Canola Meal as a Protein Source for Lactating Dairy Cows

Antonio Faciola[1] and Eduardo M. Paula
Department of Animal Sciences, University of Florida

Introduction

Canola is an offspring of rapeseed (*Brassica napus* and *Brassica campestris/rapa*), which was bred through standard plant breeding techniques to have low levels of erucic acid and glucosinolates. Canola seed is rich in oil, and after oil extraction, the remaining "canola meal" (**CM**), is a rich protein source used as feedstock to different animal species, mainly dairy cows in North America and in Europe (Canola Meal Feed Guide, 2015). Glucosinolates and erucic acid were reduced in rapeseed due to their toxicity, which may negatively affect digestion and health of most animals when fed in high levels (Kramer et al., 1990; Mawson et al., 1994). Over the past 25 years canola production in Canada has grown from approximately 3 million tons to about 17 million tons (Cliff Jamieson, 2015). Due to increased availability of canola oil, its by-product, CM, has become a viable protein source to dairy cow diets (Martineau et al., 2013).

Recent studies published in peer-review journals have shown that CM is a valuable protein source for lactating dairy cows. Results from these studies have indicated that CM can partially or completely replace the most common protein sources (e.g., soybean meal (**SBM**), cottonseed meal, dried-distiller's grains) without comprising dairy cows' performance and, in some cases, can improve performance and nitrogen (**N**) utilization of dairy cows. The objective of the present paper is to summarize and discuss the results from our studies comparing CM with SBM as a protein source for dairy cows with other recent studies published in peer-review journals comparing SBM with common protein sources fed to dairy cows.

Effects of Canola Meal on Performance of Dairy Cows

Recently, studies evaluating the replacement of CM with SBM or other common protein supplements fed to dairy cows have shown an increase in cows' performance and an overall improvement in N utilization by cows fed CM (**Table 1**).

Broderick et al. (2015) observed an increase in DMI (+ 0.4 kg/d), yields of milk (+ 1.0 kg/d) and milk true protein (+ 50 g/d), and improved efficiency of dietary N for milk N by replacing SBM with CM in isonitrogenous diets formulated with corn and/or alfalfa silage as forages. Two meta-analyses based on results of published peer-reviewed journals reported an increase of yields of milk and milk components, a reduction in milk urea N (**MUN**), and an increase in plasma concentration of branched-chain amino acids (**BCAA**) for cows fed CM compared to other protein supplements (Martineau et al., 2013, 2014). Furthermore, Huhtanen et al. (2011) in another meta-analysis evaluated

[1] Contact: 2250 Shealy Drive, Gainesville, FL 32611. Phone (352) 273-1268. E-Mail: afaciola@ufl.edu

the replacement of SBM with CM in isonitrogenous diets formulated with grass silage-based diets and observed an increase in DMI and yields of milk by cows fed CM compared to those fed SBM.

Paula et al. (2018) observed a significant reduction in MUN (8%), and a numerical increase in yields of milk, 3.5% FCM, and ECM of 1.3, 1.2, and 0.9 kg/d, respectively, by cows fed CM compared with those fed SBM. In this study the basal diets contained alfalfa and corn silage plus high-moisture corn and about 16% CP concentration. In a study with a similar basal diet as Broderick et al. (2015) and Paula et al. (2018), Brito and Broderick (2007) evaluated the performance of lactating dairy cows supplemented with equal CP concentration from urea, cottonseed meal (**CSM**), SBM, or CM. The authors observed a significant increase in DMI for cows fed CM compared to those fed SBM and intermediate values for cows supplemented with CSM of 24.9, 24.2, and 24.7 kg/d, respectively. Other findings were numerical differences in milk yield, 41.1, 40.5, and 40 kg/d, for CM, CSM, and SBM, respectively. Milk protein yield was significantly increased for cows fed CM or SBM compared to cows fed CSM.

Mulrooney et al. (2009) conducted a study evaluating the effects of replacing dried distillers grains with solubles (**DDGS**) with CM in different proportions (100, 66, 33, and 0%) on milk production of lactating dairy cows. They observed no differences in yields of milk and milk components. However, they concluded that despite no differences in yields of milk and milk components, diets with higher proportions of CM tended to be more desirable due to a reduction in MUN and a better concentration of blood amino acids (**AA**). Contrarily, Chibisa et al. (2012) evaluated the effects of replacing CM with wheat-DDGS (0, 10, 15, and 20% of DM) and observed an increase in DMI and milk yield by 1.2 to 1.8 kg/d by cows fed wheat-DDGS compare to cows fed CM. Also the authors observed a quadratic effect for milk protein yield when wheat-DDGS was fed.

Our results and the results in literature cited herein evaluating CM as protein source have indicated that CM is a valuable protein source for high-producing dairy cows. The overall improvement in cows' performance and N utilization when compared to SBM diets may be due to a greater contribution of methionine in the RUP, consequently improving the amino acid balance available for absorption when CM is fed.

Canola Meal: Ruminal Degradability and Metabolizable Protein

Overall, dairy farmers have a preference for SBM rather than CM in the diet (Huhtanen et al., 2011) possibly because SBM has a greater concentration of CP (53 vs. 42 % of DM) and of metabolizable energy (3.41 vs. 2.75 Mcal/kg) compared to CM (NRC, 2001). In addition, feed evaluation systems such as Agricultural and Food Research Council (AFRC 1993) and NRC (2001) estimate a lower amount of rumen undegraded protein (**RUP**) outflow and greater degradation rates of rumen degraded protein (**RDP**) for CM compared to SBM, consequently the estimated metabolizable protein is lower for CM.

Piepenbrink and Shingoethe (1998) observed greater ruminal CP degradability and lower intestinal digestibility for CM compared to blood meal, corn gluten meal, and menhaden fish meal. Nonetheless, the estimated AA profile reaching the small intestine of cows fed CM was closest to the milk AA profile. However, Brito et al. (2007) measured numerically greater RUP flows in vivo for CM compared to SBM diets, 34 vs. 29% (of CP), respectively. In addition, they observed similar yields of milk protein by cows fed CM or SBM, 1.27 and 1.23 kg/d, respectively, which may indicate an underestimation of MP for CM diets when using current nutritional models.

Recently, there have been speculations that RUP values and estimation of MP supply are underestimated for CM in current prediction models (Huhtanen et al. 2011; Martineau et al. 2013). Maxin et al. (2013) evaluated in situ ruminal degradation of CP from SBM and CM and reported lower CP degradability and greater RUP content for CM compared to SBM. Broderick et al. (2016) reported in a survey that included CM samples collected from 12 Canadian processing plants over 4 years that CM varied in RUP content from 43 to 51% (CP basis) with an overall average of 45% which is 26% greater than the RUP value for CM in the current NRC (2001) of 35.7% of CP with DMI at 4 times maintenance. Furthermore, studies comparing the effects of CM and SBM in the total diet in vitro (Paula et al., 2017) and in vivo (Rinne et al., 2015) on ruminal N metabolism did not observe significant differences between diets. In agreement, Paula et al. (2018) did not observe differences in microbial and non-microbial NAN flows at the omasal canal among cows fed SBM, CM, or heat-treated CM. In **Tables 2 and 3** we summarized the mean chemical composition of CM used in our recent studies and ruminal outflow of N fractions.

These results underscore the importance of revising MP, RDP, and RUP content of CM in nutrition models and feed tables to better reflect the MP supply of CM when fed to lactating dairy cows.

It is also worth mentioning that while a few attempts have been made to decrease CM ruminal degradability, for example by heat-treating CM, with the goal of increasing the RUP fraction, these have not resulted in better ruminal or post-ruminal N utilization and failed to improve milk production (Paula et al., 2018).

Interactions among Canola Meal and Forages Sources

It is well documented that the type of dietary forages may affect the limiting AA for yields of milk and protein (NRC, 2001; Schwab et al., 1976). For example, diets based on corn and corn silage are more likely to be limiting in lysine than alfalfa silage-based diets due to higher concentrations of lysine in alfalfa. On the other hand, studies have shown that histidine may be more limiting for cows fed grass silage and barley-based diets (Vanhatalo et al., 1999; Huhtanen et al., 2002).

In the meta-analysis by Huhtanen et al. (2011), authors concluded that CM value in diets based on grass silage is at least as equivalent as the value of SBM for lactating dairy cows. However, they did not include studies with diets based on corn and/or alfalfa silage (typical North American diets). Furthermore, Martineau et al. (2013) reported that type of forage (e.g., grass or legume forages vs. corn or barley silage) was one factor that influenced the responses of replacing protein supplements with CM. They observed greater milk protein content for cows fed CM compared to other common protein sources only in studies based on grass and/or legume forages. Whereas, milk lactose content was lower for cows fed CM in studies based on corn or barley silage alone or in combination with grass or legume forage.

Rinne et al. (2015) evaluated lactation performance of dairy cows fed red clover/grass silage-based diets formulated to different concentrations of CP using expeller rapeseed meal or expeller soybean meal supplementation. The authors observed a tendency for increased DMI and a significant increase in milk production and N use efficiency by cows fed expeller rapeseed meal compared to cows fed expeller soybean meal. In addition, they observed an increase in plasma methionine concentration in cows fed rapeseed meal.

Faciola and Broderick (2013) evaluated the effects of replacing SBM with CM on performance of lactating dairy cows fed diets containing 3 different ratios of alfalfa to corn silage (1:5, 1:1, and 5:1; DM basis). Diets contained (DM basis) 60% forage, 8 to 15% high moisture corn, 2 to 5% soy hulls, 1.3% mineral-vitamin premix, 16.5% CP, and 31 to 33% NDF. Regardless of the forage ratio fed to the cows, replacing SBM with CM improved yields of milk (37.3 vs. 36.4 kg/d, respectively) and milk protein and decreased MUN concentration. However, cows' performance response to CM was smaller when corn silage was fed as the major forage source, possibly due to a greater portion of MP being supplied by microbial protein rather than from RUP.

Conclusions

Results from our recent studies and other published work indicate that, when replacing SBM, CM increases DMI, milk yield, and milk protein content while reducing ruminal ammonia and MUN concentrations. While less consistent, CM may also adequately replace other commonly used protein supplements such as DDGS. Responses to CM also vary depending upon forage sources. A greater response to CM feeding has been observed when alfalfa silage was fed. Variation in CM chemical composition has also been observed, notably with regards to RUP; however, differences in chemical composition did not affect in vitro ruminal digestion. Based on both in vitro and in vivo studies, replacing SBM with CM does not greatly change ruminal fermentation, suggesting that benefits of feeding CM may be related to increased DMI and/or better post-ruminal utilization (e.g., better AA profile). Lastly, a few studies that attempted at improving CM chemical composition (e.g., RUP content) did not improve CM ruminal or post-ruminal utilization.

References

AFRC (Agricultural and Food Research Council). 1993. Energy and Protein Requirements of Ruminants. CAB International, Wallington,UK.

Brito, A., G. Broderick, and S. Reynal. 2007. Effects of different protein supplements on omasal nutrient flow and microbial protein synthesis in lactating dairy cows. J. Dairy Sci. 90:1828-1841.

Brito, A. F. and G. A. Broderick. 2007. Effects of different protein supplements on milk production and nutrient utilization in lactating dairy cows. J. Dairy Sci. 90:1816-1827.

Broderick, G. A., S. Colombini, S. Costa, M. A. Karsli, and A. P. Faciola. 2016. Chemical and ruminal in vitro evaluation of Canadian canola meals produced over 4 years. J. Dairy Sci. 99:7956-7970.

Broderick, G. A., A. P. Faciola, and L. E. Armentano. 2015. Replacing dietary soybean meal with canola meal improves production and efficiency of lactating dairy cows. J. Dairy Sci. 98:5672-5687.

Canola Meal Feeding Guide. 2015. Canola meal feeding industry guide. 5th ed. Canola Council of Canada, Winnipeg, MB, Canada.

Chibisa, G., D. Christensen, and T. Mutsvangwa. 2012. Effects of replacing canola meal as the major protein source with wheat dried distillers grains with solubles on ruminal function, microbial protein synthesis, omasal flow, and milk production in cows. J. Dairy Sci. 95:824-841.

Cliff Jamieson. 2015. The Progressive Farmer. https://www.dtnpf.com/agriculture/web/ag/perspectives/blogs/canada-markets/blog-post/2015/08/21/statistics-canada-releases-2015. (Accessed 13 Jan 2018).

Faciola, A. P., G. Broderick. 2013. Effects of replacing soybean meal with canola meal for lactating dairy cows fed three different ratios of alfalfa to corn silage. J. Dairy Sci. 96, (E-Suppl. 1): 452.

Huhtanen, P., M. Hetta, and C. Swensson. 2011. Evaluation of canola meal as a protein supplement for dairy cows: A review and a meta-analysis. Canadian J. Anim. Sci. 91:529-543.

Huhtanen, P., A. Vanhatalo, and T. Varvikko. 2002. Effects of Abomasal Infusions of Histidine, Glucose, and Leucine on Milk Production and Plasma Metabolites of Dairy Cows Fed Grass Silage Diets. J. Dairy Sci. 85:204-216.

Kramer, J. K., E. R. Farnworth, K. M. Johnston, M. S. Wolynetz, H. W. Modler, and F. D. Sauer. 1990. Myocardial changes in newborn piglets fed sow milk or milk replacer diets containing different levels of erucic acid. Lipids. 25:729-737.

Martineau, R., D. R. Ouellet, and H. Lapierre. 2013. Feeding canola meal to dairy cows: A meta-analysis on lactational responses. J. Dairy Sci. 96:1701-1714.

Martineau, R., D. R. Ouellet, and H. Lapierre. 2014. The effect of feeding canola meal on concentrations of plasma amino acids. J. Dairy Sci. 97:1603-1610.

Mawson, R., R. K. Heaney, Z. Zdunczyk, and H. Kozlowska. 1994. Rapeseed meal-glucosinolates and their antinutritional effects. Part 5. Animal reproduction. Die Nahrung 38:588-598.

Maxin, G., D. Ouellet, and H. Lapierre. 2013. Ruminal degradability of dry matter, crude protein, and amino acids in soybean meal, canola meal, corn, and wheat dried distillers grains. J. Dairy Sci. 96:5151-5160.

Mulrooney, C. N., D. J. Schingoethe, K. F. Kalscheur, and A. R. Hippen. 2009. Canola meal replacing distillers grains with solubles for lactating dairy cows. J. Dairy Sci. 92:5669-5676.

NRC. 2001. Nutrient Requirements of Dairy Cattle: Seventh Revised Edition, 2001. The National Academies Press, Washington, DC.

Paula, E. M., G. A. Broderick, M. A. C. Danes, N. E. Lobos, G. I. Zanton, and A. P. Faciola. 2018. Effects of replacing soybean meal with canola meal or treated canola meal on ruminal digestion, omasal nutrient flow, and performance in lactating dairy cows. J. Dairy Sci. 101:328-339.

Paula, E. M., H. F. Monteiro, L. G. Silva, P. D. B. Benedeti, J. L. P. Daniel, T. Shenkoru, G. A. Broderick, and A. P. Faciola. 2017. Effects of replacing soybean meal with canola meal differing in rumen-undegradable protein content on ruminal fermentation and gas production kinetics using 2 in vitro systems. J. Dairy Sci. 100:5281-5292.

Piepenbrink, M. S. and D. J. Schingoethe. 1998. Ruminal degradation, amino acid composition, and estimated intestinal digestibilities of four protein supplements. J. Dairy Sci. 81:454-461.

Rinne, M., K. Kuoppala, S. Ahvenjärvi, and A. Vanhatalo. 2015. Dairy cow responses to graded levels of rapeseed and soya bean expeller supplementation on a red clover/grass silage-based diet. Animal. 9:1958-1969.

Schwab, C. G., L. D. Satter, and A. B. Clay. 1976. Response of lactating dairy cows to abomasal infusion of amino acids. J. Dairy Sci. 59:1254-1270.

Vanhatalo, A., P. Huhtanen, V. Toivonen, and T. Varvikko. 1999. Response of dairy cows fed grass silage diets to abomasal infusions of histidine alone or in combinations with methionine and lysine. J. Dairy Sci. 82:2674-2685.

Table 1. Summary of recently published papers comparing CM and common protein sources used in North American diets on performance of lactating dairy cows.

	Item						
Reference	TRT[1]	DMI[2], kg/d	MY[2], kg/d	MP[2], %	MP[2], kg/d	MUN[2], mg/dL	Milk-N/N intake, %
Brito and Broderick (2007)	CM	24.9[a]	41.1[a]	3.12[a]	1.27[a]	11.6[a]	30.2[ab]
	SBM	24.2[b]	40.0[b]	3.15[a]	1.23[ab]	12.0[a]	30.4[a]
	CSM	24.7[ab]	40.5[a]	2.97[b]	1.18[b]	9.97[b]	28.5[b]
Mulrooney et al. (2009)	CM	25.2	35.2	3.1	1.1	7.1	-
	DDGS	25.1	34.3	3.0	1.0	7.25	-
Chibisa et al. (2012)	CM	29.7[b]	42.9[b]	3.32	1.4	-	24.1
	DDGS	31.8[a]	44.5[a]	3.30	1.4	-	24.5
Faciola and Broderick. (2013)	CM	23.8	37.3[a]	3.02	1.12[a]	12.9[a]	27.5
	SBM	23.5	36.4[b]	3.02	1.10[b]	14.0[b]	27.3
Broderick et al. (2015)	CM	25.2[a]	40.3[a]	3.06	1.22	10.3[b]	30.8[a]
	SBM	24.8[b]	39.3[b]	3.04	1.19	11.5[a]	30.0[b]
Paula et al. (2018)	CM	27.1	41.3	3.14	1.25	12.8[b]	29.2
	SBM	26.7	40.0	3.20	1.25	13.7[a]	30.7

[a,b] Means in the column within study with different superscripts differ ($P < 0.05$).

[1] Dietary treatments with the main protein source of CM = canola meal; SBM = soybean meal; CSM = cottonseed meal; DDGS = dried distillers grains.

[2] DMI = dry matter intake; MY = milk yield; MP = milk protein; MUN = milk urea nitrogen.

Table 2. Overall mean chemical composition of CM and SBM based on the chemical composition analyzed from our studies comparing CM vs. SBM on lactation performance of dairy cows.

	Canola meal		Soybean meal	
Item	Mean	Standard deviation	Mean	Standard deviation
Dry matter, % as fed	91.4	1.0	90.0	0.6
Organic matter, % DM	91.4	0.7	92.6	0.5
Crude protein, % DM	41.4	1.1	53.3	1.5
Rumen degraded protein, % of CP	55[1]	-	57[2]	-
Rumen undegraded protein, % of CP	45[1]	-	43[2]	-
NDF, % DM	27.8	2.2	8.1	1.3
ADF, % DM	19.3	2.8	4.7	0.8
NDIN, % of total N	17.9	7.3	3.7	3.3
ADIN, % of total N	5.4	1.0	0.7	0.7
B_3, % of total N	11.4	7.2	4.2	2.7

[1] Estimated according to Broderick et al. (2016).

[2] Estimated using the NRC (2001) model for a cow with DMI of 4% of BW.

Table 3. Summary of recently published papers comparing CM and common protein sources used in North American diets on ruminal outflow of nitrogen fractions.

Reference	Item			
	TRT[1]	Total NAN flow, g/d[2]	NMNAN flow, g/d[2]	Total microbial NAN flow, g/d[2]
Brito and Broderick (2007)	CM	616	172[b]	444
	SBM	639	159[b]	433
	CSM	587	206[a]	433
Chibisa et al. (2012)	CM	1,012	271[b]	743
	DDGS	1,042	311[a]	708
Paula et al. (2017; in vitro)	LCM	1.84	0.31	1.53
	HCM	1.91	0.40	1.51
	SBM	2.00	0.44	1.56
Paula et al. (2018)	CM	688	200	482
	TCM	671	183	488
	SBM	669	187	482

[a,b] Means in the column within study with different superscripts differ ($P < 0.05$).

[1] Dietary treatments with the main protein source of CM = canola meal, SBM = soybean meal, CSM = cottonseed meal, DDGS = dried distillers grains with solubles, LCM = low RUP solvent-extracted canola meal (38% RUP as a percentage of CP), HCM = high RUP solvent-extracted canola meal (50% RUP), and TCM = heat-treated canola meal.
[2] NAN = nonammonia-nitrogen; NMNAN = nonmicrobial NAN.

SESSION NOTES