WCGF were significantly lower than those of DCGF. Metabolizable protein entering the small intestine consists of intestinally absorbable RUP, intestinally absorbable microbial protein, and intestinally absorbable endogenous true protein. No significant difference in metabolizable protein content was observed between WCGF and DCGF, indicating similar nutritional value from a metabolizable protein perspective.

3.5 Essential Amino Acid Nutritional Value of DCGF and WCGF Amino acids provided by feed RUP, rumen microbial protein, and endogenous true protein are essential raw materials for body tissue and milk protein synthesis. Additionally, small amounts of amino acids are necessary precursors for synthesizing other metabolites. This trial determined 10 essential amino acid contents in DCGF and WCGF. Essential amino acid contents of WCGF were similar to results reported by Pan [3], and those of DCGF were similar to results from Lin et al. [1]. Significant differences in RUP content between the two feeds resulted in significantly higher TEAA content provided by RUP in DCGF than in WCGF. Research indicates that efficiency of metabolizable protein for protein synthesis depends on the matching degree between essential amino acid ratios in metabolizable protein and animal requirements, as well as TEAA content in metabolizable protein [7]. Most studies have shown that lysine and methionine are the first-limiting essential amino acids in dairy cow metabolizable protein, but the limiting order of methionine and lysine depends on their relative contents in RUP [26]. When corn or its byproducts provide most or all RUP in the diet, lysine is the first-limiting amino acid for dairy cows [27]. Estimation of feed digestible amino acid supply must consider two “amino acid pools” : the first pool is essential amino acids provided by RUP, and the second pool is essential amino acids from microbial protein and endogenous true protein. This trial only considered essential amino acids provided by RUP. Due to lower rumen CP degradability in DCGF, RUP provided more essential amino acids, but its significantly lower intestinal digestibility of RUP may affect essential amino acid nutritional value.

4. Conclusions

1. Both DCGF and WCGF contain high contents of available fiber and degradable protein, and can serve as fiber and protein sources for dairy cows.
2. Rumen NDF degradability was not significantly different between DCGF and WCGF, but rumen CP degradability and intestinal digestibility of RUP in DCGF were reduced, affecting its protein nutritional value.
3. DCGF and WCGF provided similar total digestible nutrients and microbial protein for dairy cows, with similar nutritional value in metabolizable protein supply.
4. RUP in DCGF provided higher total essential amino acid content than WCGF, but the lower intestinal digestibility of RUP in DCGF may reduce amino acid nutritional value.

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