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Replacement of soybean with canola improves short-term milk yield and nitrogen-use efficiency in high-producing, early-lactation Holstein cows

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Abstract

It has been demonstrated that canola meal (CM) is used more efficiently than soybean meal (SBM) by lactating dairy cows. This study was conducted to determine the effects of replacing SBM with CM on production performance, blood metabolites, and ruminal fermentation parameters of high-producing dairy cows in early lactation. Twelve lactating Holstein cows (4 primiparous and 8 multiparous; 36 ± 8 days in milk) were used in a 3 × 3 Latin square design with three treatments and four replicates (cows) over three 21-day periods. Cows were fed diets formulated with incremental amounts of CM as 0% (CM-0), 50% (CM-50), or 100% (CM-100) of SBM replaced by CM. Experimental diets were formulated to be isonitrogenous (16.8% crude protein) and isoenergetic (NEL = 1.65 Mcal/kg DM). Dry matter intake (23.2 kg/d), milk composition, energy-corrected milk production (34.5 kg/d), total VFA, and blood metabolites were not affected by treatment. However, cows fed CM diets produced an average 2.9 kg/d more milk than control cows (CM-0). Apparent N efficiency was greatest in cows fed CM-50. Compared with the control, crude protein digestibility and ruminal ammonia concentration were greater and lower for cows fed CM-50 or CM-100, respectively. CM can be a potential substitute for SBM in dairy cow diets as its partial or complete substitution of SMB improved the production performance and nitrogen-use efficiency.

Keywords: canola meal, dairy cow performance, early lactation, soybean meal
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Introduction

Previous research suggests that the efficiency of dietary crude protein (CP) in dairy cows is higher than in any other ruminants (Savari *et al*., 2018). It has been also demonstrated that canola meal is used more efficiently than soybean meal by lactating dairy cows (Paula *et al*., 2020). In general, finding the most efficient way of converting plant protein into milk production is the key to improve farm profitability and decrease the environmental emissions of dairy farms. Soybean meal (SBM) is the most commonly-used protein supplement for dairy and beef cattle. However, the increased demand for SBM and its concomitant elevation in price in recent years have motivated animal nutritionists to find potential alternatives for SBM with minimum adverse effect on the

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production performance of dairy cows. Canola meal (CM) is one of the promising alternatives in this area (Mulrooney *et al*., 2009; Maxin *et al*., 2013; Toti *et al*., 2018). Currently, CM is widely used in North America as a protein supplement for lactating dairy cows (Paula *et al*., 2018). Three comprehensive reviews (Hill 1991; Huhtanen *et al*. 2011; Martineau *et al*., 2013) concluded that feeding CM might be as effective as feeding SBM to lactating dairy cows. Inclusion of CM in dairy rations has been reported to increase dry matter intake (DMI), milk yield, and milk protein when compared with not only SBM (Huhtanen *et al*., 2011), but also other protein sources (Martineau *et al*., 2013). The positive effects of CM on milk production have been attributed to the increased supply of His (Shingfield *et al*., 2003) and, more recently, to increased absorption of essential amino acids, especially Met and Lys (Martineau *et al*., 2014). Research suggests that lactating cows would be less responsive to rumen-protected Met when fed CM than SBM (Broderick *et al*., 2015). Furthermore, recent research has indicated that dietary CP content can be lowered substantially without an adverse effect on milk yields in lactating cows (Kalscheur *et al*., 2006). Mulrooney *et al*. (2009) reported that CM as the main protein source, or in combination with dried distillers grains with solubles, was successfully used in the diets of lactating dairy cows. The positive responses in milk and milk protein yields to CM feeding have been attributed to the amino acid profile in the bypass fraction of CM (Brito *et al*., 2007). Although rather poor in Lys content, CM is rich in essential amino acids (especially His and Met; NRC 2001), whereas Met is the first-limiting amino acid in SBM (Illg *et al*., 1987; Toti *et al*., 2018). CM contains more Met and Cys but low amounts of Lys; using a blend of protein supplements (CM and SBM) has therefore been claimed to improve both microbial protein synthesis and amino acid profile (Broderick *et al*., 2015).

The present study was aimed at verifying the hypothesis that a combination of CM and SBM can improve production performance, ruminal parameters, blood metabolites, and nutrient digestibility in dairy cows. Thus, the objective of this study was to evaluate the partial or complete replacement of SBM with CM in diets of lactation dairy cows on performance, ruminal parameters, blood metabolites, and nutrient digestibility.

Materials and Methods

The study was conducted at the facilities of a dairy farm (FKA, Animal Husbandry and Agriculture Co., Isfahan, Iran) in compliance with the regulations and guidelines recommended by the Animal Care and Use Committee of the Iranian Council of Animal Care (1995).

Twelve lactating Holstein cows (8 multiparous and 4 primiparous, 38 ± 6 DIM) were used in a trial to evaluate the effects of different proportions of CM and SBM used as protein supplements. Cows were randomly assigned to one of three diets in a 3 × 3 Latin square design with three treatments and four replicates (cows), where 0%, 50% and 100% of the dietary SBM was replaced with CM, resulting in diets with 0%, 8.2% and 16.4% CM (DM basis), respectively (Table 2). The diets were formulated based on NRC (2001) in a manner to be isonitrogenous and isoenergetic. The duration of each experimental period was 21 d, with 15 d devoted to dietary adaptation and 6 d to data collection. Cows were held in free stalls throughout the experiment, had free access to water, and were weighed at the beginning and at the end of each period. All the cows were in good health and allowed 2 h of outdoor exercise every morning over the entire experimental period with free access to feed. Cows were fed twice daily (08:00 and 16:00) in amounts that permitted about 10% refusal daily.

Samples of individual feeds and orts (~0.5 kg) were taken on a daily basis and stored at −20 °C. Weekly composited samples from feeds and orts were dried at 60 °C for 48 h to be used for adjusting the as-fed composition of the diets. Cows were milked three times daily (06:00, 14:00, and 22:00) and milk weights were recorded at each milking. Milk samples were collected on days 16 to 21 of each period and preserved with potassium dichromate for future analysis. On day 21 of each period, 3 h after the morning feeding, samples of the rumen fluid (about 3 mL) were collected from the ventral sac via rumenocentesis (Nordlund & Garrett, 1994). The ruminal pH was immediately determined using a portable digital pH meter (Schott Titrator Titroline pH meter) and the samples were immediately frozen at −18 °C. Blood samples were also collected on day 21 of each period (~3 h after the morning feeding) from the coccygeal vessels using an evacuated tube containing an anticoagulant (EDTA). The samples were then centrifuged at 3,000 × *g* for 15 min. Plasma samples were separated, stored in plastic tubes, and frozen at –20 °C until analysis. Faecal grab samples were collected directly from the rectum of each cow (three times a day; in 8-h intervals) on days 18 to 21 of each period for the determination of the apparent digestibility of nutrients. The faecal samples were stored at −20 °C awaiting analysis. Spot urine was also collected (100 mL per sampling) during the last 4 d of each period at 06:00 and 18:00. The aliquots were acidified with

sulphuric acid (0.072 N) and kept at −20 °C awaiting analysis (Lee *et al*., 2012). The urine and faecal samples were pooled for each collection period.

For chemical composition analysis, the weekly feed composites were ground through a 1-mm screen using a Wiley mill. The standard methods of the Association of Official Analytical Chemists (AOAC, 2002) were used for determination of DM (65 °C), ash (550 °C), crude protein (CP), and ether extract (EE). The concentration of rumen undegradable protein (RDP) was determined using the Cornell Net Carbohydrate and Protein System method (Licitra *et al*., 1996). Neutral detergent fibre (NDF; with inclusion of α-amylase and sodium sulphite) and acid detergent fibre (ADFom) contents were measured according to the procedure of Van Soest *et al*. (1991), using an Ankom2000 Fibre Analyzer (Ankom Technology Corporation, Macedon, NY, USA). Both NDF and ADF were ash-corrected. Apparent digestibility of nutrients was determined as the ratio of acid-insoluble ash method (Van Keulen & Young, 1977). Volatile fatty acids (VFA) in the rumen fluid were quantified by using a gas chromatograph (Chrompack, model CP-9002, Chrompack International BV, Middelburg, The Netherlands) using a 50-m (0.32 mm i.d.) fused-silica column (CP-Wax Chrompack Capillary Column; Varian Inc., Palo Alto, CA) and crotonic acid as the internal standard. Nitrogen was used as the carrier gas and oven initial and final temperatures were set at 55 °C and 195 °C, respectively. Detector and injector temperatures were set at 250 °C. Ammonia-nitrogen concentration in the rumen was determined using the colorimetric method (Broderick & Kang, 1980). Plasma levels of glucose, triglyceride, non-esterified fatty acids, beta-hydroxyl butyrate, total protein, albumin, globulin, and urea nitrogen were quantified using the commercial kits supplied by Pars Azmoon Company (Tehran, Iran). Milk samples were analysed for fat, true protein, lactose, solid non-fat, and total solids using Milkoscan (Foss Electric, Denmark). Milk urea-N concentration (MUN) was determined according to the Berthelot reaction (AOAC, 2002; ChemSpec 150 Analyzer, Bentley Instruments). Allantoin content in urine samples was determined according to the method of Young & Conway (1942). The concentration of creatinine in urine samples was quantified using a colorimetric method (Oser, 1965).

Data were analysed using PROC Mixed in SAS (SAS Institute 1999) for a replicated 3 × 3 Latin square design. The following model was used:

$$Y_{ijkl} = \mu + S_i + P_j(i)\ T_k + Cl(i) + (P \times T)_{jk} + e_{ijkl}, \quad (1)$$

where, Y_{ijkl} is the dependent variable, μ is the overall mean, S_i = fixed effect of square i, $P_j(i)$ is the effect of period j, T_k is the fixed effect of treatment k, Cl is the random effect of cow k within square i, $(P \times T)_{jk}$ is the interaction between period i and treatment j, and e_{ijkl} is the residual effect. Significance was declared at $P \leq 0.05$ and trends at $0.05 < P \leq 0.10$.

Results and Discussion

The chemical composition of CM and SBM is presented in Table 1.

Table 1 Mean values of the chemical composition of canola meal and soybean meal

Item	DM	CP	RDP[1]	RUP[1]	NDF	ADF	Fat	Ash	NFC
Soybean meal	93.00	46.10	63.81	36.80	19.10	9.30	2.90	6.20	25.00
Canola meal	92.50	38.40	69.40	31.50	32.50	18.70	3.10	7.80	17.60

Values are based on % of DM

DM = dry matter; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; NFC = non-fibrous carbohydrates calculated as 100 – (NDF + CP + ether extract + ash)

[1]RDP = Rumen degradable protein; RUP = rumen undegradable protein. RDP and RUP were measured using the Cornell Net Carbohydrate and Protein System method (Licitra *et al*., 1996; Sniffen *et al*., 1992). Values of RDP and RUP are based on % of CP.

As expected, NDF and ADF contents of CM were greater than those of SBM, indicating that CM serves as a source of both CP and fibre; thus, the diets and fibre were balanced by increasing CM and decreasing barley grain and NFC, while crude protein was kept the same for all the treatments (equal to 16.8%; Table 2).

DMI tended to be greater (P = 0.10) in cows fed SMB diet than those fed CM (Table 3). The literature is inconsistent with regards to the substitution of SMB by CM; Maxin *et al*. (2013) studied the effect of substitution of SBM by CM in dairy rations and found no difference in DMI among treatments. However, Broderick *et al*. (2015) observed a positive effect in DMI only when CM was fed alone, but their combination had no effect on DMI, compared to SBM or CM diets. For unknown reasons, although we found about +1 kg difference in SBM diets compared to CM, BCS did not differ among treatments, which indicates that the cows fed CM diets produced more milk without using body deposits. Contrary to this observation, Robinson & Swanepoel (2018) found that BCS decreased linearly as the level of CM in the diet increased. The authors suggested that the maximum BCS gain occurred at a CM level of ~80 g/kg DM in the diet. Contrary to the present study, Broderick *et al*. (2015) reported that feeding canola meal instead of soybean meal increased feed intake in lactating dairy cows.

Table 2 Ingredients and chemical composition of experimental diets

Items	Experimental diets[1]		
	CM-0	CM-50	CM-100
Ingredients (% of DM)			
Alfalfa hay	12.79	12.74	12.76
Corn silage	22.21	22.15	22.18
Beet pulp, dried	6.05	6.03	6.04
Barley grain	15.82	13.84	12.21
Corn grain	15.82	15.77	15.79
Soybean meal	13.01	6.85	0.00
Extruded soybean	1.28	1.27	1.27
Cottonseed, whole	3.93	3.92	3.92
Linseed meal	1.60	1.59	1.59
Fish meal	2.15	2.14	2.14
Canola meal, solvent-extracted	0.00	8.17	16.37
Fat powder	1.77	1.96	2.16
Dicalcium-phosphate	0.19	0.19	0.19
Potassium carbonate	0.24	0.23	0.24
Sodium bicarbonate	1.22	1.21	1.21
Mineral–vitamin premix[2]	0.63	0.63	0.63
Salt	0.32	0.32	0.32
Calcium carbonate	0.75	0.75	0.75
Magnesium oxide	0.24	0.23	0.24
Chemical composition (% of DM unless otherwise stated)			
Crude protein	16.8	16.7	16.7
Ether extract	6.3	6.1	5.9
NDF[3]	28.9	30.0	31.1
ADF[3]	20.8	21.6	22.5
NFC[3]	42.6	41.2	39.7
Rumen degradable protein[4]	10.8	11.0	11.2
Rumen undegradable protein[4]	6.0	5.8	5.5
RUP digestibility, %[4]	84.6	81.6	77.9
Metabolizable protein, g/day[4]	2186	2188	2180
Caacium[4]	0.81	0.81	0.90
Phosphorus[4]	0.49	0.51	0.48
NE_L[4], Mcal/kg of DM	1.66	1.65	1.65

[1] CM-0 = control diet without canola meal (CM); CM-50 = diet with 50% soybean meal (SBM) replaced by CM; CM-100 = diet with 100% SBM replaced by CM

[2] The premix contained 195 g/kg of Ca, 21 g/kg of Mg, 2.2 g/kg of Mn, 0.3 g/kg of Zn, 0.3 g/kg of Cu, 0.12 g/kg of I,0.1 g/kg of Co, 600,000 IU/kg of vitamin A, 200,000 IU/kg of vitamin D, and 0.2 g/kg of vitamin E, 2.5 g/kg of antioxidant

[3]NDF = acid detergent fibre; ADF = acid detergent fibre; non-fibrous carbohydrates (NFC) calculated as 100 – (NDF + CP + ether extract + ash)

[4] Estimated using NRC (2001) model

Table 3 Lactation performance and total tract apparent nutrient digestibility of lactating dairy cows fed different inclusion levels of canola meal (CM)

Items	Experimental diets[1]			SEM	*P* value
	CM-0	CM-50	CM-100		
DMI, kg/day	23.8	22.6	23.1	0.50	0.10
BCS	2.68	2.62	2.75	0.13	0.82
Crude protein intake, kg/d	4.00	3.77	3.85	0.03	0.10
N intake, g/day	636[a]	604[b]	617[ab]	12.1	0.05
Milk N, g/day	193	205	202	8.55	0.35
Predict urine N, g/day[2]	309	292	303	17.6	0.44
Faecal N excretion, g/day	148	127	133	29.6	0.13
Apparent N efficiency[4], %	30.6[b]	34.1[a]	33.0[ab]	1.36	0.05
Milk production, kg/day	44.7[b]	46.7[a]	46.8[a]	1.19	0.05
FCM[3]	34.8	36.4	35.2	8.52	0.11
ECM[4]	33.7	35.5	34.2	1.34	0.36
Feed conversion[5]	1.89[b]	2.0[a]	2.03[a]	0.08	0.02
Milk component yield, kg/day					
Fat	1.13	1.18	1.10	0.06	0.66
Protein	1.20	1.28	1.26	0.04	0.67
Lactose	2.01	2.07	2.08	0.05	0.27
Milk composition %					
Fat	2.53	2.56	2.36	0.11	0.47
Protein	2.69	2.73	2.70	0.07	0.92
Lactose	4.53	4.49	4.45	0.04	0.54
Solid not fat	4.50	4.47	4.44	0.04	0.54
MUN,[6] mg/dL	13.2[a]	12.0[b]	12.0[b]	0.03	0.01
Total tract apparent nutrient digestibility, %					
Dry matter	73.3[b]	74.5[a]	74.3[b]	0.31	0.02
Organic matter	76.4	76.0	74.4	0.62	0.07
Crude protein	76.7[b]	79.2[a]	78.4[a]	0.61	0.03
Neutral detergent fibre	56.5	58.8	57.2	0.97	0.17
Acid detergent fibre	46.6	47.1	44.4	0.82	0.12

[1]CM-0 = control diet without CM; CM-50 = diet with 50% soybean meal (SBM) replaced by CM; CM-100 = diet with 100% SBM replaced by CM
[2]Predicted urine N output = 0.0283 × MUN (mg/dL) × body weight (kg) (Kohn *et al*., 2002)
[3] Apparent N efficiency= milk N/N intake
[4] Fat-corrected milk (FCM) = 0.399 × [milk yield (kg/d)] + 15.02 × [fat yield (kg/d)] (Sadri *et al*., 2009). Energy-corrected milk (ECM) = milk (kg/d) × [38.3 × fat (g/kg) + 24.2 × protein (g/kg) + 16.54 × lactose (g/kg) + 20.7]/3,140 (Sjaunja *et al*., 1990)
[5]Calculated as milk yield/DMI
[6] MUN = milk urea-N

Our findings are consistent with earlier observations (Martineau *et al*., 2013; Broderick *et al*., 2015) that reported greater milk yield when SBM and CM were compared for feeding lactating dairy cows. Huhtanen *et al*. (2011) suggested that greater milk production responses with CM inclusion could be due to the increased or more balanced amino acid supply, or both. Faverdin *et al*. (2003) suggested that the combination of SBM and CM provided a more palatable concentrate mixture than either SBM or CM alone. Martineau *et al*. (2014) reported that the positive effects of CM on milk production are attributed to increased His supply and, more recently, to increased absorption of essential amino acids (Shingfield *et al*., 2003). Contrary to the present study, Paula *et al*. (2018) reported that replacing SBM with CM did not affect milk yield in lactating dairy cows.

The greater N utilization in CM-50 might be related to the more efficient N metabolism with improved microbial protein synthesis or the greater supply of metabolizable protein (MP) from the rumen undegradable protein (RUP) fraction. Owing to the high degradability of CP and excellent amino acid profile of CM, Piepenbrink and Schingoethe (1998) suggested that RDP from CM favours microbial protein synthesis in the rumen.

The effects of treatment on MUN content are reported in Table 3. The MUN values decreased with CM usage in the ration (P <0.05). The lowest values assigned to the cows were fed CM-100,

followed by those on CM-50; the highest was in cows fed CM-0. In agreement with this observation, Shingfield *et al*. (2003) found the lower urea-N concentrations in milk of cows fed a CM diet compared with those fed an SBM diet. In accordance with the results of the present study, Paula *et al*. (2020) reported that MUN concentration decreased when CM replaced SBM. Nousiainen *et al*. (2004) stated that dietary CP concentration was the most important nutritional factor influencing MUN. It seems that CM yields a better profile of amino acids than does SBM. Schwab *et al*. (2007) reported that Met and Lys are most often the first and second limiting amino acids for milk protein production, respectively. MP efficiency was observed to improve when Lys, Met, and other essential amino acids were supplied. Improved MP efficiency in the body reportedly led to reduced BUN and MUN levels in CM compared to the SBM diet (Wattiaux & Karg, 2004; Schwab *et al*., 2007; Toti *et al*., 2018).
The NRC (2001) model predicted an NEL-limited milk yield of 46.1 kg/d for all three experimental diets; the MP-limited milk yields of 38.4, 40.9, and 42.9 kg/d were also predicted by the same model for the diets containing 16.8% CP based on SBM and CM. Responses in milk yield indicated that NEL, MP, and amino acid supplies were greater than those predicted by NRC (2001) for all diets. Assuming that essential amino acids, such as Met and Lys, limited production, the predicted supply of digestible MP-RUP was lower than adequate for CM-0 and, due to the added CM, increased MP-RUP for the two lower diets (Table 2). In the present experiment, it appears that the diets containing CM provided the most favourable and optimal amino acid profiles in MP, which possibly improved the protein utilization efficiency (Schwab *et al*., 2003; Broderick *et al*., 2008).

Although the CP content of diets was equal in all of the treatments, the daily N intake varied and tended to decrease with decreasing DMI, whereas faecal N excretion did not change (Table 3). Faecal N primarily consists of indigestible microbial protein produced in the rumen, undigested feed proteins, endogenous proteins, sloughed cells from the gastrointestinal tract, as well as the microbial protein from hind gut fermentation (Davidson *et al*., 2003). In the current experiment, CP concentrations were found to be the same among the treatments. Since indigestible feed protein is a minor component of the total faecal N, differences among the treatments were not expected in light of the values of faecal N (Davidson *et al*., 2003). Predicted urinary N excretion did not differ among the groups. The decreased N efficiency with increasing CP degradability was expected. Broderick *et al*. (2015) reported that blending equal amounts of CP from both SBM and CM, when compared with that from SBM alone, decreased MUN and urinary N excretion at low CP concentrations. In support, Broderick *et al*. (2015) and Huhtanen *et al*. (2011) also suggested that that CP concentration and AA profile were the most important nutritional factors influencing MUN. The authors suggested that the improved quality of supplemental proteins was associated with the decreased MUN concentration.

Unlike N intake, milk N was not different among the treatments so that N utilization efficiency was higher in CM-50 than in CM-0. This may be attributed to the improved amino acid balance, especially Lys and Met and other essential amino acids in MP, which enhanced not only protein utilization, but also its apparent digestibility (Table 4) in the total tract (Schwab *et al*., 2007). Brito & Broderick (2007) did not find differences in N utilization efficiency between CM and SBM diets containing 16.6% CP.

Substitution of SBM by CM was observed to increase the apparent total tract digestibility of DM, CP, and OM. More recently, Robinson & Swanepoel (2018) found that apparent total tract digestibility of OM tended to increase linearly as the level of CM in the diet increased, whereas the CP digestibility remained unaffected. The increase in CP digestibility in the CM diet in the current study concurs with the findings of Paula *et al*. (2018), who reported greater mean apparent total-tract digestibility of DM, OM, and CP for the CM diet compared to the SMB diet. They found the increase in the amount of N truly digested in the rumen and an increase, therefore, in the RDP supply at the omasal canal in the CM diet compared to the SBM diet.

Table 4 Blood metabolites in lactating dairy cows fed different inclusions of canola meal (CM)

Items	Experimental diets[1]			SEM	*P* value
	CM-0	CM-50	CM-100		
Glucose, mg/dL	48.2	51.9	50.1	1.75	0.35
Cholesterol, mg/dL	206	213	204	13.6	0.45
Triglycerides, mg/dL	50.4	49.5	49.9	1.14	0.77
BHBA, mEq/L	0.49	0.50	0.61	0.06	0.41
NEFA, mEq/L	0.21	0.21	0.19	0.02	0.92
Albumin, g/dL	3.10[b]	3.09[b]	3.25[a]	0.05	0.05
Globulin, g/dL	4.86	4.85	4.58	0.11	0.14
Albumin: globulin	0.64[b]	0.63[b]	0.71[a]	0.01	0.02
Total protein, g/dL	7.97	7.95	7.84	0.13	0.65
Blood urea N, mg/dL	15.5	13.6	13.8	0.72	0.14
Urine metabolites, mg/mL					
Allantoin	2.72	2.22	2.55	0.18	0.22
Creatinine	0.64[a]	0.54[b]	0.55[b]	0.01	0.01
Total tract apparent digestibility, %					
Dry matter	73.3[b]	74.5[a]	74.3[b]	0.31	0.02
Organic matter	76.4	76.0	74.4	0.62	0.07
Crude protein	76.7[b]	79.2[a]	78.4[a]	0.61	0.03
Neutral detergent fibre	56.5	58.8	57.2	0.97	0.17
Acid detergent fibre	46.6	47.1	44.4	0.82	0.12

[1] CM-0 = control diet without CM; CM-50 = diet with 50% soybean meal replaced by CM; CM-100 = diet with 100% soybean meal replaced by CM

Ruminal fermentation patterns of dairy cows fed the different inclusions of CM are reported in Table 5. No difference was seen in ruminal pH, total VFA, propionate, butyrate, and acetate:propionate. However, cows fed CM-50 and CM-100 tended to have higher (*P* = 0.06) acetate concentrations than did cows fed CM-0. The replacement of CM for SBM led to a lower ammonia concentration in the rumen fluid, which is indicative of less ruminal degradation of CM protein.

Table 5 Ruminal metabolism of lactating dairy cows fed different inclusions of canola meal (CM)

Items	Experimental diets[1]			SEM	*P* value
	CM-0	CM-50	CM-100		
Total VFA, mM	93.5	96.4	94.5	1.05	0.11
Acetate, % of total VFA	59.1	59.5	59.5	0.45	0.06
Propionate, % of total VFA	27.7	27.6	26.5	0.54	0.22
Butyrate, % of total VFA	10.1	10.4	11.4	0.83	0.50
Isovalerate, % of total VFA	2.30	1.81	1.88	0.14	0.11
Valerate, % of total VFA	0.77	0.67	0.63	0.09	0.63
Acetate: propionate	2.13	2.17	2.25	0.05	0.29
Ruminal pH	5.92	6.06	5.91	0.11	0.51
Urine pH	8.43	8.35	8.39	0.03	0.26
Ammonia-N, mg/dL	8.42[a]	7.58[b]	7.83[b]	0.19	0.03

[1]CM-0 = control diet without CM; CM-50 = diet with 50% soybean meal replaced by CM; CM-100 = diet with 100% soybean meal replaced by CM

Blood concentrations of glucose, triglyceride, β-hydroxybutyric acid, NEFA, BUN, total protein, and globulin remained largely unaffected by dietary treatment (Table 4). However, blood albumin and albumin: globulin were found to be greatest on the CM-100 diet. The higher plasma concentration of albumin in cows fed CM indicates that CM supplied more N to protein metabolism of lactating cows (Sánchez & Claypool, 1983).

Conclusion

The findings of the present study support the hypothesis that substituting SBM with CM in the diet had positive effects on milk production, nitrogen-use efficiency, and increased total tract digestibility of DM and CP in dairy cows. Canola meal as a total replacement for SBM or in combination with SBM, can be successfully used in dairy cow diets and improves the production performance and nitrogen-use efficiency of high-producing dairy cows.

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Authors' Contributions

F.A and M.S (ORCID 0000-0002-1773-5287) participated in designing the study, laboratory analysis, and manuscript writing. MSSF was involved in drafting and revising the manuscript for intellectual content. All authors review and approved the manuscript before submitted for publication.

Conflicts of interest

The authors declare no conflicts of interest.

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