Canola Meal versus Soybean Meal in Dairy Cow Diets

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The past decade has given rise to a shift in the paradigm around feeding protein to dairy cattle. This can be attributed to a greater understanding of dairy cattle protein requirements, desire to reduce ration costs through increased efficiency, and reduction in the environmental impact of dairy cattle waste. The use of oilseed crop by-products as animal feed is an effective way to feed dairy cattle and supply required nutrients, specifically protein. Two of these popular oilseed by-products used in dairy systems include canola and soybean meals. While soybean meal has long been a staple in North American dairy rations, the popularity of canola meal inclusion is on the rise due to an increase in canola production, particularly in Canada. The increased availability of this quality animal feed has necessitated research efforts to evaluate its value in dairy production systems. To fully utilize canola meal in an optimized system, there is a knowledge gap surrounding amino acid function, supply, and interactions within dairy cow physiology.

Canola is a variety of rapeseed. A member of the *Brassica* genus, it is bred to produce an edible oil fraction and protein feed suitable for livestock. Two endemic compounds to rapeseed, glucosinolates and erucic acid, negatively impact the use of oil and meal fractions for human or animal consumption via toxicity and decreased palatability (Tripathi and Mishra, 2007). It was not until the mid-1970s that Canadian plant breeders were able to develop cultivars low in these 2 compounds, increasing the use of canola products (Stefansson and Kondra, 1975). The nomenclature “canola,” “double-low” rapeseed, or “double-zero” rapeseed is used to identify these improved varieties from their less desirable counterparts. Meal glucosinolate levels of <30 µmol/g and oil erucic acid levels of <2% denote high quality rapeseed (Canola Council of Canada, 2015).

Canola meal has been shown to be a quality protein by-product when used as an animal feedstuff. Its position in the marketplace and use in dairy cow rations will be supported by evaluating the production response of cows fed canola meal compared directly to other protein by-products and how the nutrient fractions of canola meal behave in the dairy cow. In an evaluation of solvent-extracted canola meal from 11 different North American plants, crude protein ranged from 40.6 to 43.7% of DM over a 4-year period (Table 1; Adewole et al., 2016). Soybean meal values, on the other hand, tended to fall between 46.3 ans 55.9% DM (Table 1; Dairy One, 2016). Canola has a considerably larger NDF fraction (Table 1; 27.4 to 30.9% of DM; Adewole et al., 2016), whereas soybean meal tends to fall within 7.8 to 19.2% NDF, % of DM (Table 1; Dairy One, 2016). The RUP fraction of canola ranged from 32.3 to 46.1% of CP, with a mean of 41.0% RUP, % of CP when evaluated in situ (Table 1; Jayasinghe et al., 2014). A comparison sample of solvent extracted soybean meal was tested, and the RUP fraction was 31.0% of CP (Table 1; Jayasinghe et al., 2014).

Table 1. Canola versus soybean meal nutrient composition and digestibility.

	Canola meal		Soybean meal	
Item	Mean	Range	Mean	Range
Crude protein	41.7[a]	40.6 - 43.7[a]	51.1[b]	46.3 - 55.9[b]
Ether extract	3.5[a]	2.8 - 4.0[a]	4.38[b]	0.0 - 9.1[b]
Ash	7.5[a]	7.2 - 8.0[a]	7.3[b]	5.9 - 8.6[b]
NDF	29.4[a]	27.4 - 30.9[a]	13.5[b]	7.8 - 19.2[b]
RDP, % of CP	59.0[c]	53.9 - 67.7[c]	69.0[c]	-
RUP, % of CP	41.0[c]	32.3 - 46.1[c]	31.0[c]	-
IDP[1], % of RUP	74.8[c]	71.6 - 77.4[c]	94.5[c]	-

[1]Indigestible protein.
[a]Adewole et al. (2016).
[b]Dairy One (2016).
[c]Jayasinghe et al. (2014).

When similar samples were evaluated in vitro the mean RUP was slightly higher; approximately 44.0% RUP, % of total N for canola meal compared to solvent extracted soybean meal with 34.9% RUP, % total N (Broderick et al., 2016). While a higher proportion of canola meal CP reaches the small intestine, the availability of this protein fraction is less than soybean meal. Intestinally digestible protein (IDP) ranged from 71.6% to 77.4% when evaluated using a modified 3-step in situ/in vitro procedure, whereas soybean meal was 94.5% IDP, % of RUP (Table 1; Jayasinghe et al., 2014). These values are similar to those determined by the National Research Council, 75% for canola meal and 93% for soybean meal (NRC, 2001).

AMINO ACIDS

Our current understanding stipulates the inclusion of lysine (Lys) and methionine (Met), the first 2 limiting amino acids (AA), at a ratio of 3:1 to maximize the use of metabolizable protein for milk production (NRC, 2001; Liu et al., 2013). The AA profile of canola meal includes a ratio of Lys to Met of 3.01:1, whereas soybean meal has a ratio of 4.37:1 (NRC, 2001). Additionally, enriching diets with Lys and Met during the transition period (3 weeks prepartum to 3 weeks postpartum) increased daily milk yield 0.68 kg/d and milk protein 80 g/d throughout the first 16 weeks of lactation (Garthwaite et al., 1998; Grummer, 1995; Liu et al., 2013). Formulating diets for AA pre-calving resulted in an even greater production response, 2.27 kg/d milk, 112 g/d milk protein, and 115 g/d milk fat, than for animals not supplemented with additional AA (Garthwaite et al., 1998; Liu et al., 2013). This indicates further evaluation of ration AA profiles during the pre-calving and early-lactation periods is needed. While there is considerable research surrounding Lys and Met balances in dairy cows, there is growing evidence suggesting AA interactions contribute to performance responses and efficiencies. Formulating for AA reduces dietary requirements for RUP and may improve health status (Liu et al., 2013; Schwab, 2017). In terms of AA nutrition, Lys and Met balance in early lactation has increased glutathione and carnitine concentration in liver, thereby increasing beta-oxidation capacity and antioxidant prevalence (Osorio et al., 2014; Schwab, 2017). In addition, Met supplementation affects methyl donor (i.e. S-adenosylmethionine) and antioxidant (glutathione) availability (Osorio et al., 2014). S-adenosylmethionine is an active methyl donor, responsible for gene regulation and expression. In addition, there is increased liver inflammation during early lactation negative energy balance, and this decreases productive efficiency. Understanding the relationships between AA and their contributions to health and efficiency is important to delineating the production response observed when feeding canola meal and its value in the industry. Understanding this phenomenon will be advantageous in leveraging the favorable essential AA profile of canola meal to meet dairy cow requirements and efficiency of protein feeding. This could prove especially vital when intakes are low and animals are particularly responsive to essential AA supplies, such as in early lactation.

In the 2011 meta-analysis, which included 292 treatment means from 122 peer-reviewed studies, DMI, milk yield, and energy-corrected milk were greater for canola meal-fed cows, compared to those fed soybean meal (Huhtanen et al., 2011). Dry matter intake was 2.6 ± 0.03 kg/d greater with canola meal vs. soybean meal. Milk yield and energy-corrected milk increased 3.6 ± 0.25 kg/d and 5.0 ± 0.29 kg/d, respectively (Huhtanen et al., 2011). When feeding isonitrogenous rations that compared soybean meal and canola meal, an increase in milk yield tended to fall in the range of 0.59 to 1.32 kg/d with canola meal in mid-lactation animals (Broderick and Faciola, 2014; Broderick et al., 2015; Marostegan de Paula et al., 2015). The effect of feeding canola meal to cows in early lactation has been limited until recently.

EARLY LACTATION

During the transition period, AA and glucogenic compounds are not consumed in adequate quantities resulting in negative nutrient balances (Drackley, 1999; Ji and Dann, 2013). In addition, the adoption of lower energy and protein diets in early lactation necessitates the evaluation of metabolizable protein quality for transition cow health (Overton and Burhans, 2013). The ability of the cow to make a shift from pregnancy to lactation, efficiently and without incident, will contribute dramatically to her production potential. We conducted an experiment with 79 multiparous Holstein cows that received high protein (17.6% CP, % of DM) or low protein (15.4% CP, % of DM), where the main protein supply was provided by either canola or soybean meal. Diets were formulated to contain 55.0% forage (39.6% corn silage, 15.4% alfalfa silage) and 45% concentrate mix on DM basis. Canola meal was included at 19.4% and 11.9% DM, whereas soybean meal was included at 14.5% and 8.9% DM. Cows were enrolled at calving and production was followed for 16 weeks of lactation. Cows fed canola meal out performed those that received soybean meal, producing (mean ± SEM) 55.7 vs 51.2 ± 0.97 kg/d of milk, respectively (Table 2; Moore and Kalscheur, 2016). This additional production was not supported by a commensurate intake response. Canola meal-fed cows only tended to have higher DMI with 25.8 vs 25.0 ±

0.34 kg/d (Moore and Kalscheur, 2016). This suggests that nutrient utilization efficiency or body reserve turnover contributed to the additional energy required for greater milk production. The source of CP did not affect milk fat, protein, lactose, or total solids percentage. Decreasing dietary CP concentration increased milk fat (4.09 vs 3.90 ± 0.07% and total solids 12.8 vs 12.5 ± 0.95% (Moore and Kalscheur, 2016). Cows fed high protein diets produced greater milk urea N (MUN) than cows fed low protein diets (12.6 vs 9.82 ± 0.22 mg/dL). Milk urea N tended to be lower for cows fed canola meal compared to cows fed soybean meal (10.9 vs 11.4 ± 0.22 mg/dL), consistent with others (Martineau et al., 2014; Broderick et al., 2015). Milk fat, protein, lactose, and total solids were greater for cows fed canola meal in agreement with increased milk production. Energy-corrected milk (ECM) was greater for cows fed canola meal compared to soybean meal (57.6 vs 53.6 ± 0.95 kg/d). Cows fed canola meal exhibited a trend for improved feed efficiency (ECM/DMI) compared to cows fed soybean meal (2.27 vs 2.16 ± 0.38). These data suggest that fluid milk production and efficiency of nutrient conversion to milk can be improved in early lactation with the inclusion of canola meal in dairy rations.

Table 2. Production performance (Moore and Kalscheur, 2016).

Item	LO[1]		HI[1]		SEM	P [2]
	SBM[1]	CM[1]	SBM[1]	CM[1]		
DMI, kg/d	24.6	26.1	25.4	25.6	0.50	ST
Milk yield, kg/d	50.1	54.8	52.3	56.5	1.41	S
ECM,[3] kg/d	53.1	57.4	54.1	57.8	1.36	S
Feed efficiency[3]	2.16	2.22	2.17	2.31	0.06	ST
Milk components						
Fat, %	4.12	4.05	3.89	3.91	0.09	C
Protein, %	2.88	2.85	2.90	2.77	0.05	NS
Fat, kg/d	2.04	2.18	2.04	2.18	0.05	S
Protein, kg/d	1.45	1.54	1.50	1.54	0.05	S
MUN, mg/dL	10.0	9.6	12.9	12.2	0.30	C, ST

[1]LO = 16.3% CP, HI = 18.2% CP, CM = canola meal, SBM = soybean meal.
[2]C = main effect of protein concentration (LO or HI) $P \leq 0.05$, S = main effect of protein source (SBM or CM) $P \leq 0.05$, ST = main effect trend of protein source $0.05 \leq P \leq 0.10$, NS = No significant effect.
[3]Feed efficiency = ECM/DMI where ECM = [0.327 × milk (kg)] + [12.95 × fat (kg)] + [7.20 × protein (kg)].

While canola meal did not affect circulating glucose or beta-hydroxybutyrate concentrations in cows compared to those fed soybean meal, circulating triglyceride concentration was greater for cows fed canola (0.125 vs 0.118 ± 0.002 mM; Moore and Kalscheur, 2017). Efficiency of nitrogen utilization favored canola meal vs soybean meal-fed cows for both circulating plasma urea nitrogen (0.37 vs 0.40 ± 0.01 mM) and concentration of MUN (10.7 vs 11.4 ± 0.24 mg/dL). The increase in milk yield can be attributed in part, to an increase in circulating triglycerides and nitrogen utilization. However, further investigation into the canola meal vs soybean meal milk disparity in early lactation is needed.

ENVIRONMENT

There is a growing interest in mitigating the impact of dairy systems on the environment. Two waste products of particular interest are methane (CH_4) and ammonia (NH_3). While these are 2 inherent by-products of biological systems, there may be strategies to affect dairy cow rumination and nitrogen excretion through feeding strategies. In addition, the positive implications resulting from the inclusion of canola meal use in dairy cow diets will increase use and demand. Therefore, it is important to consider the ancillary implications of greater inclusion of this feedstuff, including if it affects greenhouse gas emissions by the dairy cow. Dietary forage concentration has a great impact on CH_4 production in dairy cattle. Increasing forage to concentrate ratio from 47:53 to 68:32 increased CH_4 production 20% in Wisconsin Holstein cows (Aguerre et al., 2011). When studied in Swedish Red cattle fed grass-based TMR diets, there was a greater reduction in g of CH_4/kg ECM when increasing CP in the diet with heat-treated canola meal vs soybean meal (Gidlund et al., 2015). However, protein source effect on greenhouse gas emission has not been evaluated in traditional Midwestern corn-forage based diets with Holstein cattle. Urinary urea N excreted by the cow increases with increasing concentrations of CP in the diet, resulting in an increase in N loss to the environment in the form of NH_3 and N_2O (Hristov, et al., 2011; Powell et al., 2015). While reducing these waste products is environmentally advantageous, it is important to maintain exceptional milk production. Following the 16-week evaluation of production, 6 blocks (24 cows total; 120.5 ± 2.24 DIM were evaluated in environmental emissions chambers. Cows fed either source or CP concentration of protein did not differ in DMI (26.67

± 0.75 kg/d) or 4% fat-corrected milk (FCM; 53.89 ± 2.04 kg/d; Moore et al., 2016). There was a source by CP concentration interaction for CH_4 emission. Cows fed high protein canola meal diets produced less CH_4 than those consuming high protein soybean meal and low protein canola meal diets (465.7 vs 528.5 and 537.9 ± 28.7 g/d; Moore et al., 2016). Methane expressed per unit of DMI (19.3 ± 1.24) or FCM (9.23 ± 0.71) did not differ among treatments (Moore et al., 2016). Ammonia excretion did not differ between protein sources, contrary to the increased nitrogen use efficiency reflected in the MUN values. Milk N (g/d) was not affected by protein source and NH_3 emission expressed per unit of milk N was not affected by diet. The mechanism by which methane release is lower with canola meal fed diets has yet to be determined. One possibility may include a shift in fiber digestion. Dry matter, organic matter, CP, and NDF digestibility were all greater when feeding canola vs soybean meal at 11.6% and 8.6% of DM on an isonitrogenous basis in multiparous Holstein cows (Marostegan de Paula et al., 2016).

CONCLUSIONS

While changes in markets dictate when canola or soybean meal can be favorably incorporated into dairy cow diets, we have outlined the potential benefits for using canola as a protein source. As further research is needed, canola meal may provide a cost-favorable source of essential AA, specifically in early lactation.

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