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Evaluation of three rape seed commodities in the rumen of steers 2. Degradation of fibre fractions and disappearance of macrominerals *in situ*

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ABSTRACT

Rate and extent of ruminal degradation of detergent fibre fractions and disappearance of macrominerals (Ca, P, Mg, Na) of rape seed and of untreated and formaldehyde-treated rapeseed meals containing less than 8 μmol glucosinolates per gram of dry matter were investigated. Feeds were incubated in polyester bags in the rumen of three fistulated steers for 0, 2, 4, 8, 16, 24 and 48 h. Degradation characteristics of fibre fractions indicated that rapeseed fibre can be more degradable than previously assumed. The rape seed had the most degradable neutral and acid detergent fibre fractions. Fibre fractions of the formaldehyde-treated rapeseed meal were more degradable than those of the untreated meal. The effective degradabilities of neutral detergent fibre at assumed ruminal passage rates of 2, 5 and 8%/h ranged from 62 to 53% for the rape seed, 52 to 38% for the untreated meal and 65 to 49% for the formaldehyde-treated meal. The three rape seed commodities were a good source of macrominerals for ruminants, as indicated by macromineral concentrations in the feeds and by pattern and extent of ruminal disappearance of the minerals. The rape seed had a faster rate of disappearance of most macrominerals than the two meals. In contrast to fibre, macrominerals tended to disappear at a faster rate from the untreated meal than from the formaldehyde-treated meal.

KEY WORDS: rape seed, rapeseed meal, formaldehyde, rumen degradation, fibre, macrominerals

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INTRODUCTION

Although rapeseed meal (RSM) competes with protein-rich supplements in the diet of ruminants, RSM contains considerable levels of non-protein constituents. It has been reported to contain 30% hulls (Bell and Shires, 1982), which are mainly composed of cell-wall components. Hulls of autumn sown varieties of rape seed (*Brassica napus*) contained 49 to 54% neutral detergent fibre (NDF), 34 to 53% acid detergent fibre (ADF) and 18 to 26% acid detergent lignin (ADL) (Grenet and Barry, 1990; Keller et al., 1995). When rape seed hulls were incubated in the rumen *in situ*, only 61% of hull dry matter (DM) had disappeared after 72 h (Grenet and Barry, 1990). McKinnon et al. (1995) reported that effective ruminal NDF and ADF degradabilities of canola (*B. campestris*) hulls at an estimated ruminal passage rate of 5%/h were as low as 19 and 12%, respectively. Assuming a passage rate of 2.5%/h, however, Tamminga et al. (1990) reported an effective ruminal NDF degradability of 60% for RSM. To the authors knowledge, no other studies report on ruminal fibre degradation of whole rape seed or RSM.

Rapeseed meal contains a relatively high amount of P (Kirby and Nelson, 1988) and other macrominerals (Bell, 1993). Little research has been carried out on mineral availability in ruminants. Ingalls and Okemo (1994) reported that *in situ* disappearance of P of five different samples of canola meal varied from 36 to 53% after 12 h, and from 64 to 78% after 16 h of ruminal incubation, respectively. These values were lower than those found for a soyabean meal used in the same study (60 and 77% after 12 and 16 h, respectively; Ingalls and Okemo, 1994).

The objectives of this study were to determine characteristics of ruminal fibre degradation and of macromineral disappearance after *in situ* ruminal incubation of three rape seed commodities.

MATERIAL AND METHODS

Rape seed commodities

Three commercially available rape seed commodities, rape seed, RSM and formaldehyde-treated RSM (FRSM; Bioprofin®), were used. The proximate constituent composition of the feeds was reported previously (Südekum and Andree, 1997). Fibre, macromineral, total glucosinolate and formaldehyde concentrations of the three commodities are presented in Table 1.

TABLE 1

Concentrations of fibre fractions, macrominerals, formaldehyde and glucosinolates in the rape seed commodities, g/kg dry matter

	Rape seed	Rapeseed meal	Formaldehyde-treated rapeseed meal
Neutral detergent fibre	397	335	395
Acid detergent fibre	317	229	225
Acid detergent lignin	152	97	102
Calcium	4.5	7.3	7.5
Phosphorus	9.2	10.9	11.2
Magnesium	3.2	4.5	1.6
Sodium	0.2	1.3	0.9
Formaldehyde	ND[a]	ND	0.88
Total glucosinolates, μmol/g DM	7.6	6.5	7.0

[a] not determined

Animals, feeding and in situ procedure

The steers and feeding used in this trial were described by Südekum and Andree (1997). A previous paper (Südekum and Andree, 1997) emphasized data regarding ruminal degradation of DM and crude protein and ruminal disappearance of amino acids. The *in situ* procedure and calculations of ruminal fibre and macromineral disappearance and of fibre degradation and effective fibre degradabilities were performed as presented in detail for DM and crude protein in the previous paper (Südekum and Andree, 1997). Briefly, polyester bags were incubated in the rumens of three steers for 0, 2, 4, 8, 16, 24 and 48 h. Water soluble material was estimated by washing a sample through filter paper. Values for water-soluble material were subtracted from 0-h values to yield small particles escaping from the bags during washing. Values for fibre and macromineral disappearance at incubation times of 0 to 48 h were then corrected for small particles as outlined by Weisbjerg et al. (1990). Degradation parameters and effective degradabilties of NDF and ADF were calculated according to McDonald (1981), the latter at assumed rumen solid outflow rates of 2, 5 and 8% per h, which is representative for low, medium, and high feeding amounts (Agricultural Research Council, 1984).

Chemical analysis

Feedstuffs and residues from polyester bag incubations were prepared, dried and analysed for formaldehyde (in FRSM only) and total glucosinolates as

reported previously (Südekum and Andree, 1997). Dried residues were pooled by feedstuff and incubation time for fibre and macromineral analyses resulting in one observation per feedstuff and incubation time (7 observations per feedstuff including 0-h values). Detergent fibre fractions in the feedstuffs and residues from polyester bag incubations were determined according to Van Soest et al. (1991). The detergent fibre analyses were performed without the use of decalin. Sodium sulphite was omitted and triethylene glycol was used instead of 2-ethoxyethanol in the NDF procedure. Macromineral analyses were performed photometrically (P) and by atomic absorption spectroscopy (Ca, Mg) or flame spectroscopy (Na) according to Bassler (1976).

RESULTS

Data on ruminal disappearance of NDF and ADF are reported in Table 2. Because fibre and macromineral analyses were performed on pooled samples, no statistical evaluation of the data could be conducted. For rape seed and FRSM, the values of NDF disappearance increased continuously from 0 to 48 h of ruminal incubation. The ADF disappearance values of rape seed and FRSM were maximized after 16 and 24 h of ruminal incubation, respectively. The NDF

TABLE 2

Effect of ruminal incubation time on disappearance (%) of neutral detergent fibre (NDF) and acid detergent fibre (ADF) from polyester bags

	Washing loss[b]	Incubation time, h						
		0	2	4	8	16	24	48
Rape seed								
NDF	36.9	13.6	38.0	44.8	54.6	63.3	66.3	68.9
ADF	50.4	52.5	64.4	66.3	68.2	73.0	74.4	75.8
Rapeseed meal								
NDF	15.2	9.0	7.1	15.4	33.4	49.3	52.6	61.7
ADF	32.5	10.5	6.9	10.3	23.6	31.8	29.8	38.1
Formaldehyde-treated rapeseed meal								
NDF	– 7.0	31.6	43.5	44.1	46.6	61.0	67.8	75.9
ADF	18.9	33.6	41.2	41.6	43.9	53.9	57.5	57.5

[a] values for disappearance were corrected for NDF or ADF escaping in small particles from the bags during washing according to Weisbjerg et al. (1990). Corrected disappearance of 0-h values equals the water-soluble fraction

[b] washing loss equals 0-h disappearance without correction for escape of small particles

TABLE 3

Nonlinear estimates and effective degradability values of neutral detergent fibre (NDF) and acid detergent fibre (ADF)

						Effective degradability[a]		
	a[b]	b	c	Lag	Undegraded[c]	2%	5%	8%
Rape seed								
NDF	15.5	50.9	22.0	0	33.6	62.1	56.9	52.8
ADF	53.8	20.3	23.7	0	25.9	72.5	70.6	69.0
Rapeseed meal								
NDF	8.1	52.3	11.0	2.5	39.6	52.4	44.1	38.4
ADF	8.7	26.3	15.9	3.5	65.0	31.7	25.5	21.7
Formaldehyde-treated rapeseed meal								
NDF	34.4	45.3	5.3	0	20.3	65.2	54.4	48.8
ADF	34.6	24.3	8.7	0	41.1	50.6	45.8	43.0

[a] effective degradability at three ruminal passage rates

[b] a = the portion (percentage) of NDF or ADF solubilized at initiation of incubation; b = the fraction (percentage) of NDF or ADF insoluble but degradable in the rumen; c = the constant rate (percentage per hour) of disappearance of fraction b; lag = lag phase (hours) prior to the commencement of degradation of fraction b

[c] undegraded = 100 − (a + b) (%)

and ADF disappearance values of RSM only exceeded the values of zero time (0 h) incubation after 4 and 8 h of ruminal incubation. After 48 h of ruminal incubation, disappearance of NDF from the rape seed commodities was ranked in the order FRSM > rape seed > RSM, whereas for ADF disappearance, the order was rape seed > FRSM > RSM.

Nonlinear parameter estimates and effective degradability values for NDF and ADF are presented in Table 3. Surprisingly, no lag phase prior to degradation of NDF and ADF was estimated for rape seed and FRSM, whereas for NDF and ADF of RSM, a lag phase occurred. The magnitude of the b fraction of NDF declined in the order RSM > rape seed > FRSM, and that of ADF declined in the order RSM > FRSM > rape seed. The difference between the highest and lowest values, however, was only 7 and 6 percentage units for NDF and ADF, respectively. The rate constant of disappearance (c) of NDF and ADF largely differed between the three commodities. The values of c for NDF and ADF of rape seed were approximately four-fold and three-fold compared with those of FRSM. The c values of RSM were intermediate. The effective NDF degradability at the low ruminal passage rate (2%/h) was slightly higher for FRSM than for rape seed, whereas at the two higher ruminal passage rates, the values for rape seed were higher. The effective NDF degradability of RSM was

TABLE 4

Effect of ruminal incubation time on concentration (g/kg dry matter) of macrominerals in rape seed commodities[a] and polyester bag residues after ruminal incubation

	Feed	Incubation time, h						
		0	2	4	8	16	24	48
Calcium								
RS	4.45	10.0	11.4	14.2	21.4	22.5	18.6	9.3
RSM	7.32	14.3	16.4	17.9	18.7	18.9	18.1	19.0
FRSM	7.53	14.3	14.7	15.2	16.2	16.4	17.2	18.1
Phosphorus								
RS	9.21	6.61	7.46	6.24	2.97	2.68	1.99	8.53
RSM	10.90	14.13	14.22	13.78	10.95	5.98	3.12	1.07
FRSM	11.24	12.82	12.51	12.12	12.14	11.30	10.56	5.68
Magnesium								
RS	3.16	2.36	2.26	1.89	1.14	1.11	0.99	2.61
RSM	4.45	4.21	4.32	3.67	2.96	2.57	2.41	2.14
FRSM	1.55	0.97	1.68	3.56	4.49	4.27	4.20	4.41
Sodium								
RS	0.22	0.40	0.37	0.30	0.31	0.38	0.31	0.29
RSM	1.28	0.49	0.70	0.62	0.55	0.42	0.32	0.19
FRSM	0.94	0.32	0.50	0.40	0.47	0.37	0.42	0.31

[a] RS, rape seed; RSM, rapeseed meal; FRSM, formaldehyde-treated rapeseed meal

always 10 to 15 percentage units lower than that of the two other feeds. With respect to the effective ADF degradability, feeds were ranked in the order rape seed > FRSM > RSM, and a maximum difference of almost 50 percentage units between rape seed and RSM was observed at a passage rate of 5%/h.

The concentration of macrominerals differed largely among commodities, mineral elements and incubation times (Table 4). The two meals had higher levels of macrominerals than the seed except Mg. The Mg concentration was lower in the FRSM than in the RSM and rape seed. There was a general pattern that washing of the feeds (0 h disappearance) elevated the Ca and P concentrations and reduced the levels of Mg and Na with the only exception that the 0 h value of Na of rape seed was higher than that of the original feed. Compared with the 0 h values, the concentrations of Ca increased, whereas those of P decreased with increasing duration of incubation but the extent of the changes differed among feeds. Only the P content after 48 h of ruminal incubation of rape seed was greater than the 24 h value. Irrespective of the direction of the changes, the FRSM exhibited a moderate pattern of raising and declining Ca and P levels in the feed residues caused by ruminal incubation for different time periods, which

TABLE 5

Effect of ruminal incubation time on disappearance[a] (%) of macrominerals of rape seed commodities[b]

	Washing loss[c]	Incubation time, h						
		0	2	4	8	16	24	48
Calcium								
RS	−69.2	25.7	26.9	18.9	23.3	55.7	68.7	87.3
RSM	−37.1	13.9	2.9	4.2	29.6	52.0	62.4	72.0
FRSM	−53.6	19.5	16.4	14.9	15.1	32.2	38.5	60.2
Phosphorus								
RS	46.0	54.8	55.7	67.2	90.2	95.1	96.9	89.3
RSM	8.9	16.4	17.1	27.4	59.4	85.1	93.6	98.5
FRSM	7.7	25.7	26.9	30.3	34.6	52.1	61.2	87.1
Magnesium								
RS	43.9	39.8	50.0	63.0	85.9	92.5	94.2	87.8
RSM	33.6	28.3	27.5	44.4	68.5	81.6	85.8	91.1
FRSM	49.1	42.0	−0.6	−110.3	−148.3	−85.8	−58.6	−2.6
Sodium								
RS	−38.4	65.1	71.8	79.7	86.9	91.0	93.9	95.3
RSM	72.8	84.5	78.5	82.7	89.3	94.5	96.6	98.5
FRSM	72.7	74.8	60.5	69.0	65.7	78.5	78.9	90.6

[a] values for disappearance were corrected for macrominerals escaping in small particles from the bags during washing according to Weisbjerg et al. (1990). Corrected disappearance of 0-h values equals the water-soluble fraction

[b] RS – rape seed; RSM – rapeseed meal; FRSM – formaldehyde-treated rapeseed meal

[c] washing loss equals 0-h disappearance without correction for escape of small particles

indicates a more steady release of Ca and P from FRSM than from either rape seed or RSM. As duration of ruminal incubation increased, the concentration of Mg decreased in the residues of rape seed (except after 48 h) and RSM and increased largely in FRSM. For Na, however, an increase was observed for RSM, a decrease for rape seed and no clear direction of changes for the FRSM residues.

When averaged across feedstuffs, zero time (0 h) disappearance increased in the order Ca < P < Mg < Na. For each macromineral, there were differences between the feedstuffs. Generally, the 0 h disappearance values of Ca and P were lowest for RSM, intermediate for FRSM and highest for rape seed. With only few exceptions, percent disappearance of P, Mg and Na from rape seed and RSM increased with longer incubation times (Table 5). The disappearance of P from FRSM was lower and slower than from the two other feeds. The disappearance values of Mg and Na of FRSM from 2 to 48 h and 2 to 8 h, respectively, were even lower than the 0 h values, indicating a substantial net inflow of these two

elements into the bags. Except for Mg of FRSM, the 48 h disappearance values of P, Mg and Na of all three rape seed commodities were > 87%. The highest values were observed for RSM. The pattern of ruminal Ca disappearance was different from that of the other macrominerals. The values of the water-soluble Ca fraction (0 h) of rape seed, RSM and FRSM were only similar after more than 2, 4 and 8 h, respectively, of ruminal incubation. The ruminal disappearance of Ca from RSM and FRSM also was lower than that of P, Mg and Na. The 48 h disappearance values of Ca were 20 to 30 percentage units lower than for the other elements. Only rape seed reached a level of Ca disappearance of >87% after 48 h of ruminal incubation.

DISCUSSION

The three rape seed commodities differed in fibre and macromineral contents and in characteristics of ruminal fibre degradation and macromineral disappearance. The NDF and ADF concentrations of rape seed and the NDF content of FRSM were much higher than those reported previously for rape seed (Ochodzki et al., 1995) and RSM (Slominski and Campbell, 1991; Moss and Givens, 1994). As values for fibre degradation and macromineral disappearance were very consistent, analytical errors can be excluded. Also, the fibre analyses were repeated by different persons and consistently gave identical results.

The few studies conducted so far on nutritive characteristics of rape seed fibre or hulls indicated low ruminal (Grenet and Barry, 1990) and whole-tract (Keller et al., 1995) digestibilities of fibre components. McKinnon et al. (1995) reported that digestible energy content of canola hulls for ram lambs was similar to that of a lucerne hay used in the same study but the hay had DM, NDF and ADF digestibilities of only 51, 39 and 28%, respectively. The effective NDF and ADF degradabilities of the same hulls at a ruminal passage rate of 5% were 19 and 12%, respectively (McKinnon et al., 1995). The effective degradabilites of NDF and ADF of the three commodities used in the present study were much higher. Even at the highest ruminal passage rate and for the least degradable feed, RSM, the values for effective NDF and ADF degradability were 19 (NDF) and 10 (ADF) percentage units higher than those reported by McKinnon et al. (1995).

Bailey and Hironaka (1984) reported that treatment of canola meal with formaldehyde at a level of 5 g/kg of meal reduced *in situ* disappearance of non-protein organic matter (DM – crude protein – ash). Surprisingly, in our study the effective degradabilities of NDF and ADF of FRSM were higher than those of RSM. The positive effect of formaldehyde treatment on fibre degradation might be related to the mode of application of formaldehyde on the RSM. Treatment was conducted under pressure, which may have weakened

cell-wall structures, and by this facilitating and accelerating access of ruminal microorganisms to the cell-wall. The observation that no lag period was found prior to NDF and ADF degradation of FRSM supports this hypothesis. It is noteworthy, however, that NDF and ADF of FRSM also contained a considerable portion of the soluble a fraction. The rate constant of fibre degradation ranked the rape seed commodities in the order rape seed > RSM > FRSM, indicating that increasing strength of physical treatment decreased the degradation rate.

Concentrations of Ca, P and Mg of rape seed were similar to the upper range values reported for 11 samples of Polish rape seed (Matyka et al., 1992) and those of RSM and FRSM were similar to the data summarized for canola meal by Bell (1993). For the macrominerals our data confirm that feeds produced from rape seed are a good source of macrominerals for ruminants (Bell, 1993). Except the concentration of Mg of FRSM was remarkably lower than reported previously (Bell, 1993). Because RSM and FRSM originated from the same batch of rape seed, it is obvious that the difference in Mg concentration between RSM and FRSM might be related to formaldehyde treatment. Moreover, only Mg in FRSM showed negative disappearance values, indicating net inflow of Mg into the bags, which additionally points to special effects of formaldehyde on Mg binding capacity of RSM.

There is a scarcity of data on ruminal release of minerals from rape seed and RSM. The *in situ* P disappearance from 5 samples of canola meal after 16 h of ruminal incubation ranged from 64 to 78% (Ingalls and Okemo, 1994). These values were lower than those observed for rape seed and RSM in our study but higher than that for FRSM. Phosphorus in rape seed and RSM appeared to be nearly completely available at the rumen level, as indicated by 24 h disappearance values of 97 and 94%, respectively. The values of P disappearance from FRSM were consistently lower up to 24 h of ruminal incubation. After 48 h, however, P disappearance from FRSM was as high as 87%. Thus, the time course of disappearance of P from FRSM indicated a slow yet steady ruminal release of this element. Because cell-wall digestion is highly sensitive to P deficiency in the rumen (Durand and Komisarczuk, 1988), the observed pattern of P release from FRSM may be beneficial especially for cell-wall degrading microorganisms.

With the one exception of Mg in FRSM mentioned above, the disappearance of Mg and Na was >90% after 24 or 48 h of ruminal incubation, indicating a high ruminal availability of these two elements in all three commodities. Within this time interval, however, the disappearance of the two elements followed a different pattern. More than 68% of total Na in rape seed and RSM were in the soluble fraction, whereas for Mg, only 31 to 42% of the total Mg that disappeared during ruminal incubation was soluble. Flachowsky and Grün (1992) observed that *in situ* Mg disappearance of artificially dried Italian ryegrass

and wheat straw was similar to DM disappearance when feeds were incubated in the rumen of sheep. In our study, Mg disappearance of rape seed and RSM was greater than DM disappearance (Südekum and Andree, 1997). Although rape seed and RSM had high concentrations of NDF providing a great number of binding sites for divalent cations that would favour cation exchange at the surfaces, ruminal disappearance of Mg of rape seed and RSM was always greater than zero for any time interval.

Within the first 2, 4 and 8 h of ruminal incubation, respectively, the values for Ca disappearance of rape seed, RSM and FRSM were lower than the respective 0 h values. This indicates that more Ca flowed into the bags and adhered to the feed particles than was released from the feeds during the observed time intervals. This supports observations that Ca plays a prominent role in cation exchange processes at cell-wall surfaces (Emanuele and Staples, 1990; Flachowsky and Grün, 1992; Flachowsky et al., 1994). After 48 h of ruminal incubation, the disappearance of Ca from the three commodities ranged from 60 to 87%. Ledoux and Martz (1991) reported a similar variation for 5 forages and 10 diets containing these forages.

CONCLUSIONS

In the present study, detergent fibre fractions of rape seed, RSM and FRSM were more degradable ruminally than previous studies on ruminal degradation of hulls of rape seed or *in vivo* digestibility of NDF and ADF of rape seed had indicated. The general ranking of fibre degradabilties of the three commodities in decreasing order, namely rape seed > FRSM > RSM, further indicate that treatment with formaldehyde increased microbial access to cell-walls and may thus account for enhanced degradation compared with the untreated RSM. Our data confirm earlier observations that, based on mineral concentrations in the original feeds, feedstuffs produced from *B. napus* are a good source of macrominerals to ruminants. The slow but steady ruminal release of most macrominerals from all three commodities could have an additional positive effect on ruminal microorganisms and hence cell-wall degradation.

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STRESZCZENIE

Ocena wartości różnych rodzajów pasz rzepakowych w żwaczu buhajków. 2. Trawienie włókna i uwalnianie makroelementów oznaczane metodą *in situ*

Szybkość i rozmiar trawienia frakcji włókna oraz ubytek Ca, P, Mg i Na z nasion rzepaku, poekstrakcyjnej śruty rzepakowej zwykłej lub traktowanej formaldehydem, zawierającej w 1 g suchej masy mniej niż 8 μm glukozynolanów, oznaczano inkubując te pasze w woreczkach z tkaniny poliestrowej umieszczonych w żwaczu 3 buhajków przez 0, 2, 4, 8, 16, 24 i 48 godzin. Otrzymane parametry rozkładu frakcji włókna wskazują, że włókno nasion rzepaku może być trawione w większym stopniu niż to dotychczas przyjmowano. Frakcje włókna poekstrakcyjnej śruty traktowanej formaldehydem były trawione w większym stopniu niż śruty nie poddanej działaniu formaldehydu. Efektywny rozkład NDF nasion rzepaku, przy założeniu tempa wypływu treści ze żwacza 2, 5 i 8%/godz, osiągnął wartości od 62 do 53%, natomiast poekstrakcyjnej śruty rzepakowej od 52 do 38%, a traktowanej formaldehydem od 65 do 49%. Zawartość makroelementów i tempo ich uwalniania w żwaczu ze wszystkich badanych prób wskazują, że wszystkie badane pasze rzepakowe były dobrym źródłem makroelementów dla przeżuwaczy. Większość makroelementów była uwalniana szybciej z nasion rzepaku niż z obydwóch śrut poekstrakcyjnych. Z poekstrakcyjnej śruty zwykłej większość makroelementów, w przeciwieństwie do włókna, miała tendencję do szybszego uwalniania niż ze śruty formaldehydowanej.