J. Dairy Sci. 98:1–9
http://dx.doi.org/10.3168/jds.2015-9312

Effect of dietary energy source and level on nutrient digestibility, rumen microbial protein synthesis, and milk performance in lactating dairy cows

X. Q. Zhou,*†[1] Y. D. Zhang,†[1] M. Zhao,† T. Zhang,† D. Zhu,† D. P. Bu,†‡§[2,3] and J. Q. Wang*†[2,3]
*College of Animal Science and Technology, Northeast Agricultural University; Harbin 150030, P. R. China
†State Key Laboratory of Animal Nutrition, Institute of Animal Science, Chinese Academy of Agricultural Sciences, Beijing, 100193, P. R. China
‡Synergetic Innovation Center of Food Safety and Nutrition, Harbin, 150030, P. R. China
§Chinese Academy of Agricultural Sciences-International Center for Research in Agroforestry, Joint Laboratory on Agroforestry and Sustainable Animal Husbandry, World Agroforestry Centre, East and Central Asia, Beijing 100193, P. R. China

ABSTRACT

This study was conducted to examine the effects of dietary energy source and level on intake, digestion, rumen microbial protein synthesis, and milk production in lactating dairy cows, using corn stover as a forage source. Eight multiparous Holstein cows, 4 of which were fitted with rumen cannulas, were evaluated in a replicated 4 × 4 Latin square design, with each period lasting 21 d. The cows were randomly assigned into 4 treatment groups: low-energy (LE) ground corn (GC), LE steam-flaked corn (SFC), high-energy (HE) GC, and HE SFC. Changes to ruminal energy degradation rates were induced by feeding the cows diets of either finely ground corn or SFC as components of diets with the same total energy level. Milk yield, milk protein content and yield, and milk lactose yield all increased in response to higher levels of dietary energy, whereas contents of milk fat and lactose were unaffected. Cows fed HE diets had a higher crude microbial protein yield and total-tract apparent digestibility than those receiving LE diets. Milk yield, milk protein yield, and microbial protein yield were also higher when SFC replaced GC as the main energy source for lactating cows fed LE diets. These results suggest that an increased dietary energy level and ruminal degradation rate are beneficial to milk protein production, which we suggest is due to increased yields of microbial proteins, when cows are fed corn stover as a dietary forage source.
Key words: energy, corn stover, microbial protein, nutrient digestibility, lactation performance

Received January 5, 2015.
Accepted June 19, 2015.
[1]These authors contributed equally to the study.
[2]Corresponding authors: budengpan@126.com and wang-jia-qi@263.net
[3]Current address: State Key Laboratory of Animal Nutrition, Institute of Animal Science, Chinese Academy of Agricultural Sciences, No. 2 Yuanmingyuan West Road, Haidian District, Beijing, 100193, P. R. China.

INTRODUCTION

Efficient milk production and high quality milk composition are both of great economic importance to dairy farmers. Lactation performance can be effectively improved by managing cow diets and enhancing the conversion of feed into milk (Brun-Lafleur et al., 2010), and it is well documented that high dietary energy input and protein supplementation are critical for effective lactation (Wang et al., 2014). In China, corn stover (**CS**) is the primary forage material used on small dairy farms (Zhao and Li, 2009; Zhu et al., 2013); however, CS contains low levels of CP, NFC, and readily fermentable carbohydrates. Corn stover is therefore an inadequate source of the energy necessary to synthesize microbial crude protein (**MCP**), and reliance solely on CS feeding often leads to decreased milk production (Cooke et al., 2008; Zhao and Li, 2009). Indeed, it has been concluded that feed with an adequate energy content for MCP synthesis is critical for lactation in dairy cows fed low-quality forage such as CS (Zhu et al., 2013).

Ground corn (**GC**) is an excellent source of energy due to its high content of readily fermentable carbohydrates (i.e., starch). However, the different methods that are used for corn processing can change ruminal starch availability (Theurer et al., 1999). When compared with intact corn grains, steam-flaked corn (**SFC**) is more readily digestible due to changes in the structure of the starch granules following exposure to a combination of moisture, heat, and pressure. As a result, the use of SFC improves starch utilization and increases the energy available for MCP synthesis (Theurer et al., 1999). Additionally, the combination of corn grain and forage in a cow's diet can make an important contribution to total energy and protein availability. Differences in energy metabolism, and hence ruminal carbohydrate fermentation and milk production, have been observed when the diets of dairy cows consist of processed corn in combination with different forages (Wilkerson et al., 1997; Yu et al., 1998). However, little is known about the effects of SFC on lactation performance in cows fed CS as their primary forage. This current study was conducted to evaluate the digestibility of the feed, MCP synthesis and lactation performance of dairy cows fed different amounts of CS in the form of either GC or SFC.

MATERIALS AND METHODS

The use and care of the animals used in this study were approved by the Animal Care Advisory Committee of the Chinese Academy of Agricultural Sciences. The health of the cows was monitored continuously before and during the experimental period.

Animals and Experimental Design

Eight primiparous Chinese Holstein cows (138 ± 19.4 DIM, 29 ± 0.8 kg/d milk, and 589 ± 57.6 kg of BW), 4 of which were fitted with ruminal cannula, were used in a replicated 4 × 4 Latin square design, with a 2 × 2 factorial arrangement of treatments [energy level: NE_L 1.52–1.53 Mcal for low energy (**LE**) and 1.71–1.72 Mcal for high energy (**HE**); energy source: SFC and GC]. The Latin square was balanced for carryover effects. Each experimental period consisted of 14 d for adaptation and 7 d for sample collection. The cows were housed in a free-stall barn using a computerized monitoring system (RIC system, Insentec B.V., Marknesse, the Netherlands). The system automatically identified individual cows by ear tags and recorded their feeding behaviors, including time and duration, as well as the quantity of feed intake at each meal.

The experimental diets (Tables 1 and 2) were formulated to meet the nutrient demand of energy, protein content, minerals, and vitamins according to the Feeding Standards of Dairy Cattle (Ministry of Agriculture of P. R. China, 2004). The treatments included 2 forages (36% CS or13% CS plus 22% corn silage) and 2 forms of corn (Table 3): GC (mean particle size: 1,030 μm) and SFC (density: 360 g/L). The experimental diets were provided twice daily (0630, 1630 h) for ad libitum intake, allowing for 5% orts, with free access to water. Cows were milked 3 times daily, at 0700, 1330, and 2030 h.

Sample Collection and Analysis

Milk production was recorded and milk samples were collected on d 15, 16, and 17 of each experimental period. Two 50-mL aliquots of milk were collected during each milking, and these were pooled in a proportion of 4:3:3 (Zhu et al., 2013; Wang et al., 2014). To one subsample, Bronopol (milk preservative, D&F Control Systems, San Ramon, CA) was added as a preservative, and this subsample was then stored at 4°C for future analysis of protein, fat, lactose, TS, and SCC content by infrared analysis (Laporte and Paquin, 1999) with a Foss-Milkoscan Minor (MilkoScan FT120, Foss Electric

Table 1. Composition of the 4 experimental diets with different dietary energy level and grain processing method[1]

	LE		HE	
Item	GC	SFC	GC	SFC
Corn silage	0	0	22	22
Corn stover	35.6	35.6	13	13
Soybean meal	11.29	11.29	11.29	11.29
Rapeseed meal	6.32	6.32	6.32	6.32
Extruded soybeans	2.06	2.06	2.06	2.06
Beet pulp	4.16	4.16	4.16	4.16
Cottonseed meal	10.44	10.44	10.44	10.44
Ground corn	25.56	0	25.56	0
Steam-flaked corn	0	25.56	0	25.56
EB100[2]	1.24	1.24	1.84	1.84
XP[3]	0.33	0.33	0.33	0.33
Limestone	0.74	0.74	0.74	0.74
Salt	0.46	0.46	0.46	0.46
Premix[4]	0.53	0.53	0.53	0.53
Sodium bicarbonate	0.92	0.92	0.92	0.92
Magnesium oxide	0.35	0.35	0.35	0.35

[1]LE = low energy TMR; HE = high energy TMR; GC = ground corn; SFC = steam-flaked corn.

[2]EB100 is mainly a saturated FFA supplement (EnergyBooster 100, Milk Specialties Global, Eden Prairie, MN).

[3]XP is a yeast culture supplement (Diamond V, Cedar Rapids, IA).

[4]Premix contained (DM basis) 99.07% of ash, 14.27% of Ca, 5.42% of P, 4.96% of Mg, 0.05% of K, 10.67% of Na, 2.98% of Cl, 0.37% of S, 11 mg/kg of Co, 577 mg/kg of Cu, 4,858 mg/kg of Fe, 51 mg/kg of I, 1,806 mg/kg of Mn, 13 mg/kg of Se, 1,694 mg/kg of Zn, 115,240 IU/ kg of vitamin A, 46,100 IU/kg of vitamin D, and 576 IU/kg of vitamin E.

Table 2. Nutrient composition of the 4 experimental diets with different dietary energy level and grain processing method[1]

	LE		HE	
Item	GC	SFC	GC	SFC
DM, %	42.1	42.8	44.9	44.9
OM, % of DM	92.9	93.0	93.5	93.8
Ash, % of DM	7.07	7.05	6.49	6.16
CP, % of DM	16.5	16.5	16.8	16.1
Ether extract, % of DM	2.58	2.78	3.92	3.95
NDF, % of DM	43.8	43.0	36.2	36.7
ADF, % of DM	35.4	36.9	31.4	31.3
NFC,[2] % of DM	30.0	30.7	36.6	37.1
Starch, % of DM	22.3	22.8	24.4	24.9
Ca, % of DM	0.64	0.64	0.57	0.57
Total P, % of DM	0.36	0.44	0.45	0.45
NE_L,[3] Mcal/kg of DM	1.52	1.53	1.71	1.72

[1]LE = low energy TMR; HE = high energy TMR; GC = ground corn; SFC = steam-flaked corn.

[2]Calculated as 100 − (% NDF + % CP + % ether extract + % ash).

[3]Calculated based on Feeding Standards of Dairy Cattle (Ministry of Agriculture of P. R. China recommendations, 2004).