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Effect of diets containing roasted soybean, extruded soybean or their combination on performance and milk fatty acid profile of lactating Holstein cows

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Summary

The aim of this study was to investigate the effect of diets containing roasted soybean (R), extruded soybean (E) or their combination (RE) on dairy cow performance and milk fatty acid (FA) profile. Nine multiparous lactating Holstein cows (680 ± 25 kg BW; 90 ± 10 DIM; means ± SD) were randomly assigned to a triple 3 × 3 Latin square design. Dry matter intake (DMI), apparent nutrient digestibility, milk yield, composition and FA profile and efficiency of nitrogen (N) utilization for milk production were measured. Cows fed R and RE had higher 4% fat corrected milk (FCM) yield and DMI compared to those fed the E ($P<0.05$). The efficiency of 4% FCM production per unit of DMI was not influenced by experimental diets ($P>0.05$). Experimental diets had no effect on milk fat and protein concentrations and nutrient digestibility ($P>0.05$). Milk fat concentrations of vaccenic acid (VA; C18:1 trans-11) and conjugated linoleic acid (CLA; C18:2 cis-9, trans-11) were higher for cows fed with RE compared to other groups ($P<0.05$). We concluded that cows fed with RE had similar milk production and fat content compared to those fed with R and a similar beneficial milk FA profile compared to those fed with E. Thus, feeding a diet with RE improved the quality and quantity of dairy cow milk.

Key words: Animal performance, Extruded soybean, Lactating cow, Milk fatty acid profile, Roasted soybean

Introduction

Saturated fatty acids (SFA) such as myristic (C14:0), palmitic (C16:0) and stearic (C18:0) acids are the main fatty acids (FA) in the milk of cows because of the extensive biohydrogenation (BH) of unsaturated FA (USFA) by ruminal microorganisms (Jenkins *et al.*, 2008). These FAs are believed to increase the risk of cardio-vascular diseases in humans, while certain dietary polyunsaturated FA (PUFA), including omega-3 FA and conjugated linoleic acids (cis-9, trans-11-CLA), have beneficial effects on human health. Vaccenic acid (VA, C18:1 trans-11) is another intermediate of PUFA BH in the rumen that could be converted to CLA endogenously in the mammary glands by the action of the enzyme Δ^9-desaturase (Shingfield *et al.*, 2013). Therefore, changing the FA profile of bovine milk toward a more nutritionally beneficial profile has received increasing attention. Addition of oilseeds or oils rich in C18 USFA increased concentrations of CLA and PUFA in the milk fat of dairy cows (Peterson *et al.*, 2002). Soybean seed is one of the important sources of protein and energy for dairy cows. Thermal processing such as roasting and extruding is among the most prevalent processing techniques applied to the whole soybean seeds. These methods protect the USFA from ruminal BH, making them more available for absorption at the intestinal level (McNiven *et al.*, 2004). Lactating cows fed with extruded soybean (E) had lower concentrations of C18:2 cis-9, 12 and C18:3 cis-9, 12, 15 in milk fat than those fed with roasted soybean (R) (Chouinard *et al.*, 1997). In contrast, *in vitro* and *in situ* studies found that the extrusion of soybean decreased BH of C18:2 cis-9, cis-12 and C18:3 cis-9, cis-12, cis-15 and increased BH intermediates, particularly C18:2 cis-9, trans-11 and C18:1 trans-11 compared to the roasted whole soybean seed (Troegeler-Meynadier *et al.*, 2006, 2014). To the best of our knowledge, the effects of feeding lactating cows with RE on milk production and composition had not been studied previously. We hypothesized that feeding lactating dairy cows with RE not only increased milk production but also improved the FA profile of milk fat. Therefore, the objective of the current study was to determine the effects of supplementing the ration of lactating dairy cows with R, E or a combination of both on dry matter intake (DMI), nutrient digestibility and milk yield, composition and FA profile.

Materials and Methods

Animals and experimental diets

Nine multiparous lactating Holstein cows (680 ± 25 kg BW; 90 ± 10 DIM) were randomly allocated to one of the three experimental diets containing either R, E, or their combination (RE; Table 1). The chemical composition of soybean meal, R and E are presented in Table 2. Animals were housed in individual stalls and the trial was performed in a balanced triplicate 3 × 3 Latin square design. Each experimental period lasted 21 days with 14 days of diet adaptation and 7 days of data collection. All diets were formulated according to the recommendations of NRC (2001). Roasted and extruded soybeans were supplied by Tehran Daneh Co. (Tehran, Iran). The same batch of raw soybean seeds was used for both roasting and extrusion. Extrusion processing of soybean seeds consisted of a 20-min preconditioning at 90°C, followed by extrusion at 145°C for 60 s. Thereafter, extruded material was ground to pass through a 1-mm screen. Roasting of the whole soybean seeds was performed by heating at 140°C for 20 min. Experimental diets were prepared as total mixed rations (TMR), and fed *ad libitum* with a daily refusal target of 10%. All cows were individually fed their respective diets three times daily at 08:30, 16:30 and 00:30 h. The cows had free access to drinking water, and were milked three times daily at 08:00, 16:00 and 24:00 h. The FA profile of experimental diets and R and E are shown in Table 3.

Sample collection, calculations and analysis

Samples of TMR and refusal from individual cows

Table 1: Ingredient and chemical composition of experimental diets

	Experimental diet		
	R	E	RE
Ingredient (g/kg of DM)			
Alfalfa hay	156.00	156.00	156.00
Corn silage	302.00	302.00	302.00
Ground barley	111.00	111.00	111.00
Ground corn	102.00	102.00	102.00
Calcium salts of FA *	13.50	13.50	13.50
Corn gluten meal	50.00	50.00	50.00
Cottonseed meal	35.00	35.00	35.00
Soybean meal	31.00	31.00	31.00
Roasted soybean seed	89.00	-	44.50
Extruded soybean seed	-	89.00	44.50
Fish meal	4.500	4.50	4.50
Wheat bran	58.00	58.00	58.00
Calcium carbonate	11.00	11.00	11.00
Salt	5.00	5.00	5.00
Sodium bicarbonate	10.00	10.00	10.00
Mineral and vitamin premix †	22.00	22.00	22.00
Chemical composition (g/kg of DM, if not otherwise stated)			
CP	173.00	169.50	171.00
RUP	68.95	68.89	68.76
RDP	104.05	100.61	102.24
MP	110.65	109.24	111.37
EE	52.40	50.80	52.70
NDF	303.00	309.00	299.00
NFC	381.80	388.30	384.30
Ash	90.00	85.00	93.00
NE_L (MJ/kg of DM)	6.99	6.91	7.11

E: Diet containing extruded soybean seed, R: Diet containing roasted soybean seeds, RE: Diet containing a blend of roasted and extruded soybean seed, CP: Crude protein, EE: Ether extract, NDF: Neutral detergent fiber, MP: Metabolizable protein, NFC: Non-fiber carbohydrate, calculated by equation: NFC (g/kg of DM) =1000 - (CP + NDF + EE + ash), NE_L: Net energy for lactation, and RDP: Rumen degradable protein, RUP: Rumen undegradable protein. Experimental diets consisted of TMR containing roasted (R), extruded (E) or combination of roasted and extruded soybean (RE). * Nutracor, Wawasan, Malaysia. Each kg contained: 130 g of ash, 30 g of moisture, 90 g of Ca, 850 g of fat (2 g of C12:0, 12 g of C14:0, 470 g of C16:0, 50 g of C18:0, 380 g of C18:1 and 80 g of C18:2. † Each kg (DM basis) of mineral and vitamin premix contained: 180 g of Ca, 70 g of P, 35 g of K, 50 g of Na, 58 g of Cl, 30 g of Mg, 32 g of S, 5 g of Mn, 4 g of Fe, 3 g of Zn, 300 mg of Cu, 100 mg of I, 100 mg of Co, 20 mg of Se, 500 000 IU of vitamin A, 100 000 IU of vitamin D3, 100 IU of vitamin E, and 3 g of antioxidant

Table 2: Chemical composition of soybean meal, roasted soybean and extruded soybean

Chemical composition (g/kg of DM)	Soybean product		
	Soybean meal	Roasted soybean	Extruded soybean
CP	440	358	356
EE	92.40	229	226
NDF	110	188	183
Ash	56.22	58.80	61.50

CP: Crude protein, EE: Ether extract, and NDF: Neutral detergent fiber

Table 3: Fatty acid (FA) composition of the experimental diets, roasted soybean and extruded soybean

FA profile (g/kg of total FA)	Experimental diet			Roasted soybean	Extruded soybean
	R	E	RE		
C14:0	7.30	6.80	6.90	5.70	6.90
C16:0	229.4	231.9	220.1	205.8	217.7
C18:0	30.90	23.50	26.30	20.60	31.50
C18:1 cis-9	187.0	181.9	192.0	211.2	198.0
C18:2 cis-9, 12	516.5	518.7	515.3	521.3	512.1
C18:3 cis-9, 12, 15	15.30	24.70	26.40	6.30	4.50
Others *	13.60	12.50	13.00	29.10	29.30
Saturated †	267.6	262.2	253.3	232.1	256.1
Unsaturated ‡	718.8	725.3	733.7	738.8	714.6

E: Diet containing extruded soybean seed, R: Diet containing roasted soybean seeds, and RE: Diet containing a blend of roasted and extruded soybean seed. * Unidentified peaks, † Sum of C14:0 + C16:0 + C18:0, ‡ Sum of C18:1 cis-9 + C18:2 cis-9, 12 + C18:3 cis-9, 12, 15

were collected daily during the data collection period, dried at 60°C in a forced air oven for 48 h, ground to pass through a 1-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ, USA) and composited per cow for each experimental period. The feeds and refusal samples were analyzed according to AOAC (2007) for DM (method 934.01), ash (method 942.05), crude protein (CP, method 976.05) and ether extract (EE, method 973.18). Organic matter (OM) was calculated from the difference between DM and ash. Neutral detergent fiber (NDF) was determined without α-amylase and sodium sulfite, and expressed exclusive of residual ash (Van Soest *et al*., 1991). Non-fiber carbohydrate (NFC) was calculated according to NRC (2001). Milk yield was recorded daily during the 7-d data collection period. On days 16 and 17 of each experimental period, milk samples were collected from the six consecutive milkings, and pooled within the cow and period to obtain one composite milk sample per cow per period. Milk samples were analyzed for protein, fat and lactose contents using Milk-O-Scan 133B (Foss Eletric, Hillerod, Denmark). Milk N was calculated as milk protein divided by 6.38. Efficiency of utilization of feed N for milk yield was calculated as (milk N (kg/d)/N intake (kg/d)) × 100 (NRC, 2001). Another sub-sample of milk was stored at -20°C without any preservative until analyzed for FA profile. Fatty acid profile of R and E, milk fat, and TMR samples were determined according to Qui *et al*.'s (2004) procedure using a gas chromatograph (GC; model Varian 3400, Walnut Creek, CA, USA) fitted with a flame ionization detector. The GC was equipped with a CP-88 fused silica capillary column (100 m, 0.25 mm i.d., film thickness 0.25 mm). The temperatures of injector and detector ports were set at 280 and 300°C, respectively. Initially, the column temperature was held at 160°C for 5 min and then increased at a rate of 2°C/min to 180°C. The column temperature was held at 180°C for 5 min and then ramped (2°C/min) to 190°C. Erucic acid (C22:1) was used as a qualitative internal standard. Apparent nutrient digestibility was measured during the measurement week in each period using acid-insoluble ash (AIA) as an internal marker (McGeough *et al*., 2010). Faecal samples (approximately 250 g wet weight) were collected from the rectum of each cow twice daily (09:00 and 16:00) for 5 days beginning on day 16. The faecal samples were composited across sampling times per cow in each period, dried at 60°C in a forced air oven for 72 h, ground to pass a 1-mm screen and stored for chemical analyses. Chemical composition of the faecal samples was determined according to the procedures mentioned previously for TMR and refusal samples.

Statistical analysis

Data on DMI, milk yield, milk components, milk FA profile, digestibility and milk production efficiency relative to feed N intake were analyzed by a-3 times replicated 3 × 3 Latin squares design, using the MIXED procedure of SAS 9.2 (SAS Institute Inc., Cary, NC) using the following model:

$$Y_{ijkl} = \mu + S_i + P_{j(i)} + C_{k(i)} + T_l + \varepsilon_{ijkl}$$

where,
Y_{ijkl}: The dependent variable
μ: The overall mean
S_i: The fixed effect of square i
$P_{j(i)}$: The fixed effect of period j (within square i)
$Ck_{(i)}$: The random effect of cow k (within square i)
T_l: The fixed effect of treatment l
ε_{ijkl}: The random residual error

Tukey's test was used to compare multiple-means to find out whether differences among the three dietary treatments were significant (P≤0.05). Significance was considered at P≤0.05 and trends at P≤0.10, unless otherwise stated.

Results

Dry matter intake and digestibility

As shown in Table 4, DMI was greater in cows fed with R and RE than those fed with E (P<0.05). Apparent total tract digestibility of DM, OM, CP, NDF and EE were not affected by experimental diets (P>0.05).

Milk yield and composition and nitrogen utilization efficiency

Milk yield and 4% FCM were higher in cows fed with R and RE than those fed with E (Table 5, P<0.05). Dietary treatments had no effect on milk fat, protein and lactose proportions FCM:DMI (P>0.05), while milk

Table 4: Feed intake and apparent total tract digestibility of nutrients in lactating dairy cows fed with experimental diets

Item	Experimental diet			SEM	P-value
	R	E	RE		
Intake					
Dry matter (kg/d)	20.88[a]	19.50[b]	20.82[a]	0.31	0.04
N (g/d)	578	529	570	18.00	0.26
EE (g/d)	1094	991	1097	28.00	0.12
NE_L (MJ/d)	146	135	148	4.50	0.27
Digestibility (g/kg)					
Dry matter	690	700	720	10	0.14
Organic matter	720	720	720	10	0.45
Crude protein	750	730	730	10	0.45
Neutral detergent fiber	540	540	580	20	0.23
Ether extract	830	830	870	20	0.07

E: Diet containing extruded soybean seed, EE: Ether extract, N: Nitrogen, NE_L: Net energy for lactation, R: Diet containing roasted soybean seeds, and RE: Diet containing a blend of roasted and extruded soybean seed. [a, b] Means within a row with different superscripts differ significantly (P≤0.05)

Table 5: Milk yield and composition and utilization efficiency of nitrogen and net energy for lactation into milk in lactating dairy cows fed with experimental diets

Item	Experimental diet			SEM	P-value
	R	E	RE		
Milk yield (kg/d)	34.31[a]	31.71[c]	32.68[b]	0.25	0.03
4% FCM (kg/d)	30.98[a]	28.26[b]	30.54[a]	0.54	0.04
Milk composition (g/kg)					
Fat	33.50	32.50	34.00	0.60	0.24
Protein	31.10	30.40	31.20	0.70	0.31
Lactose	46.30	45.60	45.70	0.30	0.31
Efficiency					
Milk yield/DMI	1.65[a]	1.63[a]	1.58[b]	0.02	0.04
FCM/DMI	1.48	1.45	1.47	0.03	0.22
Milk N/N intake	22.55[a]	20.37[b]	21.80[ab]	0.32	0.03

DMI: Dry matter intake, E: Diet containing extruded soybean seed, FCM: Fat corrected milk, N: Nitrogen, R: Diet containing roasted soybean seeds, and RE: Diet containing a blend of roasted and extruded soybean seed. [a, b, c] Means within a row with different superscripts differ significantly (P≤0.05)

Table 6: Fatty acid (FA) profile in milk fat from lactating dairy cows fed with experimental diets

FA (g/kg total FA)	Experimental diet			SEM	P-value
	R	E	RE		
C4:0	13.60	17.70	14.40	1.60	0.21
C6:0	12.70	15.50	12.80	1.20	0.19
C8:0	10.50	10.20	9.90	1.00	0.93
C10:0	17.30	18.00	17.20	1.50	0.90
C12:0	27.50	25.80	26.90	1.70	0.73
C14:0	88.70	91.40	87.90	4.10	0.83
C14:1 cis-9	17.00	16.50	19.70	1.60	0.35
C15:0	5.40	7.60	4.10	1.30	0.19
C16:0	300.50[a]	272.30[b]	288.30[ab]	6.80	0.03
C16:1 cis-9	19.00	21.20	18.50	1.60	0.48
C17:0	8.80[a]	6.60[b]	5.80[b]	0.40	0.01
C18:0	142.60	121.50	119.70	7.00	0.07
C18:1 cis-9	204.10[b]	250.20[a]	237.80[a]	7.90	0.03
C18:1 trans-11	34.30[b]	42.10[b]	56.50[a]	3.50	0.02
C18:2 cis-9, 12	19.20[b]	27.70[a]	26.00[a]	0.80	0.01
C18:2 cis-9, trans-11	2.20[b]	5.00[a]	5.20[a]	0.30	0.02
C18:2 trans-10, cis-12	1.50[b]	3.90[a]	3.90[a]	0.40	0.01
C18:3 cis-9, 12, 15	0.50[b]	2.00[a]	2.30[a]	0.20	0.01
SFA	627.60[a]	586.50[b]	587.20[b]	8.90	0.03
USFA	303.10[b]	379.50[a]	377.60[a]	9.00	0.01
SCFA	81.60	87.00	81.30	4.00	0.53
MCFA	444.50	426.40	432.20	10.80	0.50
LCFA	404.50[b]	452.60[a]	451.40[a]	7.90	0.02
MUFA	279.50[b]	340.70[a]	340.40[a]	8.70	0.03
PUFA	23.50[b]	38.70[a]	37.30[a]	1.10	0.01

E: Diet containing extruded soybean seed, LCFA: Long-chain fatty acids (C18:0 to C18:3 cis-9, 12, 15), MCFA: Medium-chain fatty acids (C14:0 to C17:0), MUFA: Monounsaturated fatty acids (C14:1 cis-9 + C16:1 cis-9 + C18:1 trans-11 + C18:1 cis-9), PUFA: Polyunsaturated fatty acids (C18:2 cis-9, 12 + C18:2 cis-9, trans-11 + C18:2 trans-10, cis-12 + C18:3 cis-9, 12, 15), R: Diet containing roasted soybean seeds, RE: Diet containing a combination of roasted and extruded soybean seeds, SCFA: Short-chain fatty acid (C4:0 to C12:0), SFA: Saturated fatty acid, and USFA: Unsaturated fatty acids. [a, b] Means within a row with different superscripts differ significantly (P≤0.05) production:DMI into and milk N:feed N were higher in cows fed with R than cows fed with RE and E, respectively (P<0.05).

Fatty acid profile of milk

According to Table 6, milk fat concentration of C16:0 was lower in cows fed with E compared those fed with RE and R (P<0.05). Higher milk fat C17:0 and lower C18:2 trans-10, cis-12 concentrations were observed in cows fed with R (P<0.05). The milk fat of cows fed with E and RE had higher concentrations of C18:1 cis-9, C18:2 cis-9, cis-12 and C18:3 cis-9, cis-12, cis-15 compared with cows fed with R (P<0.05). Milk fat concentrations of C18:1 trans-11 and C18:2 cis-9, trans-11 were higher in cows fed with RE than those fed with E or R (P<0.05).

Discussion

Dry matter intake and digestibility

The effect of experimental diets on DMI in the current study was similar to Chilliard *et al*. (2009) who reported a lower DMI in cows fed with extruded linseed compared to those fed with raw linseed, while feeding the animals with diets containing roasted (Fathi Nasri *et al*., 2007b; Abdi *et al*., 2013) or extruded (Zhang *et al*., 2015) soybean had no effect on DMI of lactating dairy cows. Fat supplements may contribute to decreased DMI through actions on gut hormones, oxidation of fat in the liver, ruminal passage rate and the general acceptability of fat sources by cattle (Allen, 2000). Previous studies have shown that the extrusion process increases the rate of oil release from oilseeds into the rumen (Chilliard *et al*., 2009); therefore, the different processing method applied to soybean seeds might have affected the rate of oil released into the rumen. This may, in turn, increase PUFA flow to the duodenum and stimulate cholecystokinin (CCK) secretion. Hypophagic effects of CCK are related to its direct action on brain satiety centers or peripheral action of gut motility (Allen, 2000). The lack of effect of experimental diets on nutrient digestibility in the present study was in agreement with other studies (Abdi *et al*., 2013; Rafiee-Yaradi *et al*., 2016). Feeding lactating dairy cows with a diet containing R had no effect on apparent digestibility of NDF and EE compared with those fed with a diet containing raw soybeans (Abdi *et al*., 2013). On the other hand, total tract digestibility of DM, OM and CP was not affected by feeding lactating dairy cows with a diet containing R compared to those fed with soybean meal and calcium salt of FA (Rafiee-Yaradi *et al*., 2016). The discrepancy among the results of the aforementioned studies on nutrient digestibility may be related to many factors including soybean variety, processing method conditions (e.g. temperature, moisture, duration of processing), feeding level, total dietary fat content and overall diet composition (McNiven *et al*., 2004; Rafiee-Yaradi *et al*., 2016).

Milk yield and composition and nitrogen utilization efficiency

The milk production response to diets containing heat treated soybeans in our study was not in agreement with others that found no effect of feeding roasted (Abdi *et al*., 2013) or extruded (Zhang *et al*., 2015) soybeans on milk yield and 4% FCM. Cows fed with R and RE had greater DMI compared with cows fed with E (Table 4), which likely explains the differences in milk yield between dietary treatments in the current study. However, DMI of lactating dairy cows in Abdi *et al*. (2013) and Zhang *et al*. (2015) was not influenced by feeding roasted or E. A positive correlation was reported between milk yield and DMI in early lactation (NRC, 2001). The absence of any effect of feeding cows with diets containing thermally processed soybean seed on milk fat and protein content in the present study was in agreement with some previous studies (Chilliard *et al*., 2009; Abdi *et al*., 2013; Zhang *et al*., 2015), but disagreed with the study of Fathi Nasri *et al*. (2007b). The effect of feeding the animals with heated soybeans on the efficiency of feed N for milk N in the present study was in the line with previous findings (Abdi *et al*., 2013; Zhang *et al*., 2015). The higher utilization efficiency of feed N for milk N production in cows fed with R compared with cows fed with E could be attributed to their higher milk yield (Table 5).

Fatty acid profile of milk

In our study, the effect of experimental diets on milk fat concentration of C16:0 was in agreement with results of Neves *et al*. (2007) and Chilliard *et al*. (2009), while Abdi *et al*. (2013) reported no effect of feeding R on C16:0 concentration in milk fat. The lower C16:0 concentration of milk fat in E-fed cows could be related to higher C18:2 trans-10, cis-12 concentration in milk fat. As shown in Table 6, milk fat C18:2 trans-10, cis-12 concentrations were higher in cows fed with E and RE than those fed with R. Previous research has demonstrated that C18:2 trans-10, cis-12 decreases the expression of genes involved in milk lipid synthesis in mammary tissues of dairy cows (Peterson *et al*., 2002). Nevertheless, in the present study, milk fat content was similar among treatments, indicating that fat synthesis in mammary glands may be influenced by other factors such as volatile FA profiles produced in the rumen (NRC, 2001). The higher concentration of C18:1 cis-9, C18:2 cis-9, cis-12 and C18:3 cis-9, cis-12, cis-15 in the milk fat of cows fed with the E and RE diets were not in agreement with previous studies that found no effect for roasting (Abdi *et al*., 2013) and extruding (Neves *et al*., 2007) soybeans on these FA concentrations. However, McNiven *et al*. (2004) reported higher meat concentrations of C18:2 cis-9, cis-12 and C18:3 cis-9, cis-12, cis-15 when beef cattle were fed a diet containing R compared to those fed a diet containing either extruded or raw soybean seeds. Such discrepancies between results may be attributed to animal type, diet composition, processing method of soybean seeds and lactation period. The results of previous studies conducted *in vitro* (Troegeler-Meynadier *et al*., 2006) and *in situ* (Troegeler-Meynadier *et al*., 2014) showed lower ruminal BH of USFA in extruded compared to roasted soybean seeds. The effect of heat processed soybeans on milk fat concentrations of C18:1 trans-11 and C18:2 cis-9, trans-11 in the present study was consistent with the results of previous studies (Troegeler-Meynadier *et al*., 2006; Neves *et al*., 2007; Troegeler-Meynadier *et al*., 2014), indicating higher C18:1 trans-11 and C18:2 cis-9, trans-11 concentrations in milk fat when animals were fed with diets containing E compared with those fed with diets containing R. In contrast, Abdi *et al*. (2013) observed no difference in milk fat concentrations of C18:1 trans-11 and C18:2 cis-9, trans-11 in cows fed with R, whereas in the study reported by Rafiee-Yarandi *et al*. (2016), feeding R to lactating dairy cows increased milk fat concentration of C18:2 cis-9, trans-11 with no effect on C18:1 trans-11 compared to those fed with the control diet. Troegeler-Meynadier *et al*. (2014) showed that lipid oxidative metabolites could, at least partly, be responsible for the modification of PUFAs during ruminal BH *in vitro*, and that the protection of PUFA from this process was likely linked to the heating temperatures during soybean processing. Vaccenic acid can be converted to C18:2 cis-9, trans-11 in the mammary glands and other tissues by the action of Δ^9-desaturase (Shingfeild *et al*., 2001). Therefore, an increased flow of C18:1 trans-11 from the rumen to the small intestine is desirable because it could elevate the concentration of C18:2 cis-9, trans-11 in milk fat, which has numerous health benefits for humans including the reduction of body fat mass, as well as anticarcinogenic, antiatherogenic, antidiabetogenic and immune modulating effects (Shingfield *et al*., 2006). Therefore, nutritional strategies that increase C18:2 cis-9, trans-11 content in the milk fat of dairy cows are of interest. Supplementing the ration of dairy cows with extruded or RE soybeans might be one such strategy.

In the current study, lactating cows fed with E or RE had similar 4% FCM production and FCM production per unit of DMI. Milk fat concentrations of C18:1 trans-11 and C18:2 cis-9, trans-11 were higher in cows fed with RE compared to those fed with E or R. Therefore, feeding lactating cows with RE not only improved performance and utilization efficiency of DMI for 4% FCM production but also increased beneficial FA in milk fat.

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