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Production effects of extruded soybean meal replacing canola meal in the diet of lactating dairy cows

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اثرات تولیدی کنجاله سویا اکسترود جایگزین کنجاله کلزا در جیره گاوهای شیرده

این مطالعه اثرات کنجاله سویای اکسترود (ESBM) را در مقایسه با کنجاله کانولا (CM) تغذیه شده بر اساس پروتئین خام معادل (CP) بر عملکرد شیردهی و تخمیر شکمبه ای گاوهای شیری بررسی کرد. پس از یک دوره متغیر ۲ هفته ای، ۴۸ گاو هلشتاین به طور میانگین: ۱۴۶ روز شیردهی (DIM) و ۴۳ کیلوگرم در روز تولید شیر (MY) در یک آزمایش طرح بلوک های کامل تصادفی، که شامل یک دوره ۲ هفته ای برای سازگاری با جیره قبل از جمع آوری داده های تجربی بود، به ۱ جیره از ۲ تیمار اختصاص داده شدند.. پس از دوره سازگاری، نمونه‌ها و داده‌های تجربی در مجموع ۷ هفته جمع‌آوری شد. گاوها بر اساس شکم زایش، روزهای شیردهی و تولید شیر گروه بندی شدند. جیره های تیمار حاوی ٪۱۵.۸ کنجاله کانولا (حاوی ٪۴۱.۲ CP) یا ٪۱۳.۲ ESBM (با ٪۴۸.۷ CP) از کل ماده خشک جیره (DM)، با گنجاندن مشابه سایر مواد خوراکی بود. جیره CM با روغن کانولا تکمیل شد، در حالی که جیره ESBM با پوسته سویا تکمیل شد تا میزان عصاره اتری و فیبر شوینده خنثی مشابه بین جیره‌ها به دست آید. اوره و Met و Lys محافظت شده از شکمبه به هر دو جیره اضافه شد تا نیازهای گاو را برآورده کند یا از آن فراتر رود. نمونه های هضم کامل شکمبه ای از ۱۰ گاو کانوله در شکمبه (۵ در هر تیمار) جمع آوری شد. هشت گاو کانولا شده در هفته آخر آزمایش برای شرکت در مطالعه دیگری خارج شدند. تیمار بر مصرف خوراک و تولید شیر خام یا تصحیح انرژی در گاوها تأثیری نداشت. تولید شیر تصحیح شده با انرژی، جدا از هفته ۵ آزمایش، بین تیمارها مشابه بود. به غیر از هفته ۳ و ۷ آزمایش، غلظت و تولید چربی شیر برای گاوهایی که با ESBM تغذیه شده بودند در مقایسه با کنجاله کانولا بیشتر بود. تنها در گاوهای چند شکم، تولید پروتئین واقعی شیر برای گاوهایی که با کنجاله کانولا تغذیه شده بودند در مقایسه با ESBM بیشتر بود. غلظت شکمبه ای کل اسیدهای چرب فرار و نسبت مولی استات برای ESBM بیشتر بود و پروپیونات و والرات در گاوهای تغذیه

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شده با کنجاله کانولا بیشتر بود. نسبت استات به پروپیونات برای گاوهای تغذیه شده با ESBM در مقابل جیره کنجاله کانولا بیشتر بود. در مقایسه با جیره کنجاله کانولا، جیره ESBM غلظت پلاسمایی Ile، Leu و Phe را افزایش داد اما مجموع اسیدهای امینه ضروری را افزایش نداد. قابلیت هضم ظاهری فیبر شوینده اسیدی در گاوهای تغذیه شده با ESBM نسبت به CM بیشتر بود. در این آزمایش، CM و ESBM بر اساس CP برابر در جیره گاوهای شیری گنجانده شد، که منجر به ماده خشک مصرفی، تولید شیر و کارایی خوراک مشابه شد.

در شرایط آزمایش فعلی، میزان RUP کنجاله کانولا بیشتر از NRC، ۲۰۰۱ یا NASEM ۲۰۲۱ بود و نزدیکتر به مقادیر RUP برای ESBM اکسترود شده در ۱۶۳ درجه سانتیگراد بود. جایگزینی کنجاله کانولا با ESBM در جیره گاوهای شیرده تاثیری بر افزایش ماده خشک مصرفی، تولید شیر خام و تصحیح شده، وزن بدن و افزایش وزن بدن نداشت. به غیر از هفته ۵ آزمایش، راندمان خوراک بین گاوهای تغذیه شده با جیره کنجاله کانولا و ESBM مشابه بود. گاوهای تغذیه شده با ESBM غلظت و تولید چربی شیر بیشتری (به ترتیب ۱۳ و ۱۱ درصد) نسبت به گاوهایی که با جیره کنجاله کانولا تغذیه شده بودند، داشتند. تنها در گاوهای چند شکم، تولید پروتئین شیر برای ESBM نسبت به کنجاله کانولا کاهش یافت. در مقایسه با کنجاله کانولا، غلظت کل VFA در شکمبه و نسبت مولی استات افزایش یافت اما پروپیونات و والرات توسط ESBM کاهش یافت. به طور کلی، این آزمایش نشان داد که جایگزینی کنجاله کانولا با ESBM، بر اساس CP برابر، در جیره‌های حاوی متیونین و لایزین کافی و با میزان چربی و NDF مشابه، منجر به عملکرد شیردهی مشابه در گاوهای شیری می‌شود.

Table 1. Ingredient and nutrient composition of the diets used in the experiment

Item	Diet[1]	
	CM	ESBM
Ingredient, % of DM or as indicated		
Corn silage[2]	36.25	36.25
Alfalfa haylage[3]	14.00	14.00
Straw-hay mixture[4]	4.00	4.00
Cottonseed, whole	6.00	6.00
Corn grain, ground	16.09	16.09
CM	15.80	—
ESBM	—	13.20
Soybean hulls[5]	—	3.40
Molasses[6]	5.00	5.00
Canola oil	0.50	—
Urea	0.48	0.30
Ajipro-L	0.26	0.22
Mepron	0.08	0.13
Mineral mix[7]	1.48	1.48
CP supply from protein meals, g/kg of DMI	65.5	64.5
Nutrient composition, % of DM (or as indicated)		
CP[8]	16.5	16.3
RDP[9]	10.5	9.9
RUP[9]	6.1	6.4
aNDF[8]	29.2	27.9
ADF[8]	19.5	18.4
Ether extract[8]	4.9	4.9
NE_L,[9] Mcal/kg of DM	1.55	1.58
NE_L balance,[9] Mcal/d	3.2	2.0
MP supply,[9] g/d	2,764	3,006
MP balance,[9] g/d	−10	271
Digestible Met,[9] g/d	64	72
Digestible Lys,[9] g/d	189	211
NFC[8]	45.9	46.8
Starch[8]	25.5	26.2
Ca[8]	0.70	0.63
P[8]	0.42	0.32

[1]Average diet composition for adaptation and experimental periods (i.e., experiment wk 1–7). CM = canola meal; ESBM = extruded soybean meal.

[2]Corn silage was 39.9% DM and contained (DM basis) 6.7% CP and 33.5% NDF.

[3]Alfalfa haylage was 32.6% DM and contained (DM basis) 17.5% CP and 42.4% NDF.

[4]Straw-hay mixture was 85.6% DM and contained (DM basis) 10.1% CP and 69.6% NDF.

[5]Soybean hulls were 88.2% DM and contained (DM basis) 12.6% CP and 61.0% NDF.

[6]Liquid molasses from Westway Feed Products (Tomball, TX).

[7]Mineral/vitamin premix (Cargill Animal Nutrition, Cargill Inc., Roaring Spring, PA) contained (%, as-is basis) limestone, 36.75; dry corn distillers grains with solubles, 29.00; NaCl, 24.85; MgO (54% Mg), 4.15; Bio-Phos, 2.45; zinc sulfate, 0.96; mineral oil, 0.5; vitamin E, 0.37; manganese sulfate, 0.37; copper sulfate, 0.26; ferrous sulfate, 0.16; selenite, 0.13; vitamin A, 0.03; vitamin D_3, 0.013; calcium iodate, 0.008; cobalt carbonate, 0.005.

[8]Values calculated using the chemical analysis (Cumberland Valley Analytical Services Inc., Waynesboro, PA) of the feed ingredients and their inclusion in the diets.

[9]Estimated based on NRC (2001) and in situ data from the current experiment for the protein meals using average DMI, milk yield, milk composition, and BW of the cows during the experiment.

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Table 2. Chemical composition and AA concentration (% of DM or as indicated) of canola meal (CM) and extruded soybean meal (ESBM) used in the experiment

	Meal	
Item	CM	ESBM
CP[1]	41.2	48.7
RDP,[2] % of CP	51.3	46.4
RUP,[2] % of CP	48.7	53.6
RUP intestinal digestibility,[3] % of RUP	81.1	99.4
aNDF[1]	29.6	9.90
NDFICP[1,4]	6.30	0.70
ADF[1]	20.4	4.40
ADFICP[1,5]	2.40	0.40
Ash[1]	7.46	7.13
Ca[1]	0.85	0.27
P[1]	1.23	0.68
Ether extract[1]	4.23	8.03
EAA,[6] % CP		
Arg	5.50	6.91
His	2.60	2.53
Ile	4.00	4.56
Leu	6.80	7.48
Lys	5.60	6.02
Met	1.90	1.29
Phe	4.05	5.14
Thr	4.15	3.80
Trp	1.05	1.21
Val	5.02	4.79
Total EAA	40.7	43.7
NEAA,[6] % CP		
Ala	4.22	4.15
Asp	6.55	10.67
Cys	2.47	1.36
Glu	15.92	17.10
Gly	4.87	4.09
Pro	5.72	4.58
Ser	3.37	3.97
Tyr	2.45	3.25
Total NEAA	45.6	49.2
Total EAA and NEAA	86.3	92.9

[1]Analyzed by Cumberland Valley Analytical Services Inc. (Waynesboro, PA) using wet chemistry methods.

[2]Estimated using in situ values and NRC (2001) based on average BW and DMI of cows during the experiment. Passage rates were 7.85 and 7.62%/h for CM and ESBM, respectively.

[3]Analyzed by Rock River Laboratories Inc. (Watertown, WI) using the Calsamiglia and Stern (1995) method.

[4]NDFICP = neutral detergent insoluble crude protein.

[5]ADFICP = acid detergent insoluble crude protein.

[6]Analyzed by University of Missouri-Columbia's Agricultural Experiment Station Chemical Laboratories (Columbia, MO) following the procedures of Deyl et al. (1986) and Fekkes (1996).

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Table 3. Ruminal in situ degradability of CP in canola meal (CM) and extruded soybean meal (ESBM)[1]

	Meal			
Item	CM	ESBM	SEM[2]	*P*-value
Soluble fraction (a), %	29.9	27.2	0.22	0.001
Potentially degradable fraction (b), %	70.1	72.8	0.22	0.001
Rate of degradation of b (c), %/h	3.43	2.73	0.053	0.007
Effective degradability,[3] %	55.4	50.2	0.32	0.003

[1]The fractional rate of ruminal degradation of CP in protein meals was derived by plotting the natural logarithm of the fraction of meals remaining in the bag over time and fitting the data to a linear regression model (SigmaPlot 13.0; Systat Software Inc., San Jose, CA; $R^2 \geq 0.88 \pm 0.12$).

[2]Largest SEM reported in table; n = 6 (n represents the number of observations used in the statistical analysis).

[3]Esimated using the equation of Ørskov and McDonald (1979): effective degradability $= a + b \times [c \div (c + k)]$, where a, b, and c are as specified above, and k is the rate of passage assumed to be 6%/h.

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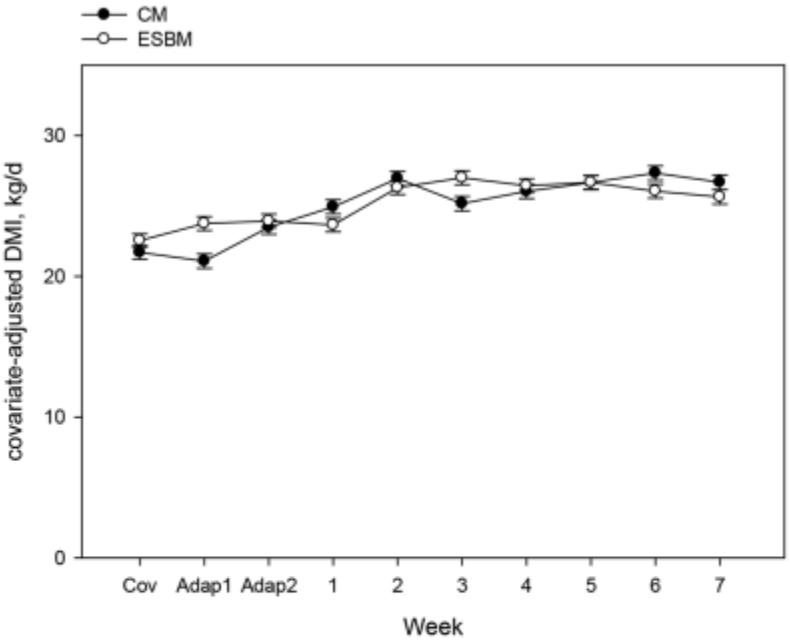

Figure 1. Dry matter intake of dairy cows fed diets with inclusion of canola meal (CM) or extruded soybean meal (ESBM). Data from covariate wk 2, designated as Cov, are LSM, and error bars represent SEM. All other data are covariate-adjusted LSM. Following the covariate measurement period, the first 2 wk of feeding the treatment diets were allowed for adaptation and are designated as Adap1 and Adap2, respectively. Following the adaptation period, data and samples for statistical analysis were collected for a total of 7 experimental weeks. Main effect of treatment: $P = 0.67$. Treatment × week: $P < 0.001$. Eight cows (4 per treatment) were removed to participate in another experiment during experimental wk 7.

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Table 4. Dry matter intake, milk production and composition, BW, and body condition of dairy cows fed diets containing canola meal (CM) and extruded soybean meal (ESBM)[1]

	Treatment[2]			
Item	CM	ESBM	SEM[3]	*P*-value[4]
DMI, kg/d	26.2	25.9	0.46	0.67
Milk yield, kg/d	39.2	38.5	0.59	0.24
Feed efficiency,[5] kg/kg	1.48	1.49	0.023	0.71
Milk fat, %	3.51	3.95	0.094	0.003
Yield, kg/d	1.33	1.47	0.048	0.02
ECM,[6] kg/d	35.8	36.6	0.90	0.31
ECM feed efficiency,[7] kg/kg	1.37	1.40	0.035	0.38
Milk true protein, %	3.18	3.19	0.049	0.93
Yield, kg/d				
Primiparous	1.06	1.12	0.037	0.09
Multiparous	1.27	1.20	0.032	0.05
Milk lactose, %	4.80	4.85	0.020	0.07
Yield, kg/d	1.86	1.83	0.04	0.47
MUN, mg/dL				
Primiparous	11.8	12.0	0.28	0.58
Multiparous	10.6	11.8	0.23	0.001
SCC,[8] $\times 10^3$ cells/mL	100.4	43.8	22.0	0.36
BCS[9]	3.05	3.01	0.07	0.69
BW, kg	636.2	632.3	3.82	0.27
BCS change[10]	0.07	−0.10	0.081	0.11
BW change,[11] g/d	551	713	131.8	0.40

[1]Milk samples for composition analysis were collected from experimental wk 3 to 7. Milk composition data were from 40 cows only during experimental wk 7.

[2]Dietary treatments were CM diet (canola meal included at 15.8% of dietary DM) and ESBM diet (extruded soybean meal included at 13.2% of dietary DM).

[3]Largest SEM reported in table; n = 320 for DMI, milk yield; n = 274 for BW; n = 320 for feed efficiency; n = 225 for milk composition and ECM data; n = 40 for BCS and BW change (n represents the number of observations used in the statistical analysis).

[4]Main effect of treatment. Treatment × week interaction, $P \geq 0.09$, except for DMI ($P < 0.001$), ECM feed efficiency ($P = 0.004$), and milk fat concentration ($P = 0.03$) and yield ($P = 0.02$). Treatment × parity (primi- vs. multiparous) interaction, $P > 0.07$, except for milk true protein yield ($P = 0.01$) and MUN ($P = 0.05$).

[5]Milk yield ÷ DMI.

[6]ECM (kg/d) = kg of milk × [(38.3 × % fat × 10 + 24.2 × % true protein × 10 + 16.54 × % lactose × 10 + 20.7) ÷ 3,140]; Sjaunja et al. (1990).

[7]ECM yield ÷ DMI.

[8]Statistical analysis was performed on log-transformed data.

[9]BCS. Edmonson et al. (1989).

[10]BCS change was: (average BCS during experimental wk 7 − average BCS covariate wk 2).

[11]BW change: (average BW during experimental wk 7 − average BW covariate wk 2) ÷ days on study.

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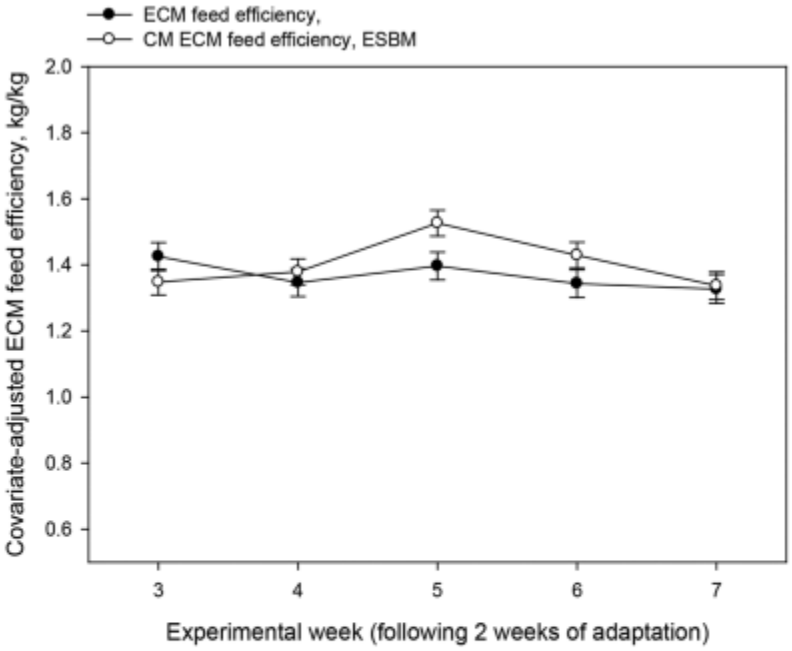

Figure 2. Energy-corrected milk feed efficiency (i.e., kg of ECM/kg of DMI) of dairy cows fed diets with inclusion of canola meal (CM) or extruded soybean meal (ESBM). Data are covariate-adjusted LSM, and error bars represent SEM. Main effect of treatment: $P = 0.38$. Treatment × week: $P = 0.004$. Cows were allowed a 2-wk period for adaptation to dietary treatments before the beginning of a 7-wk period of data and sample collection (i.e., experimental wk 1–7). Eight cows (4 per treatment) were removed to participate in another experiment during experimental wk 7.

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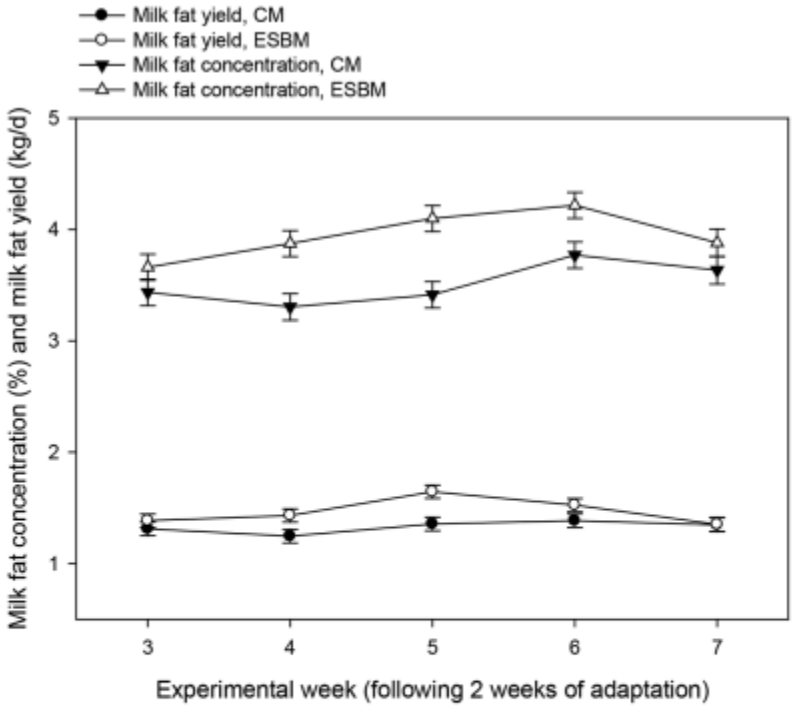

Figure 3. Milk fat concentration and yield of dairy cows fed diets with inclusion of canola meal (CM) or extruded soybean meal (ESBM). Data are covariate-adjusted LSM, and error bars represent SEM. Main effect of treatment: $P \leq 0.02$ for both variables. Treatment × week: $P \leq 0.03$ for both variables. Cows were allowed a 2-wk period for adaptation to dietary treatments before the beginning of a 7-wk period of data and sample collection (i.e., experimental wk 1–7). Eight cows (4 per treatment) were removed to participate in another experiment during experimental wk 7.

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Table 5. Rumen fermentation parameters of dairy cows fed diets containing canola meal (CM) and extruded soybean meal (ESBM)[1]

	Treatment[2]			
Item	CM	ESBM	SEM[3]	*P*-value[4]
pH	6.12	6.10	0.087	0.92
Total VFA, m*M*	111	130	4.2	0.01
VFA (mol %)				
Acetate	56.3	60.3	1.19	0.05
Propionate	26.3	23.2	0.96	0.01
Butyrate	10.9	11.7	0.81	0.52
Isobutyrate	0.87	0.88	0.065	0.84
Valerate	3.70	2.11	0.351	0.03
Isovalerate	1.86	1.84	0.091	0.89
Acetate:propionate	2.18	2.65	0.129	0.006
NH_3, m*M*	7.85	9.68	0.966	0.22
Total protozoa,[5] $\times 10^4$/mL	8.10	10.9	0.35	0.002

[1]Whole ruminal contents were collected during experimental wk 5 for rumen fermentation analyses.

[2]Dietary treatments were CM diet (canola meal included at 15.8% of dietary DM) and ESBM diet (extruded soybean meal included at 13.2% of dietary DM).

[3]Largest SEM reported in table; n = 40 (n represents the number of observations used in the statistical analysis).

[4]Main effect of treatment.

[5]Actual protozoal counts were log-transformed for the statistical analysis.

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Table 6. Blood plasma AA concentrations (μM) in dairy cows fed diets containing canola meal (CM) and extruded soybean meal (ESBM)

	Treatment[1]			
Item	CM	ESBM	SEM[2]	*P*-value[3]
EAA, μM				
Arg	74.1	73.4	2.99	0.87
His	50.6	51.9	1.87	0.61
Ile	133.4	147.0	4.41	0.03
Leu	134.0	152.2	5.32	0.01
Lys	81.1	81.5	3.41	0.92
Met	25.4	24.6	1.12	0.60
Phe	39.8	44.4	1.24	0.01
Thr	95.3	90.8	3.55	0.33
Trp	38.9	37.1	1.24	0.32
Val	268.2	276.7	8.26	0.45
Total EAA	915.6	955.7	26.57	0.29
NEAA, μM				
Ala	284.7	281.6	9.47	0.81
Asn	34.1	38.2	1.49	0.06
Asp	6.50	7.67	0.446	0.05
Cit	74.4	71.5	2.30	0.26
Cys	0.04	0.05	0.026	0.85
Gln	215.3	204.9	6.98	0.25
Glu	72.7	66.1	2.13	<0.001
Gly	308.8	289.9	15.08	0.26
Orn	52.6	49.8	2.27	0.39
Pro	83.0	85.3	3.09	0.54
Ser	83.5	87.1	3.46	0.47
Tau	57.7	52.1	2.79	0.16
Tyr	42.9	47.3	2.03	0.13
Total NEAA	1,317	1,280	38	0.46
Total EAA and NEAA	6,832	6,804	177	0.90
Carnosine	11.0	10.9	0.67	0.88
1-Methyl-L-histidine	14.0	17.3	0.69	<0.001
3-Methyl-L-histidine	4.05	4.00	0.17	0.86

[1]Dietary treatments were CM diet (canola meal included at 15.8% of dietary DM) and ESBM diet (extruded soybean meal included at 13.2% of dietary DM).

[2]Largest SEM reported in table; n = 40 (n represents the number of observations used in the statistical analysis).

[3]Main effect of treatment.

Table 7. Blood metabolites of cows fed diets containing canola meal (CM) and extruded soybean meal (ESBM)

	Treatment[1]			
Item	CM	ESBM	SEM[2]	*P*-value[3]
Glucose, mg/dL	56.1	51.4	1.29	0.001
Urea N, mg/dL	24.3	23.9	0.99	0.70
BHB, μM	681.5	661.3	40.0	0.67
Fatty acids, μM	223.1	208.2	13.0	0.37

[1]Dietary treatments were CM diet (canola meal included at 15.8% of dietary DM) and ESBM diet (extruded soybean meal included at 13.2% of dietary DM).

[2]Largest SEM reported in table; n = 40 (n represents the number of observations used in the statistical analysis).

[3]Main effect of treatment.

Table 8. Nutrient intake and apparent total-tract digestibility in dairy cows fed diets containing canola meal (CM) or extruded soybean meal (ESBM)

	Treatment[1]			
Item	CM	ESBM	SEM[2]	*P*-value[3]
Intake,[4] kg/d				
DM	26.0	25.4	0.60	0.48
OM	24.4	24.0	0.56	0.53
NDF	9.02	8.66	0.210	0.21
ADF	5.06	4.98	0.117	0.59
CP	4.29	4.14	0.098	0.28
Starch	6.81	6.49	0.155	0.13
Apparent total-tract digestibility, %				
DM	69.9	69.6	0.38	0.46
OM	71.2	70.7	0.40	0.37
NDF	49.3	47.7	0.56	0.12
ADF	40.1	42.8	0.72	0.02
CP	73.5	72.3	0.61	0.15
Starch	98.4	98.2	0.15	0.21

[1]Dietary treatments were CM diet (canola meal included at 15.8% of dietary DM) and ESBM diet (extruded soybean meal included at 13.2% of dietary DM).

[2]Largest SEM reported in table; n = 40 (n represents the number of observations used in the statistical analysis).

[3]Main effect of treatment.

[4]DMI reported is during the fecal and urine collection period (experimental wk 7) for the digestibility analysis.

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Table 9. Nitrogen utilization and purine derivative (PD) excretion in dairy cows fed diets containing canola meal (CM) or extruded soybean meal (ESBM)

	Treatment[1]			
Item	CM	ESBM	SEM[2]	*P*-value[3]
N intake, g/d[4]	686.5	663.2	15.74	0.28
N excretion or secretion, g/d				
Urine N	201.2	210.4	11.81	0.59
UUN[5]	111.2	132.9	10.68	0.16
Fecal N	195.9	184.4	6.79	0.22
Total excreta N	398.3	407.5	15.78	0.68
Milk N				
Primiparous	163.2	176.7	11.13	0.32
Multiparous	207.8	175.2	9.49	0.01
As % of N intake				
Urine N	29.7	31.9	1.77	0.39
UUN	16.4	20.1	1.51	0.09
Fecal N	28.6	27.8	0.69	0.45
Total excreta N	58.4	59.7	1.61	0.55
Milk N				
Primiparous	25.6	28.7	1.63	0.17
Multiparous	28.7	25.0	1.39	0.06
Unaccounted N	12.5	14.2	2.27	0.56
Urine output, kg/d	22.0	23.3	1.52	0.54
Urinary PD excretion, mmol/d				
Allantoin	596.5	625.8	38.34	0.58
Uric acid	58.9	66.6	4.60	0.20
Total PD	657.3	730.6	48.46	0.28

[1]Dietary treatments were CM diet (canola meal included at 15.8% of dietary DM) and ESBM diet (extruded soybean meal included at 13.2% of dietary DM).

[2]Largest SEM reported in table; n = 40 (n represents the number of observations used in the statistical analysis).

[3]Main effect of treatment. Treatment × parity interaction ($P \leq 0.03$) for milk N excretion (in g/d and as % of N intake).

[4]N intake reported is during the fecal and urine collection period (experimental wk 7).

[5]UUN = urinary urea nitrogen.