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Effects of substitution of cottonseed meal by canola meal on milk yield and apparent digestibility of dry matter, organic matter and crud protein in diets of dairy cow

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ABSTRACT

Six midlactation Holstein cows were used in a replicated 3 × 3 Latin square design with 3 periods of 20 d. This study aimed to evaluate the effects of dietary substitution of unprocessed canola meal (CM) for cottonseed meal (CSM) on nutrient digestibility, productivity, and peripheral levels of albumin and thyroid hormones. Treatments included diets with 1) CM, 2) CM + CSM, and 3) CSM. Total crude protein (CP), non-protein nitrogen, and rapidly degradable true protein were greater in CM than in CSM, whereas cell-wall fibers, slowly degradable true protein, and unavailable proteins were lower in CM than in CSM. Feeding CM enhanced milk percents of protein and solids non-fat, and improved total tract digestibility of dry matter and CP. Dry matter intake, total tract digestibility of organic matter and cell-wall fibers, milk yield, and circulating albumin and thyro id hormones remained unchanged by feeding CM instead of CSM. Results suggest that unprocessed CM could be substituted for CSM in the diets of midlactation cows when the gossypol content and commercial availability of CSM are of the main concerns.

(**Key words:** canola meal, cottonseed meal, protein fractions, midlactation cows).

Abbreviation key: Amino acids, acid insoluble ash, CNCPS, solids non-fat, total solids.

INTRODUCTION

The less interest of poultry and hog industries in cottonseed meal (**CSM**) besides its lower price and greater content of fiber and escape protein as compared to soybean meal have been suitably advantaged in the diets of dairy cows (Coppock et al., 1987). Deficient Lysine and Methionine, variable lignin and gossypol content, and the limited commercial accessibility of CSM yet seem to restrict its inclusion in dairy rations (Blackwelder et al., 1998; Clark et al., 1987; Lindsey et al., 1980).

The high ruminal degradability of CP has noticeably led researchers to consider processing CM by physical (McKinnon et al., 1995; Moshtaghi Nia and Ingalls, 1994) and chemical (Khorasani et al., 1993; Wright et al., 2005) means. Such processing methods have been adopted to minimize the ruminal N waste and optimize the intestinal supply of the limiting AA for milk synthesis i.e., Methionine, Lysine, and Histidine. However, the benefits of escape protein seem to be offset by conducting the costly, standardized processing techniques, particularly for cows in mid and late lactation. In addition, while suggested as a ruminal stimulator of microbial protein synthesis, CM has been shown to encompass a ruminally undegradable protein (RUP) residue whose profile of AA is remarkably close to that of milk protein (Piepenbrink and Schingoethe, 1998).

We hypothesized that full dietary substitution of highly degradable N of unprocessed CM for more slowly degradable N of CSM maintains lactation performance without affecting feed intake, nutrient digestibility, and circulating levels of thyroid hormones. The diet of midlactation Holsteins was supplemented by CM, CM + CSM, or CSM to test this hypothesis.

MATERIALS AND METHODS

Cow Management and Experimental Design

Six (3 primiparous and 3 multiparous) Holstein cows (600 ± 50 kg body weight) in 120 ± 10 days in milk with 34 ± 2 kg/d initial milk yield (mean ± SD) were utilized in a replicated 3 × 3 Latin square design. The trial consisted of three 20-d periods. The first 15-d of each period were for acclimatization to the experimental conditions and the remaining 5-d for sampling and data collection.

Treatments, DMI, and Sample Analyses

Treatments included the diets supplemented with: 1) unprocessed canola meal (**CM**), 2) unprocessed canola meal + cottonseed meal (**CC**), or 3) cottonseed meal (**CSM**). Diets were formulated to contain equal levels of NE_L,CP, and NDF (NRC, 2001). The CP fractions and cell-wall fibers of the protein meals, dietary ingredients, and nutrient composition of the diets are given in Tables 1 and 2. Cows were offered the total mixed rations (TMR) twice daily at 0600 h and 1600 h. The TMR were offered at the rates to allow for 5-10 % orts. Fecal samples were obtained from the rectum at 1100 h everyday of the collection period. Upon sampling, a portion of feces was thoroughly mixed with the same volume of distilled water to obtain adequate uniformity for pH measurement. Urine was sampled by manual stimulation of the vulva and its pH was measured immediately. Feed and fecal samples were dried at 60^{o}C for 48 h, ground using a Wiley mill through a 1 mm screen (Wiley's pulverizer for laboratory, Ogaw Seiki Co., LTD, Tokyo, Japan), and stored at -20^{o}C for the wet chemistry analyses. All feed and fecal samples were analyzed for CP (Kjeldahl procedure, AOAC, 1990), NDF (Van Soest et al., 1991), ADF, ether extract, ash (AOAC, 1990) and acid insoluble ash (**AIA**) (Van Keulen and Young, 1977). The AIA was used as an internal marker for measuring apparent total tract digestibility of nutrients. The CP of canola meal and cottonseed meal was fractioned according to the Cornel Net Carbohydrate and Protein System (**CNCPS)** (Sniffen et al., 1992), and as analytically described by Licitra et al. (1996). On the last d of each period, the tail vein blood was sampled into the vacutainers containing EDTA, and centrifuged (Eppendorf AG, 5810R, Hamburg, Germany) at 3000 rpm for 10 min. The plasma harvested were frozen at -20^{o}C for later analyses of thyroid hormones by RIA. The circulating albumin was assayed in serum by acetate cellulose electrophoresis.

Milk production was recorded during last 5 d of each period. Milk was sampled thrice daily at each milking in pre-labelled 50 ml plastic vials, preserved using potassium dichromate, and stored at 4^{o}C until later analysis of fat, protein, solids non-fat (**SNF**), lactose, and total solids (**TS**) by Milk-O-Scan (134 BN Foss Electric, Hillerod, Denmark).

Statistical Analyses

Data were analyzed with General Linear Model Procedure of SAS (1996) using Type Ш estimation method of least square means. The initial model included the fixed effects of treatment, period, parity, and treatment × parity, and random effect of cow within parity. The effect of parity was assessed against the random effect of cows nested within parity. Because of insignificance, parity was excluded from the final models. Tukey's multiple range test (SAS, 1996) was used to establish the differences between treatments. Differences were declared significant at $P < 0.05$.

RESULTS

Cell-Wall Fibers and CP Fractions of CM and CSM

The CSM used in this study contained significantly greater ($P < 0.01$) levels of NDF and ADF than did CM (Table 1). The CSM was lower in CP, but higher in EE as compared to CM ($P < 0.01$). The fractionation of CP revealed that NPN and rapidly degradable true protein (B_1) were significantly ($P < 0.01$) greater in CM than in CSM. However, the slowly degradable (escape) true protein (B_3), total true protein, and unavailable N (C) were greater ($P < 0.01$) in CSM than in CM. Accordingly, the ruminally degradable protein (RDP) and RUP content of the experimental diets were increased and declined, respectively as CM replaced CSM (Table 2). Despite the discrepancies in CP and cell-wall fibers between two protein meals, the experimental diets contained comparable levels of CP, NDF, and ADF (Table 2).

Table 1. Crude protein (CP) fractions and cell-wall fibers of canola meal and cottonseed meal (DM basis)[1].

Item	Canola meal	Cottonseed meal	*P*
DM, %	94.9	94.2	NS
CP, %	44.0	29.0	***
CP fractions, % of total CP			
Non protein nitrogen, NPN (A)	13.9	5.2	***
Rapidly degradable true protein (B_1)	27.5	3.9	***
Moderately degradable true protein (B_2)	47.4	43.5	NS
Slowly degradable true protein (B_3)[2]	8.6	36.6	***
Acid detergent insoluble protein (C)[3]	2.6	10.8	***
Total true protein	86.1	94.8	**
NDF, %	27.5	50.0	***
ADF, %	20.8	36.5	***
EE, %	2.4	6.1	**
Ash, %	6.2	4.0	*

[1] The canola meal contained 6.62 μmol/g glucosinolates. The CP was fractioned according to Licitra et al. (1996) and based on Cornell Net Carbohydrate and Protein System (CNCPS).
[2] Neutral detergent insoluble protein – unavailable CP.
[3] Unavailable protein.
* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.01$.

Table 2. Ingredients and nutrient composition of the experimental diets (DM basis). [1]

	Dietary Treatments		
Item	CM	CC	CSM
Alfalfa hay	49.6	46.2	39.5
Corn grain	13.7	13.7	13.8
Barley grain	16.1	16.2	16.3
Canola meal	14.3	9.0	-
Cottonseed meal	-	9.0	23.6
Whole linted cottonseed	2.4	2.4	2.4
Wheat bran	2.4	2.0	2.9
Sodium bicarbonate	0.9	0.9	0.9
Vitamine and mineral supplement[2]	0.6	0.6	0.6
NE_L (Mcal/kg)[3]	1.50	1.51	1.52
CP, %	17.2	17.3	17.2
RDP[3], %	12.4	12	11.4
RUP[3], %	4.8	5.3	5.8
NDF, %	36.4	37.5	37.8
ADF, %	21.6	22.7	23.2
NFC, %	37.8	37.0	36.1
EE, %	3.0	3.1	3.3
Ca, %	1.0	0.9	0.8
P, %	0.4	0.5	0.5
DCAD, mEq/kg	282	290	303

[1] CM = unprocessed canola meal, CC = unprocessed canola meal + cottonseed meal, CSM = cottonseed meal.

[2] Contained 19.6% Ca, 9.6% P, 7.1% Na, 1.9% Mg, 0.3% Fe, 0.03% Cu, 0.2% Mn, 0.3% Zn, 100 ppm Co,100 ppm I, 0.1 ppm Se and 50×10^5 IU of vitamin A, 10×10^5 IU of vitamin D and 0.1 g of vitamin E /kg.

[3] Calculated from NRC (2001). RDP = ruminally degradable protein, RUP = ruminally undegradable protein.

DMI, Milk Yield and Composition, and Feed Efficiency

Daily dry matter intake (DMI) was similar among treatments ($P > 0.05$, Table 3). Actual milk yield, milk fat content and yield, and the yield of 4% fat-corrected milk (FCM) were not altered ($P > 0.05$) by the treatments. Milk content of protein and SNF were increased ($P < 0.05$) by dietary substitution of CM for CSM. However, the yields of milk protein and SNF, and milk protein efficiency remained unchanged ($P > 0.05$). The cows fed CM tended ($P = 0.09$) to have greater percent of milk lactose than did cows on CC. Milk content and yield of TS were not influenced ($P > 0.05$) by the dietary inclusion of CM instead of CSM (Table 3).

Table 3. Dry matter intake, feed efficiency, and milk yield and composition of cows fed canola meal (CM), cottonseed meal (CSM), or a combination of both (CC).

	Treatments				
Item	CM	CC	CSM	SEM	*P* =
DMI, kg/d	23.4	23.8	23.9	0.38	0.61
Actual milk yield, kg/d	28.0	28.5	27.0	0.98	0.55
4% FCM[1], kg/d	24.3	25.6	24.8	0.82	0.53
FCM:DMI	1.04	1.08	1.05	0.03	0.33
Milk components					
Fat, %	3.15	3.35	3.44	0.14	0.37
Fat yield, kg/d	0.87	0.95	0.93	0.04	0.37
Protein, %	3.08[a]	3.02[b]	2.98[b]	0.02	0.01
Protein yield, kg/d	0.86	0.86	0.81	0.03	0.45
Milk protein efficiency[2]	213	209	198	5.8	0.23
Lactose, %	5.41	5.36	5.39	0.01	0.09
Lactose yield, kg/d	1.52	1.53	1.46	0.05	0.56
SNF[3], %	8.49[a]	8.38[b]	8.38[b]	0.02	0.01
SNF yield, kg/d	2.37	2.39	2.27	0.09	0.57
TS[4], %	12.4	12.5	12.6	0.14	0.66
TS yield, kg/d	3.47	3.56	3.41	0.11	0.66

[a,b] Values with different superscripts in the same row differ significantly ($P < 0.05$).
[1] 4% fat-corrected milk.
[2] The ratio of milk protein yield (g/d) to protein intake (kg/d).
[3] Solids non-fat.
[4] Total solids.
SEM = standard error of mean.

Apparent Total Tract Digestibility of Nutrients, and Plasma levels of Albumin and Thyroid Hormones

Complete substitution of dietary CM for CSM in the diet of midlactation cows improved (P = 0.01) the apparent total tract digestibility of DM and CP (Table 4). The dietary treatments did not significantly affect ($P > 0.05$) the total tract digestibility of OM, NDF, and ADF (Table 4). Peripheral concentrations of albumin and thyroid hormones including thriiodothyronine (T_3) and tetraiodothyronine or thyroxin (T_4) were not impacted ($P > 0.05$) by feeding cows with CM instead of CSM.

Table 4. Apparent total tract digestibility of nutrients in cows fed canola meal (CM), cottonseed meal (CSM), or a combination of both (CC).

	Treatments				
Digestibility, %	CM	CC	CSM	SEM	*P* =
DM	75.8^{a}	70.7^{b}	70.4^{b}	1.1	0.01
OM	77.0	72.5	72.8	1.5	0.12
CP	78.3^{a}	74.5^{b}	73.1^{b}	0.8	0.01
NDF	64.3	57.5	58.7	2.5	0.19
ADF	50.7	47.3	45.7	1.9	0.21

^{a,b} Values with different superscripts in the same row differ significantly ($P < 0.05$).
SEM = standard error of mean.

CONCLUSIONS

Full substitution of more ruminally degradable N from CM for the greater escape N of CSM in the diet of midlactation cows increased milk percents of protein and SNF, and enhanced apparent total tract digestibility of DM and CP. These improvements were coupled with unchanged DMI, milk yield, feed efficiency, and peripheral levels of thyroid hormones and albumin. Continuous monitoring of glucosinolates in CM and consideration of their possible long-term effects on lactation performance are recommended.

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