PENNSYLVANIA SOYBEAN BOARD PROJECT

COMPARING THE EFFECTS OF SOYBEAN MEALS VS. CANOLA MEAL ON THE LACTATIONAL PERFORMANCE OF DAIRY COWS

FINAL REPORT

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SUMMARY

This study investigated the effect of 3 feed protein sources, solvent-extracted soybean meal (**SSBM**), canola meal (**CM**), and extruded soybean meal (**ESBM**), on dry matter intake (**DMI**), milk production and composition, and enteric (i.e., rumen) methane emission in lactating dairy cows. All meals were included in the diet on an equal crude protein basis. Data from the experiment suggest that substitution of SSBM or ESBM with CM, on an equal CP basis, may enhance DMI in dairy cows. The reason for this effect is unclear. It should be noted that canola has to first go through an extrusion process before solvent extraction, which increases the rumen undegraded content of CM, making it comparable to ESBM and considerably different from SSBM. In this experiment, both CM and ESBM increased milk yield, compared with SSBM, and SSBM tended to increase milk fat percentage. These effects, however, have to be considered in the context of lack of treatment effect on component yields and energy-corrected milk yield. In addition, the soybean meal diets tended to result in numerically greater feed efficiency, which indicates that the effect on milk yield by CM was a result of increased DMI and not increased efficiency of feed energy utilization. Both soybean meals increased milk urea nitrogen, which suggests less efficiency utilization of dietary protein, compared with CM. Canola meal decreased enteric methane yield, compared with the soybean meal diets. A more thorough discussion of the methane data will be possible when all analyses from the project are completed.

BACKGROUND AND OBJECTIVES

The objective of this study is to evaluate the effect of protein source, in terms of rumen by-pass protein and essential amino acid (**AA**) supply on feed intake, milk production and milk components in dairy cows. The protein sources tested were solvent-extracted soybean meal (**SSBM**), canola meal (**CM**), extruded soybean meal (**ESBM**), included in the diet on an equal crude protein (**CP**) basis. Our hypothesis was that, when feeding SSBM, ESBM and CM at equal CP-basis and with adequate methionine (**Met**) and lysine (**Lys**) supply, ESBM will result in greater availability of metabolizable protein (**MP**) and histidine (**His**), which may increase dry matter intake (**DMI**) and milk production, when compared to SSBM and CM. Our previous work with ESBM demonstrated increased DMI and consequently milk yield in dairy cows fed diets in which SSBM was substituted with ESBM (processed at 300 or 340°F). In that study, ESBM had rumen undegraded protein of 40 and 59%, compared with 26% for the SSBM. Plasma concentration of His, an AA that research at Penn State has shown to be limiting production in dairy cows, was increased 25% by the 340°F ESBM. Plasma Met, however, was lowered by ESBM, which may have prevented demonstration of the full potential of ESBM to promote milk yield and milk protein synthesis in dairy cows.

MATERIALS AND METHODS

Animals and procedures: The animals involved in this experiment were cared for according to the guidelines of Penn State's Institutional ACUC at PSU. The committee reviewed and approved all procedures involving animals used in this experiment.

Treatments and Experimental Design: The experiment was conducted in the tie stall barn of Penn State's Dairy Research and Teaching Center. Fifteen high producing dairy cows were used in the study. Cows were 95 (SD = 20) days in milk at the beginning of the trial. The design of the experiment was a replicated 3 × 3 Latin Square. The experiment had 3 periods and the duration of each period was 28-days, with 3 weeks for adaptation and 1 week of sampling. Feed DMI and milk production data were collected throughout the experiment. Cows were milked twice a day, around 5:00AM and 5:00PM and were fed once daily at around 8:00AM.

The following treatments were tested in this experiment:

(1) control – SSBM
(2) ESBM extruded at 320°F
(3) CM (solvent extracted)

The inclusion rate of the meals in the total mixed ration **(TMR)** was (DM basis):

(1) 13.6% SSBM
(2) 14.2% ESBM
(3) 17.0% CM

At this inclusion rate, all meals contributed an equal amount of CP to the total dietary CP.

Diets: The experimental diets were based on the inclusion of SSBM, ESBM, and CM as the main source of protein. The main idea was to feed the same amount of CP from each protein source, rather than have the same physical inclusion. Vegetable oil (soybean or canola) was added to the SSBM and CM diets to reach the ether extract concentration of the ESBM diet. All 3 diets had the same ingredients composition and met or exceeded NRC (2001) requirements for net energy of lactation; MP supply met or exceeded NRC (2001) requirements for the SSBM and ESBM diets, but was approx. 10% deficient for the CM diet. The SSBM was locally-sourced and the ESBM was produced by Fabin Bros., Indiana, PA. The canola meal was purchased through Gavilon Group, LLC (Omaha, NE) and was sourced from plants in Canada (Bunge in Harrowby, MB and

ADM in Windsor, ON). The canola meal was first mechanically-extracted (to bring the oil content to around 18%) and then solvent-extracted.

Feed and TMR sampling: Feed offered and refusals weights were recorded daily. Feeding was ad libitum targeting 10% refusals. Fresh TMR samples were collected twice weekly, immediately after being prepared and as feed was delivered to the cows. Weekly composite samples were prepared from the TMR and forages. Concentrate feeds were sampled weekly and composited per experimental period for further analyses. All samples were oven-dried to constant weight and ground through a 1-mm screen before being analyzed for OM, N, NDF, ADF, and starch; TMR samples were also analyzed for indigestible-NDF (used as a digestibility marker). All analyses, except starch and iNDF, were conducted by Cumberland Valley Analytical Services (CVAS; Waynesboro, PA). All feeds will be also analyzed for AA and the meals will also be analyzed for fatty acid profile (pending).

Protein degradability: The 3 meals (SSBM, ESBM, and CM) were analyzed for in situ and in vitro protein degradability using 2 procedures. In vitro protein degradability was analyzed by CVAS using the *Streptomyces griseus* protease method (Krishnamoorthy et al., 1983; Br. J. Nutr. 50:555–568). Protein degradability was also analyzed by the in situ procedure as described in Lee et al. (2012; J. Dairy Sci. 95:6042–6056). Three rumen-cannulated cows were used for the rumen incubation; 7 g of each meal per bag were incubated in the rumen of the cows in triplicate for 0, 2, 4, 8, 24, and 48 h. Rumen-degraded (**RDP**) and undegraded (**RUP**) protein will be estimated using NRC (2001) equations (pending).

Methane measurements: Enteric methane, carbon dioxide, and hydrogen emissions were measured using the GreenFeed (C-Lock, Rapid City, SD) system. Emission were measured during the last week of each experimental period following our standard tie-stall protocol. Emission data were collected on 3 consecutive days as follows: at 0900, 1500, and 2100 h (sampling day 1), 0300, 1200, and 1700 h (sampling day 2), and 0000 and 0500 h (sampling day 3).

Blood sampling: Blood samples were collected from the tail vein/artery 4 times in 2 consecutive days (at 3 and 9 h after feeding on d 1 and 6 and 12 h after feeding on d 2) during week 4 of each experimental period. Samples were processed and plasma analyzed for AA profile and carnosine.

Fecal and urine sampling: During the last 3 days of each experimental period, 8 spot fecal and urine samples were collected. The 8 samples were collected over 3 days as follows: Day 1 – at 0500, 1100, 1700 and 2300 h, Day 2 – at 0800, 1400 and 2000 h, and Day 3 – at 0200 h. These samples will be used to estimated total tract digestibility of dietary nutrients and urinary excretion of total N, urea, and purine derivatives (as markers for microbial protein synthesis in the rumen). These analyses are being finalized but the data were not ready for inclusion in this report.

Milk sampling: Milk samples from consecutive PM and AM milkings were collected during experimental week 4 and analyzed for fat, true protein, milk urea N (**MUN**), and lactose. Separate milk samples were collected and will be analyzed for milk fatty acid profile (pending).

Statistical analysis: Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC) with cow within square as random effects; most data were analyzed as repeated measures with the ar(1) covariance structure and square and.

RESULTS AND DISCUSSION

The analysis of CP content and in vitro protein degradability of the meals is shown below. The CM had considerably higher RUP and lower RDP content than the SSBM. This was likely a result of heat generated during the oil extraction process. Canola has to be first mechanically processed to bring the oil content down to 18% before solvent extraction. Due to its lower oil content, soybeans don't have to be mechanically extracted before solvent extraction. Mechanical extraction, or extrusion, generates heat, which decreases protein degradability and increases RUP content of the meal. Thus, CM had RUP content similar to ESBM, which was extruded at 320ºF.

(1) SSBM: 52% CP; 67.8% RDP & 32.2% RUP
(2) ESBM: 49% CP; 43.7% RDP & 56.3% RUP
(3) CM: 40.7% CP; 41.5% RDP & 58.5% RUP

Data available to date are presented in Tables 1-3. One of the main outcomes of this experiment was that CM increased ($P \leq 0.01$) DMI, compared with both ESBM and SSBM. The increase compared with SSBM was 2.4 kg/d and 1.6 kg/d compared with ESBM. ESBM also tended to increase ($P = 0.12$) DMI compared with SSBM, which was in line with our previous observations (Giallongo et al., 2015; J. Dairy Sci. 98:6471–6485). The difference in DMI between CM and ESBM was not enough to trigger a statistical increase in milk yield (a trend at $P = 0.10$). Compared with SSBM, however, CM increased ($P = 0.002$) milk yield by 2.7 kg/d. Since there was no statistical difference in feed efficiency ($P = 0.13$) among treatments, the effect on milk yield by CM was clearly a result of increased DMI. Feed efficiency tended ($P = 0.08$), in fact, to be higher for both ESBM and SSBM, compared with CM. Importantly, treatment had no effect on energy-corrected milk (**ECM**) yield or ECM feed efficiency, which means all 3 meals performed the same in terms of production responses.

Except for milk true protein and milk urea N (**MUN**) concentrations, treatment did not affect milk composition ($P \geq 0.05$). Milk true protein concentration tended to be higher ($P = 0.08$) for SSBM, compared with the other treatments ($P = 0.07$, compared with CM and $P = 0.04$, compared with ESBM). This was likely a result of higher RDP supply with the SSBM diet (67 vs 42 to 44% RDP, SSBM and CM/ESBM, respectively), which may have stimulated microbial protein synthesis in the rumen and AA supply to the small intestine, compared with the CM and ESBM diets. Milk urea N concentration was lowest ($P < 0.001$) for CM, followed by SSBM and was highest for ESBM. The likely explanation for this is greater RUP supply with ESBM (and CM), compared with SSBM, that was not accompanied by greater milk protein synthesis, thus resulting in increased AA catabolism and MUN secretion (supported also by the increased plasma urea concentration data in Table 2).

Compared with CM and SSBM, ESBM increased ($P \leq 0.003$) plasma concentrations of Ile, Leu, Val, and the sum of essential AA and resulted in decreased ($P < 0.001$) Met and Cys (Table 2). The overall increase in essential AA concentrations by ESBM can be explained by higher rumen by-pass and perhaps higher intestinal digestibility of AA from ESBM, compared with the other 2 meals. The increased plasma urea concentration with ESBM and SSBM is in agreement with the MUN data and is likely a reflection of higher rumen CP by-pass with ESBM and higher total CP and RDP with SSBM. Interestingly, plasma concentration of 1-methylhistidine was decreased ($P < 0.001$) by SSBM, compared with the other 2 treatments. This response was similar to what we have observed in a previous experiment (Giallongo et al., 2015) where concentration of plasma 1-methylhistidine was increased by ESBM processed at 340°F, compared with SSBM. It is not clear why plasma 1-methylhistidine concentration was decreased by SSBM, but it is logical to conclude that it was a result of decreased RUP supply, compared with CM and ESBM.

Absolute enteric methane emission was not affected by treatment (Table 3), but animals fed CM produced less ($P = 0.008$) enteric methane per kg of DMI (i.e., methane yield) than both ESBM and SSBM. Methane emission intensity (i.e., per kg of milk or energy-corrected milk) was similar among treatments. The effect of CM on methane yield is interesting, but data on the effect of various oilseeds (or meals) on enteric methane emission have been contradictory, and our results cannot be fully explained until all analyses from the project are completed.

CONCLUSIONS

Data from this experiment suggest that substitution of SSBM or ESBM with CM, on an equal CP basis, may enhance DMI in dairy cows. The reason for this effect is unclear. It should be noted that canola has to first go through an extrusion process to bring the oil content down to 18% before solvent extraction. The extrusion process results in generation of heat and increases the RUP content of CM, which makes it similar to ESBM and considerably different from SSBM. Both CM and ESBM increased milk yield, compared with SSBM, and SSBM tended to increase milk fat percentage. These effects, however, have to be considered in the context of lack of treatment effect on component yields and energy-corrected milk yield. In addition, the soybean meal diets tended to result in numerically greater feed efficiency, which indicates that the effect on milk yield by CM was a result of increased DMI and not increased efficiency of feed energy utilization. Both soybean meals increased MUN, which suggests less efficiency utilization of dietary protein, compared with CM. Canola meal decreased enteric methane yield, compared with the soybean meal diets. A more thorough discussion of the methane data will be possible when all analyses from the project are completed.

Table 1. Dry matter intake, BW, and milk production variables in dairy cows fed diets containing canola meal (CM), extruded soybean meal (ESBM) or solvent extracted soybean meal (SSBM)

	Diet[1]				
Item	CM	ESBM	SSBM	SEM[2]	*P*-value[3]
DMI, kg/d	26.9[a]	25.3[b]	24.5[b]	0.82	<0.001
Milk yield, kg/d	43.8[a]	42.6[a]	41.1[b]	1.82	0.002
Milk Yield ÷ DMI, kg/kg	1.64	1.70	1.70	0.03	0.13
Milk fat, %	3.65	3.64	3.65	0.11	0.99
Milk fat, kg/d	1.60	1.55	1.54	0.09	0.65
Milk true protein, %	3.10	3.09	3.17	0.04	0.08
Milk true protein, kg/d	1.36	1.32	1.34	0.08	0.81
Milk lactose, %	4.79	4.85	4.81	0.35	0.23
Milk lactose, kg/d	2.10	2.08	2.05	0.11	0.83
MUN, mg/dL	9.22[a]	12.0[b]	10.4[c]	0.40	<0.001
ECM, kg/d[4]	41.4	40.3	40.3	2.20	0.72
ECM ÷ DMI, kg/kg	1.56	1.65	1.66	0.06	0.33
Milk NEL, Mcal/d[5]	30.8	30.1	30.0	1.64	0.72
BW, kg	602	598	594	2.73	0.13

[a,b,c]Means with different letter superscripts differ at $P < 0.05$.

[1]CM = Canola meal; ESBM = Extruded soybean meal; SSBM = Solvent soybean meal.

[2]Largest SEM published in table; DMI, n = 447; Milk yield, n = 421; Milk Yield ÷ DMI, n = 418; Milk composition variables, n = 44; BW, n = 450; (n represents number of observations used in the statistical analysis). Data are presented as LSM.

[3]Main effect of treatment.

[4]Energy-corrected milk (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).

[5]Milk NEL (Mcal/d) = kg of milk × (0.0929 × % fat + 0.0563 × % true protein + 0.0395 × % lactose) (NRC, 2001).

Table 2. Blood plasma AA concentration (μM) in dairy cows fed diets containing canola meal (CM), extruded soybean meal (ESBM) or solvent extracted soybean meal (SSBM)

	Diet[1]				
Item	CM	ESBM	SSBM	SEM[2]	*P*-value[3]
Arg	78.9	84.0	79.1	4.60	0.32
His	48.0	51.3	46.3	2.49	0.31
Ile	129[a]	153[b]	128[a]	5.57	<0.001
Leu	142[a]	171[b]	132[a]	5.79	<0.001
Lys	80.6	83.1	80.1	3.38	0.71
Met[4]	25.4[a]	20.0[b]	23.0[a]	0.77	0.001
Phe	46.4[ab]	49.1[a]	42.2[b]	1.65	0.01
Thr	102	93.4	95.6	4.58	0.39
Trp	30.0	29.4	27.3	0.95	0.06
Val	271[a]	302[b]	250[c]	9.26	<0.001
∑EAA[5]	953[a]	1,036[b]	904[a]	30.4	0.003
∑EAA without Met	927[a]	1,016[b]	881[a]	30.0	0.002
Ala	263	236	245	8.57	0.09
Asn	44.5	50.4	46.0	2.32	0.08
Asp	5.08[a]	7.08[b]	6.23[ab]	0.59	0.03
Cit	71.2[a]	80.6[b]	70.9[a]	2.69	0.008
Cys	1.96[a]	1.27[b]	1.59[c]	0.08	<0.001
Gln	243	241	249	9.57	0.67
Glu	54.6	53.8	51.9	2.15	0.49
Gly	283	279	286	11.8	0.87
Orn	43.8	48.4	42.4	2.06	0.12
Pro	78.8	82.3	74.5	4.14	0.18
Ser	76.5	79.8	74.3	3.44	0.26
Tau	50.2	50.4	47.6	3.74	0.60
Tyr	48.1	48.7	44.4	1.93	0.12
∑NEAA[6]	1,273	1,268	1,251	35.6	0.86
∑TAA[7]	2,226	2,304	2,154	60.9	0.13
Carnosine	14.2	14.3	13.5	0.44	0.40
1-MH[8]	18.0[a]	17.7[a]	15.0[b]	1.43	<0.001
3-MH[8]	3.78	3.57	3.46	0.13	0.18
Urea	3,433[a]	4,695[b]	4,397[c]	116	<0.001

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]CM = Canola meal; ESBM = Extruded soybean meal; SSBM = Solvent soybean meal.

[2]Largest SEM published in table; n = 45 (n represents number of observations used in the statistical analysis).

[3]Main effect of treatment.

[4]CM vs. SSBM, $P = 0.06$.
[5]Sum of essential AA.
[6]Sum of Non-essential AA (Ala, Asn, Asp, Cys, Cit, Gln, Glu, Gly, Orn, Pro, Ser, Tau, and Tyr were considered as Non-essential AA).
[7]Sum of total amino acids.
[8]1- and 3-methylhistidine.

Table 3. Enteric gas emissions[1] in dairy cows fed diets containing canola meal (CM), extruded soybean meal (ESBM) or solvent extracted soybean meal (SSBM)

Item	Diet[2]				
	CM	ESBM	SSBM	SEM[3]	*P*-value[4]
CO_2, g/d	13,118	12,868	13,163	341	0.40
H_2, g/d	0.49	0.43	0.48	0.05	0.27
CH_4, g/d	396	411	414	17.2	0.45
CH_4, g/kg of DMI	15.0^a	16.9^b	17.0^b	0.86	0.008
CH_4, g/kg of ECM[5]	9.53	9.94	10.4	0.60	0.14

[a,b]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]Rumen gas emissions were measured using GreenFeed (C-Lock Technology Inc., Rapid City, SD). Data were derived from 8 individual measurements staggered over a 3-d period.

[2]CM = Canola meal; ESBM = Extruded soybean meal; SSBM = Solvent soybean meal.

[3]Largest SEM published in table. CO2, n = 42; CH4, n = 38; CH4/DMI, n = 39; CH4/ECM, n = 37 (n represents the number of observations used in the statistical analysis). Data are presented as LSM.

[4]Main effect of treatment.

[5]Energy-corrected milk (kg/d) = milk yield (kg/d) × (38.3 × % fat + 242 × % true protein + 165.4 × % lactose + 20.7) ÷ 3,140 (Sjaunja et al., 1990).