



Effects of Feeding Corn-lablab Bean Mixture Silages on Nutrient Apparent Digestibility and Performance of Dairy Cows

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ABSTRACT: This study estimated the fermentation characteristics and nutrient value of corn-lablab bean mixture silages relative to corn silages. The effects of feeding corn-lablab bean mixture silages on nutrient apparent digestibility and milk production of dairy cows in northern China were also investigated. Three ruminally cannulated Holstein cows were used to determine the ruminal digestion kinetics and ruminal nutrient degradability of corn silage and corn-lablab bean mixture silages. Sixty lactating Holstein cows were randomly divided into two groups of 30 cows each. Two diets were formulated with a 59:41 forage: concentrate ratio. Corn silage and corn-lablab bean mixture silages constituted 39.3% of the forage in each diet, with Chinese wildrye hay constituting the remaining 60.7%. Corn-lablab bean mixture silages had higher lactic acid, acetic acid, dry matter (DM), crude protein (CP), ash, Ca, ether extract concentrations and ruminal nutrient degradability than monoculture corn silage ($p < 0.05$). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations of corn-lablab bean mixture silages were lower than those of corn silage ($p < 0.05$). The digestibility of DM, CP, NDF, and ADF for cows fed corn-lablab bean mixture silages was higher than for those fed corn silage ($p < 0.05$). Feeding corn-lablab bean mixture silages increased milk yield and milk protein of dairy cows when compared with feeding corn silage ($p < 0.05$). The economic benefit for cow fed corn-lablab bean mixture silages was 8.43 yuan/day/cow higher than that for that fed corn silage. In conclusion, corn-lablab bean mixture improved the fermentation characteristics and nutrient value of silage compared with monoculture corn. In this study, feeding corn-lablab bean mixture silages increased milk yield, milk protein and nutrient apparent digestibility of dairy cows compared with corn silage in northern China. (**Key Words:** Corn-lablab Bean Mixture Silages, Corn Silage, Dairy Cow, Performance)

INTRODUCTION

Corn silage is a major forage source for dairy cows in northern China because of its relatively constant nutritive value, high yield, and high-net energy for lactation requirements ranging from 1.17 Mcal/kg to 1.21 Mcal/kg dry matter (DM) (China standard NY/T 34, 2004) compared with other forage crops (Darby and Lauer, 2002). However, its crude protein (CP) concentration is low, ranging from 55 g/kg to 70 g/kg DM (China standard NY/T 34, 2004). Therefore, additional protein supplementation is required for milk production.

Legumes have long been recognized as a good source of CP. Intercropping corn with legumes is a viable option to increase forage protein content and thereby improve forage quality through the synergistic effects of two or more crops

grown simultaneously. Intercropping corn with legumes can also enhance the fermentation characteristics, CP concentration, and overall nutritive value of silages (Eichelberger et al., 1997; Titterton and Maasdorp, 1997; Anil et al., 2000; Dawo et al., 2007; Contreras-Govea et al., 2009a; Contreras-Govea et al., 2009b). However, not all legumes play the same role when combined with corn (Dawo et al., 2007). Contreras-Govea et al. (2009b) determined the nutritive value of corn in monoculture or mixture with one of three climbing beans, namely, -velvet bean (*Mucuna pruriens* (L.) D.C.), lablab bean (*Lablab purpureus* (L.) Sweet), and scarlet runner bean (*Phaseolus coccineus* L.). Among the three beans, lablab bean elicited the greatest effect on the fermentation characteristics of silage compared with monoculture corn. Similarly, Armstrong et al. (2008) found that lablab bean intercropped with corn had the greatest potential among the three climbing beans to increase CP concentration compared with monoculture corn.

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Lablab bean is a common legume in South Asia, China, Japan, West Africa, and the Caribbean (Vamenzuela and Smith, 2002). It can grow in a diverse range of environmental conditions worldwide because of its adaptability and resistance to drought (Murphy and Colucci, 1999). In addition, lablab bean serves as an adequate source of protein. In a pasture setting, lablab bean can be used as a feed for grazing animals. Furthermore, it can be planted as a companion crop of corn, mixed with corn silage, and intercropped with corn. In several studies, lablab bean has been observed to increase livestock weight and milk production (Murphy and Colucci, 1999; Mupangwa et al., 2000a). Lablab hays fed as a supplement to cattle on a basal diet of straw increase rumen ammonia-N concentration, enhance intake and straw digestibility, hasten particulate passage rate, and decrease mean retention time (Abule et al., 1995). In addition, lablab hays fed to sheep improve diet intake and digestibility (Umunna et al., 1995; Mupangwa et al., 2000b). Thus, lablab bean can be used in solving problems associated with nutrient deficiencies in poor-quality diets. Previous research conducted in our laboratory showed that the average yield dry matter (DM) of corn-lablab mixture silage (1267.04 kg/acre) was slightly ($p > 0.05$) higher than that of monoculture corn silage (1228.61 kg/acre), but the crude protein concentration (CP) was on average 11.92% (81.7 g/kg DM) greater in corn-lablab mixture silage than monoculture corn silage (73.0 g/kg DM, $p < 0.05$) (Qu et al., 2010).

Intercropping and ensiling corn with lablab bean provide a feasible option to increase CP concentration in silage. However, the effects of feeding corn-lablab bean mixture silages on the performance of dairy cows compared with corn silage have not been fully elucidated. This study aims to estimate the fermentation characteristics and nutrient value of corn-lablab bean mixture silages relative to corn silages (Longfudan 208). Then the effects of feeding corn-lablab bean mixture silages on nutrient apparent digestibility and milk production of dairy cows in northern China were determined.

MATERIAL AND METHODS

Field management and silage preparation

Field experiments were carried out at Mudanjiang Shuangfeng farm (44°36' latitude N, 129°35' longitude W), Heilongjiang, China, from May 2009 to September 2009. We used hilly albic soil mixed with sand at a 30 cm average soil depth. Soil fertility levels at the location were maintained at optimal levels for corn silage production. Silage corn (Longfudan 208) was sown alone or intercropped with lablab bean at a planting density of 80/40 thousand corn/lablab bean plants/ha. On 10 May 2009,

silage corn (Longfudan 208) was sown in two different 10 ha herbicide-free areas. After 2 d, lablab beans were sown in rows 15 cm apart from the rows of corn in a randomized 10 ha area. Chemical herbicide application was completed in 5 d. Corn and corn-lablab bean mixtures were harvested on 23 September 2009 at a corn maturity stage of 2/3 milk line.

The monoculture corn and corn-lablab mixtures were chopped to a theoretical cut length of 15 mm using a forage harvester and then ensiled in two individual bunker silos for 50 d. At the time of ensiling, two 1,000 g fresh samples were taken for the initial characterization of corn and corn-lablab bean mixture. After 50 d of storage, two 1,000 g samples of silage were taken from each silo and frozen to -20°C until analysis.

Corn and corn-lablab bean mixture silages were analyzed for pH in triplicate by placing a 20 g sample in 100 ml distilled water, and blending for 60 s in a high-speed blender. The diluted sample was filtered through three layers of cheesecloth, and pH was measured with a pH meter (Mettler Toledo Delta320, Switzerland). A 20 ml aliquot was centrifuged at 25,000×g for 20 min at 4°C, and supernatant was decanted into 20 ml scintillation vials and stored at -20°C for later analysis of organic acids and ammonia-N. The organic acids (lactate, acetate, and butyrate) were analyzed by high performance liquid chromatography (column: Sodex RS Pak KC-811, Showa Denko K.K., Kawasaki, Japan; detector: DAD, 210 nm, SPD-20A, Shimadzu Co., Ltd, Kyoto, Japan; 1.0 ml/min; temperature: 50°C). Concentration of ammonia-N was measured using the indophenolblue method.

Corn and corn-lablab bean mixture silages samples were dried at 55°C for 72 h in a forced-air drying oven and then ground in a Wiley mill to pass through a 1 mm screen (FZ102, Shanghai Hong Ji Instrument Co. Ltd, Shanghai, China). Dry matter, Ca, P, ash and ether extract (EE) contents of silage samples were determined by following the procedure of AOAC (1990), and N content was determined by the Kjeldahl method (AOAC 1990), CP was calculated as $N \times 6.25$. The neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the methods described by Van Soest et al. (1991). Concentrations of Water Soluble Carbohydrate (WSC) in silage samples were measured using the anthrone technique (Thomas, 1977).

In situ ruminal nutrient degradabilities

The corn silage (Longfudan 208) and corn-lablab bean mixture silages were ground with a mill to pass through a 2.5 mm screen (FZ102, Shanghai Hong Ji Instrument Co. Ltd, Shanghai, China). Duplicate samples weighing 5.0 g were placed into nylon bags (9×16 cm, 50µm pore size,

Beijing Feidi Business Co. Ltd, Beijing, China) and heat sealed. The nylon bags were then incubated in the rumen of three ruminally cannulated Holstein cows (two bags per treatment per time period per cow) for 0, 4, 8, 12, 24, 48 and 72 h. The cows were fed *ad libitum* a 51:49 forage:concentrate total mixed diet that contained (DM basis) 92.3% DM, 10.8% CP, 28.7% ADF, and 45.8% NDF. Zero-hour disappearance was estimated by washing duplicate bags containing samples. At the end of the incubations, all bags were removed from each cow and were manually rinsed in cold tap water until the rinsing water was clear. Washed bags were dried at 65°C for a constant weight. Residues from the nylon bags were analyzed for DM, CP, NDF, and ADF as previously described.

Kinetic parameters of nutrient disappearance in the rumen were estimated using an iterative least squares method of the nonlinear regression procedure of SAS (2001) by fitting the following model (Ørskov and McDonald, 1979): $y = a + b \times (1 - e^{-ct})$, where y is ruminal nutrient disappearance at time t ; a is soluble fraction (%), b is slowly degradable fraction (%), c is fractional degradation rate constant at which b is degraded and t is the time of incubation (h). Effective degradability (ED) was calculated from the equation: $ED = a + bc / (c + k)$, where k is the ruminal outflow rate (0.036/h) and a , b , and c are as described above.

Production study

Sixty multiparous lactating Holstein cows selected from Heilongjiang dairy farm were stratified on the basis of milk production and were randomly divided into two groups of 30 cows each. The cows were housed in tie stalls with water freely available. Two diets were formulated with a 59:41 forage: concentrate ratio to meet the nutrient requirements of dairy cows (NRC, 2001). The forage part of the diets consisted of 39.3% corn silage (Longfudan 208) or 39.3% corn-lablab bean mixture silages, with the remaining 60.7% consisting of Chinese wildrye hay in both diets (Table 1). The experimental period lasted for 70 d, including a 10-d adaptation period and a 10-d metabolism trial. The diet was fed *ad libitum* per d at 04:00, 11:00, and 17:00 h, and the animals were milked daily at 05:00 and 18:00 h.

Five cows from each treatment group with similar food intake were housed in metabolism crates designed to collect total fecal excretion during the last 10 d of the experiment. The cows were acclimatized to their assigned diets for 5 d, followed by 5 d of fecal collection. The weight of the total daily feces was recorded for each cow and a 10% aliquot was stored at 5°C every morning of the collection period. Feed offered and feed refusals were also recorded daily for each cow. At the end of the collection period, feed offered, feed refusals, and all feces from a cow were thawed, mixed

Table 1. Ingredients and chemical composition of dietary treatments

Item	Dietary treatment	
	Corn silage	Corn-lablab bean mixtures silages
Ingredient (% , fed basis)		
Corn silage (Longfudan 208)	23.2	0.00
Corn-lablab bean mixture silages	0.00	23.2
Chinese wildrye hay	35.8	35.8
Corn	18.7	18.7
Cottonseed meal	4.80	4.80
DDGS	3.70	3.70
Rice bran meal	1.50	1.50
Rapeseed meal	2.10	2.10
Corn gluten meal	1.00	1.00
Soybean meal	7.00	7.00
Soybean cake	0.80	0.80
Premix ^a	1.00	1.00
Baking soda	0.40	0.40
Chemical composition ^b (DM basis)		
Net energy for lactation (MJCal/kg)	6.57	6.68
Dry matter (%)	92.10	92.88
Crude protein (%)	14.60	15.47
Neutral detergent fiber (%)	45.99	42.68
Acid detergent fiber (%)	23.06	22.00
Calcium (%)	0.40	0.49
Phosphorus (%)	0.41	0.47

^a Premix contained the following per kilogram: FeSO₄·7H₂O, 170 g; CuSO₄·5H₂O, 70 g; MnSO₄·5H₂O, 290 g; ZnSO₄·7H₂O, 240 g; CoCl₂·6H₂O, 510 mg; KI, 200 mg; Na₂SeO₃, 130 mg; vitamin A, 620,000 IU; vitamin D, 3,324,000 IU; vitamin E 540 IU; vitamin K₃, 150 mg; vitamin B₁₂, 0.9 mg; vitamin B₅, 450 mg; calcium pantothenate, 750 mg; folic acid, 15 mg.

^b Analyzed values except net energy for lactation. Net energy for lactation was calculated by net energy for lactation in ingredients of the basal diet (NY/T 34, 2004).

thoroughly, and subsampled for subsequent analysis. The analysis of DM, CP, NDF, and ADF concentrations in the feeds and feces was used to determine nutrient digestibility. The analytical procedures were the same as previously described.

Individual milk yields were recorded electronically at each milking (HerdMaster Galaxy Management System, Alfa-Laval Agri Inc., St. Louis, MO, USA). Milk samples were obtained for each milking on day 0, 15, 30, 45, 60 and analyzed for milk fat, milk protein, solids non fat (SNF), and milk somatic cell count (SCC). The content of fat, protein and SNF, respectively, was analyzed by spectroscopic mid infrared technique (MilcoScan FT 120. Foss Electric, Hillerød, Denmark) according to Lakic et al. (2009). The SCC was analyzed in fresh milk with no additives by fluorescence-based electronic cell count

(Fossomatic 5000. Foss Electric, Denmark) according to Burriel (2000).

Statistical analysis

The data were analyzed using the GLM procedure of SAS program package (SAS Institute, version 9.1). The following model was used: $Y_{ij} = \mu + T_i + \epsilon_{ij}$, where Y_{ij} is the dependent variables; μ is the overall mean; T_i is the fixed effect of group or treatment; ϵ_{ij} is the random error. Duncan's multiple range tests were used to detect statistical significance between treatment groups.

RESULTS

Silage fermentation characteristics, chemical composition and effective ruminal degradability

The fermentation characteristics and chemical composition of corn silages and corn-lablab bean mixture silages are presented in Table 2. The lactic acid and acetic acid concentrations of corn-lablab bean mixture silages were higher compared with those of corn silage ($p < 0.05$). The pH and ammonia-N concentrations of all silages indicated well-fermented silage ($p > 0.05$).

Dry matter, CP, ash, Ca, EE, NDF, and ADF concentrations were significantly different between corn silage and corn-lablab bean mixture silages ($p < 0.05$). Dry matter, CP, ash, Ca, and EE concentrations of corn-lablab

Table 2. Fermentation characteristics and chemical composition corn silages and corn-lablab bean mixtures silages

Item	Dietary treatment	
	Corn silage	Corn-lablab bean mixtures silages
Fermentation characteristics		
pH	3.78±0.05	3.56±0.05
Ammonia-N/total N (%)	5.51±0.46	5.30±0.73
Lactic acid (%)	20.45±1.12 ^a	22.73±1.28 ^b
Acetic acid (%)	3.42±0.57 ^a	3.68±0.64 ^b
Butyric acid (%)	0.71±0.08	0.15±0.03
Chemical composition		
Dry matter (fresh forage %)	22.31±0.06 ^a	23.35±0.08 ^b
Ash (DM %)	4.73±0.16 ^a	5.18±0.01 ^b
Neutral detergent fiber (DM %)	51.97±2.27 ^b	39.19±1.18 ^a
Acid detergent fiber (DM %)	39.53±0.70 ^b	31.96±0.71 ^a
Ether extract (DM %)	2.94±0.07 ^a	3.28±0.17 ^b
Crude protein (DM %)	7.30±0.19 ^a	8.17±0.23 ^b
Calcium (DM %)	0.23±0.02 ^a	0.48±0.06 ^b
Phosphorus (DM %)	0.22±0.03	0.24±0.03
Water soluble carbohydrate (DM %)	1.48±0.09	1.69±0.09

Means within the same row with different letters (a-b) are different ($p < 0.05$).

Table 3. *In situ* ruminal nutrient degradabilities of corn-lablab bean mixtures silages relative to corn silage (%), X±SD

Item	Dietary treatment	
	Corn silage	Corn-lablab bean mixtures silages
Dry matter		
a	26.72±0.44 ^a	31.22±1.87 ^b
b	28.74±1.15 ^a	52.87±2.76 ^b
c (/h)	0.02±0.02	0.02±0.001
ED	37.81±0.96 ^a	44.64±1.12 ^b
Crude protein		
a	34.43±0.40 ^a	45.90±2.67 ^b
b	26.23±2.76 ^a	31.78±5.80 ^b
c (/h)	0.10±0.04	0.09±0.01
ED	55.14±1.92 ^a	62.23±1.22 ^b
Neutral detergent fiber		
a	4.05±0.64 ^a	6.78±1.34 ^b
b	38.14±0.19 ^a	58.75±5.09 ^b
c (/h)	0.07±0.01	0.05±0.01
ED	23.26±2.56 ^a	32.75±2.19 ^b
Acid detergent fiber		
a	6.03±1.10	5.55±5.98
b	41.70±1.06 ^a	62.35±0.04 ^b
c (/h)	0.02±0.01	0.03±0.01
ED	22.54±1.20 ^a	30.00±3.44 ^b

Means within the same row with different letters (a-b) are different ($p < 0.05$).

bean mixture silages were 1.04%, 0.45%, 0.87%, 0.25%, and 0.34% greater than those of monoculture corn silage, respectively ($p < 0.05$). Moreover, NDF and ADF concentrations of corn-lablab bean mixture silages were 12.78% and 7.57% lower than those of corn silage, respectively ($p < 0.05$). The P and WSC concentrations were similar between monoculture and mixture silages ($p > 0.05$).

In situ ruminal digestion kinetics and ED of corn silage and corn-lablab bean mixture silages are shown in Table 3. Ruminal DM, CP, NDF, and ADF degradability of corn-lablab bean mixture silages were higher than corn silage ($p < 0.05$).

Nutrient apparent digestibility

Effects of feeding corn-lablab bean mixture silages on nutrient apparent digestibility of dairy cows are presented in Table 4. The digestibility of DM, CP, NDF, and ADF was different between two dietary treatments ($p < 0.05$). The digestibility of DM, CP, NDF, and ADF for cows fed corn-lablab bean mixture silages was 7.67%, 7.84%, 5.18%, and 8.54% greater than for those fed corn silage, respectively ($p < 0.05$).

Performance

No significant differences in milk yield between two

Table 4. Effects of feeding corn-lablab bean mixtures silages on nutrient apparent digestibility of dairy cows (% , X±SD)

Item	Dietary treatment	
	Corn silage	Corn-lablab bean mixtures silage
Dry matter	66.12±2.54 ^a	73.79±3.26 ^b
Crude protein	62.77±1.68 ^a	70.61±2.38 ^b
Neutral detergent fiber	45.64±1.23 ^a	50.82±2.02 ^b
Acid detergent fiber	38.74±3.22 ^a	47.28±3.67 ^b

Means within the same row with different letters (a-b) are different (p<0.05).

dietary treatments (p>0.05) were observed in the first 15 d of the experiment. However, in the next 16 d to 60 d, cows fed corn-lablab bean mixture silages produced a higher milk yield compared with cows fed corn silage (p<0.05). During the 60-d experimental period, the overall mean of milk yield was 3.02 kg/d greater for cows fed corn-lablab bean mixture silages than for those fed corn silage (p<0.05). Milk proteins were greater (p<0.05) in the milk of cows fed corn-lablab bean mixture silages than in the milk of cows fed corn silage. Milk fat and SNF content were similar for both dietary treatments (p>0.05). However, milk somatic cell counts for cows fed corn-lablab bean mixture silages were lower than for those fed corn silages (p<0.05).

Economic benefit

During the experimental period, the prices of each ingredient (yuan/kg) were as follows: corn silage, 2.8; Chinese wildrye hay, 1.2; and mixture concentrate, 2.57. Experiments were carried out at Heilongjiang dairy farm, which belongs to Wandanshan Milk production base. According to the provisions of Wandashan fresh milk purchase price, milk purchase price was 2.97 yuan/kg.

Effects of feeding corn-lablab bean mixtures silages on economic benefit are shown in Table 6. The two diets containing corn silages and corn-lablab bean mixture silages had the same cost. But the economic benefit for cows fed corn-lablab bean mixture silages was 8.43 yuan/d/cow higher than that for those fed corn silage.

DISCUSSION

Most previous studies were concerned with nutritive value and fermentation characteristics of corn silage intercropping with lablab bean to ruminants (Contreras-Govea et al., 2009b). The objective of this study was focused on nutritive and feeding effect for cows in northern China. In addition, the region of northern China in this study is located in the alpine region. Since nutritive value of silage is affected significantly by climate, this study was important to northern Chinese dairy farmers as it provides a method of improving corn silage quality by intercropping

Table 5. Effects of feeding corn-lablab bean mixtures silages on the performance of dairy cows

Item	Dietary treatment	
	Corn silage	Corn-lablab bean mixtures silage
Milk yield (kg/d)		
1-15 d	18.04±2.33	20.75±1.59
16-30 d	18.74±1.66 ^a	21.23±1.81 ^b
31-45 d	18.92±1.21 ^a	21.47±2.08 ^b
46-60 d	18.57±1.78 ^a	22.90±1.43 ^b
1-60 d (overall mean)	18.57±1.75 ^a	21.59±1.73 ^b
Milk fat (%)		
15 d	3.72±0.53	3.67±0.43
30 d	3.75±0.67	3.59±1.00
45 d	3.52±0.33	3.65±0.46
60 d	3.48±0.53	3.62±0.71
1-60 d (overall mean)	3.62±0.52	3.63±0.65
Milk protein (%)		
15 d	2.98±0.23 ^a	3.25±0.33 ^b
30 d	3.00±0.17 ^a	3.28±0.10 ^b
45 d	2.94±0.19 ^a	3.35±0.16 ^b
60 d	3.02±0.43 ^a	3.47±0.21 ^b
1-60 d (overall mean)	2.99±0.26 ^a	3.34±0.20 ^b
Solids non fat (%)		
15 d	8.41±1.45	8.91±2.03
30 d	8.73±2.31	8.93±1.79
45 d	8.71±2.45	8.90±2.51
60 d	8.62±1.76	8.95±1.87
1-60 d (overall mean)	8.62±1.99	8.92±2.05
Milk somatic cell count (×10 ³ cells/ml)		
15 d	325.46±35.12 ^b	272.86±27.63 ^a
30 d	300.67±25.46 ^b	280.12±28.74 ^a
45 d	300.48±29.60 ^b	283.81±31.39 ^a
60 d	310.25±35.77 ^b	279.10±28.54 ^a
1-60 d (overall mean)	309.22±31.49 ^b	278.97±29.08 ^a

Means within the same row with different letters (a-b) are different (p<0.05).

with lablab bean.

Silage fermentation characteristics, chemical composition and effective ruminal degradability

Legumes are expected to have higher organic acid concentrations than grasses because of their greater

Table 6. Effects of feeding corn-lablab bean mixtures silages on economic benefit (yuan/d/cow)

Item	Dietary treatment	
	Corn silage	Corn-lablab bean mixtures silage
Cost of diet	37.84	37.84
Income from milk	55.69	64.12
Economic benefit	17.85	26.28

buffering capacity (McDonald et al., 1991; Albrecht and Beauchemin, 2003; Muck et al., 2003). In the present experiment, corn-lablab bean mixture silages contained higher lactic acid and acetic acid concentrations than monoculture corn silage. The higher buffering capacity of lablab bean may have extended the fermentation period, resulting in greater lactate and acetate concentrations. Similar observations have been recorded by Contreras-Govea et al. (2009a), who observed an increase in lactic acid and acetic acid concentrations when corn was ensiled in mixture with lablab bean. Meanwhile, in the present study, the pH value, and ammonia-N concentrations of silages indicated that the monoculture corn (Longfudan 208) and corn-lablab bean mixture silages were well-fermented silage. This result is in agreement with earlier studies conducted by Mazaheri (1979) and Anil et al. (2000).

As expected, corn-lablab bean mixture improved the nutrient value of silage compared with monoculture corn. Combining corn with lablab bean increased CP concentrations and decreased fiber concentrations in silage. These results can be attributed to the greater protein and lower fiber content of legumes compared with grasses (NRC, 2001). Kaiser and Lesch (1977) revealed similar results, demonstrating that the increase in CP concentration can reach as high as 78% from a monoculture corn to an intercrop corn with lablab bean. Similarly, Contreras-Govea et al. (2009b) compared the chemical composition of corn-lablab bean mixture silage with corn silage and found that the mixture silage has 13% greater CP concentration than corn alone. In another study, Armstrong et al. (2008) intercropped corn with lablab bean and concluded that adding lablab bean in low-density corn stands can increase the CP concentration and feed nutrient value of the forage.

In the present study, *in situ* ruminal nutrient degradabilities of corn-lablab bean mixture silages were greater than those of corn silages. This result may be attributed to the difference in protein composition and structure between corn silage and corn-lablab bean mixture silages, which altered the fermentation substrate of the rumen microbial population and thus improved nutrient degradability. For corn-lablab mixture silage, a higher CP content may mean a high concentration of buffer soluble CP and a low concentration of slowly degradable fractions. The high effective degradabilities of DM, NDF and ADF maybe due to its higher soluble *in situ* soluble DM, NDF and ADF fractions than monoculture corn silage. Other researchers also reported higher rates of ruminal degradation of DM, NDF and ADF derived from higher CP legumes than grasses (A. F. Mustafa et al., 2000).

Nutrient apparent digestibility

Corn for silage is a major forage source for dairy cows in northern China. The composition and content of various

nutrients in the silage directly affect cow digestibility and production. In this experiment, cows fed corn-lablab bean mixture silages increased the digestibility of DM, CP, NDF, and ADF compared with those fed corn silage. This results was derived from lower NDF, ADF content and higher CP concentration in corn-lablab mixture. This finding is in agreement with Mupangwa et al. (2000a), who found that lablab bean supplementation improves the apparent digestibility of DM and NDF in the basal diet compared with the control diet of growing goats.

The cell wall constituents NDF (hemicellulose, cellulose, and lignin) and ADF (cellulose and lignin) are negatively correlated with NDF and ADF digestibility (Theander and Westerlund, 1993). Legumes, including lablab bean, contain higher CP and lower NDF content than grasses, such as corn (NRC, 2001), which may elicit an effect on digestibility. Thus, higher CP and lower NDF and ADF concentrations of corn-lablab bean mixture silages may lead to remarkable higher digestibility of DM (up to 76.7 g/kg DM), CP (up to 78.4 g/kg DM), NDF (up to 51.8 g/kg DM) and ADF (up to 85.4 g/kg DM) compared with monoculture corn silage ($p < 0.05$). Similar observations were recorded by earlier studies (Paterson et al., 1994).

Performance and economic benefit

The performance of dairy cows can be estimated primarily from milk yield and milk composition, which are affected by genetic and environmental factors, including bio-geophysical (such as photoperiod), nutritional, and management factors. Generally, variations in animal nutrition elicit the most important environmental effect on performance. In this study, milk yield was greater for cows fed corn-lablab bean mixtures silages than for those fed corn silage. Dietary NDF contents are major factors affecting the milk yield of dairy cows (Allen, 2000). The reduction in milk yield, for cows fed the corn silage diet can be attributed, at least in part, to the greater (7.2% more) NDF content of the corn silage diet relative to that of the corn-lablab bean mixture silage diet.

Moreover, milk protein content in the milk of cows fed corn-lablab bean mixture silages was increased. By contrast, Mugwenti et al. (2006) found that feeding mixed cereal-tree forage legume silages does not elicit an effect on milk yield and composition in lactating dairy cows. Our result may differ because feeding corn-lablab bean mixture silages diet increased CP concentration and digestibility compared with corn silage diet. As a result, milk yield and milk protein were improved.

Methods to reduce production costs and obtain the highest possible income are still the main focus for animal nutrition researchers studying dairy cows. In this study, feeding corn-lablab bean mixture silages diet had 8.43 yuan/d/cow higher economic benefit compared with corn

silage diet.

CONCLUSION

It can be concluded that corn-lablab bean mixture improved the fermentation characteristic and nutrient value of silage compared with monoculture corn. Under the conditions of our study, feeding corn-lablab bean mixture silages increased nutrient apparent digestibility, milk yield and milk protein of dairy cows when compared with corn silage, likely because of a reduced content of NDF and its increased ruminal degradability. More research is needed to determine the long-term effects of feeding forage corn-lablab bean mixture to dairy cows in the northern China.

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