PROCESSING OF OILSEED RAPE AT GENTLE CONDITIONS RESULTING IN LIMITED GLUCOSINOLATE DEGRADATION AND FRACTIONATION INTO HULLS, OIL, SYRUP AND PROTEIN RICH MEAL

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INTRODUCTION

Traditional rapeseed processing (pressing and hexane extraction) results often in appreciable glucosinolate degradation: 40-60% of aliphatic glucosinolates (Daun, 1986) and even higher for indolylglucosinolates (Campbell and Cansfield, 1983) of which 4-hydroxyglucobrassicin is the most important in relation to double low rapeseed (Bjerg et al., 1987b; Jensen et al., 1991).

Various types of processing procedures have been developed for the removal of glucosinolates and other harmful compounds present in the seeds or formed during traditional rapeseed processing. These processes comprise physical, chemical, and enzymatic treatments, heat treatment followed by water extraction (Rauchberger et al., 1979), aqueous ethanol extraction (Van Megen, 1983; Finnigan et al., 1989), ammonia treatment or methanol-ammonia-water extraction (Naczk et al., 1986), preparation of protein concentrates (Mieth et al., 1984) and other detoxification procedures (Vaccharino et al., 1978; Maheswari et al., 1981; Lacroix et al., 1988).

A new type of oilseed rape processing has been developed (Olsen, 1988; Jensen et al., 1990). This process is based on myrosinase inactivation followed by enzyme catalyzed cell wall degradation in an aqueous slurry of dry milled rapeseed. This aqueous enzymatic process is performed at gentle conditions, without use of organic solvents, and result in four fractions: oil, protein-rich meal, syrup and hulls. The work now performed has comprised an evaluation of the product quality.

MATERIAL AND METHODS

Seeds of Danish-grown double low rapeseed (Brassica napus L.; spring variety) were obtained from Trifolium Silo A/S (Taastrup, Denmark). The enzymes used in the process were a multi-activity preparation (SP-311; Novo Nordisk A/S, Bagsværd, Denmark). The process was performed in the Pilot Plant, Novo Nordisk Enzyme Process Development using 100 kg seed for each batch and with details of the process as described previously (Olsen, 1988; Jensen et al., 1990). The reaction with cell wall degrading enzymes required approx. 4 hours at 50°C. Separation and purification of the products comprised decanting to remove hulls. Oil, protein-rich meal (Novo rapeseed meal; NRM) and syrup ("Sugar") were separated in three washing and centrifugation steps. The NRM fraction was spray-dried and the syrup was evaporated to a concentration of approx. 30% dry matter (DM).

The analytical methods used for the various compounds have been described elsewhere; chemical composition (AOAC, 1980), HPLC of glucosinolates (Sørensen, 1990), HPLC of aromatic choline esters (Clausen et al., 1983; Clausen et al., 1985), HPLC of carbohydrates (Jensen et al., 1990), HPLC of amino acids (Eggum and Sørensen, 1990), determination of myrosinase activity (Michaelsen et al., 1991b) and dietary fibres (Bjergegaard et al., 1991).

Details of the procedures and specific results from the animal trials will be presented elsewhere. The techniques used have followed the previously described methods for balance trials with rats (Bille et al., 1983), pig trials (Danielsen et al., 1987), and mink trials (Henriksen et al., 1987).

RESULTS

Chemical composition of the products obtained from different batches exhibited some variations as illustrated in Table 1.

Table 1. Chemical composition (% dry matter basis) of the samples used in the balance trials with rats, broilers, piglets and in mink trials (series 2 and 3).

	Protein (Nx6.25)	Stoldt fat	RHC	Ash	IDF	SDF
Casein	89.2	0.3	5.3	3.1	-+	-
NRM (series 2)	59.8	19.0	5.3	5.2	21.9	3.5
Defatted NRM	71.0	3.2	6.3	6.2	16.2	4.2
NRM (series 3)	56.6	26.4	2.1	-	22.1	1.8
Rape syrup	28.1*	0.6	24.6	21.0	0.0	8.2
Sugar beet molasses	17.8*	-	67.6	9.5	-	-
Pea (cv Solara)	24.9	2.6	45.1	3.1	12.2	4.1

* Various free amino acids and other N-containing LMW compounds contribute considerably.
\+ Not determined.

NRM had a high content of protein and a relative high content of fat and insoluble dietary fibres (IDF), whereas the content of soluble dietary fibres (SDF) was relative low. Rapeseed and NRM had a low content of readily hydrolyzable carbohydrates (RHC), whereas pea had a high content of RHC, dominated by starch.

Table 2 shows the composition of essential amino acids (free and protein bound). The samples varied in their content of essential amino acids. NRM had a relative high content of threonine, cysteine, methionine and tryptophan.

Table 2. Concentrations (g/16 g N) of the limiting amino acids in the samples used in the animal trials.

	Lys	Thr	Cys	Met	Try
Casein + 1% DL-Met	8.13	4.45	0.75	4.08	1.34
NRM (series 2)	5.54	4.75	1.97	2.18	1.56
Defatted NRM	5.53	4.78	1.93	2.18	1.56
NRM (series 3)	5.20	4.84	1.89	2.03	1.58
Rape syrup	5.75	4.02	2.44	1.58	0.65
Sugar beet molasses	0.34	0.55	0.34	0.19	0.20
Pea (cv Solara)	7.25	3.70	1.39	0.87	1.00

The majority of water soluble LMW rapeseed constituents including glucosinolates, aromatic choline esters, phytate and phenolics are extracted to the syrup fraction . The meal fraction contains only low concentrations of these LMW-compounds. Details of this has been described previously (Jensen et al., 1990), and an illustration for glucosinolates and aromatic choline esters are presented in Table 3.

Table 3. Glucosinolate and aromatic choline ester content in the rape samples (μmol/g dry matter) used in series 2 and 3.

	Glucosinolates					Aromatic choline esters		
	2*	4*	23*	26*	Total	sina-pine	lignane types	Total
NRM (series 2)	0.21	0.82	0.08	0.25	1.36	5.6	0.6	8.0
Defatted NRM	0.33	1.07	0.10	0.30	1.80	6.6	0.7	9.5
NRM (series 3)	0.25	0.87	0.07	0.22	1.41	5.8	0.6	8.3
Rape syrup	2.55	9.23	0.31	1.95	14.04	32.5	2.7	41.8

* 2) = Gluconapin, 4)= Progoitrin, 23) = Glucobrassicin, 26) = 4-Hydroxyglucobrassicin

Results from energy- and N-balance trials with young growing rats are shown in Table 4. Rats from group 1 were fed NRM (series 2), group 2 and 3 were fed with the same batch of NRM but with 10% rape syrup added or using defatted NRM. Group 4 and 5 were fed with NRM (series 3), for group 5 with 50% pea meal added and fortified with Met + Thr + Try.

Table 4. TD, BV, NPU, DE, and final rat weight obtained by energy- and N-balance trials with young growing rats using NRM, series 2 and 3 as protein source.

Series	Group No.	TD (%)	BV (%)	NPU (%)	DE (%)	Final rat weight (g)
2	1	82.3	94.9	78.0	84.4	85.71
	2	83.0	92.4	76.7	86.6	87.48
	3	85.0	95.4	81.2	86.8	84.32
3	4	82.3	89.4	73.6	85.6	81.22
	5	84.0	98.3	82.5	84.5	87.63

The protein digestibility (TD) and digestible energy (DE) were on the same level as for rapeseed meal from traditional rapeseed processing (Bille et al., 1983; Michaelsen et al., 1991a). The biological values (BV) can, however, be very high (group 5, Table 4), indicating that the amount of antinutritional compounds, especially glucosinolates, have been reduced to an acceptable level in NRM.

Tables 5 and 6 show selected data obtained with NRM (series 2; Tables 1-4) fed to broilers and piglets, respectively.

Table 5. Results from energy- and N-balance trial with increasing levels of NRM fed to broilers (twelve broilers with four collection periods = 48 observations per diet).

Diet % Novo rapeseed meal	1 0	2 6	3 12	4 18	F[1]
Initial weight, g	242	231	232	244	
Final weight, g	1439	1505	1506	1372	
Weight gain, g	1197	1274	1274	1128	
Average daily weight gain, g	42.7	45.5	45.5	40.3	NS
Feed consumption, g	2498	2328	2349	2063	
Feed consumption, kg per kg weight gain	2.10^{a2}	1.84^{b}	1.85^{b}	1.84^{b}	***
Digestible DM %	71.4^{c}	73.2^{ab}	74.2^{a}	72.3^{bc}	***
Metabolizable energy in % of gross energy	74.7^{b}	76.4^{ab}	76.9^{a}	75.1^{ab}	*
Deposited N per day, g	1.97^{a}	1.74^{ab}	1.88^{ab}	1.64^{b}	**
Deposited N in % of consumed N	56.3	55.7	58.5	57.4	NS

1) *** = $P \leq 0.001$, ** = $0.001 < P \leq 0.01$ * = $0.01 < P \leq 0.05$. NS = Non Significant (Tukey's test).
2) Values with different superscripts within a row are significantly different.

Table 6. Results from production trial with NRM added 0.17% Flavodan SW-783 and fed to four week old piglets.

Diet % Novo rapeseed meal	1 0	2 6	3 12	4 18	F[1]
No. of reiterations	10	10	10	10	
No. of piglets	20	20	20	20	
Average weight, kg					
at 4 weeks	8.5	8.6	8.5	8.5	
at 8 weeks	20.8	20.7	20.2	20.1	
Daily weight gain, g	440	431	419	413	NS
Feed consumption					
kg per piglet	17.0	16.6	15.7	15.2	
FUp[a] per piglet	20.6	20.3	19.5	19.0	
FUp[a]/kg weight gain	1.66	1.68	1.67	1.64	NS
Diarrhoea frequency					
days per piglet	1.1	1.0	1.0	1.4	NS

1) *** = $P \leq 0.001$, ** = $0.001 < P \leq 0.01$; NS = Non Significant
a) FUp = feed units for pigs = 7.72 MJNE (Eggum et al., 1985)

Production trials have been performed with mink (240 animals/trial) fed NRM at levels of 7.5% and 15%, where 15% correspond to 54% of the total protein and 41% of total fat in the mink diet. Results obtained are presented in Tables 7 and 8.

Table 7 Final weights and relative figures and deviation in g of the mink fed 7.5% and 15% NRM with and without molasses in the diets.

Group No.	Male (g)	Relative figures	Deviation (±)	Female (g)	Relative figures	Deviation (±)
Standard						
1 Control	2154	(100)	231	1204	(100)	134
2 7.5% NRM	2098	(97)	217	1212	(101)	168
3 15% NRM	2052	(95)	205	1187	(99)	88
4 7.5% NRM+M*	1977	(92)	361	1184	(98)	113
5 15% NRM+M*	2001	(93)	248	1212	(101)	127
Pastel						
1	2116	(100)	235	1137	(100)	125
2	2025	(96)	334	1159	(102)	149
3	2081	(98)	248	1137	(100)	125
4	2006	(95)	248	1095	(96)	130
5	2025	(96)	301	1192	(105)	162

M* = Sugar beet molasses.

Table 8 Feed consumption (FC, Mcal metabolizable energy per animal) of the mink fed the different diets (average of all animals) and fur quality and size of the male mink.

		STANDARD		PASTEL	
Group No.	FC Mcal/animal	Fur size cm	Fur* quality	Fur size cm	Fur* quality
1	45.3	75.1	7.2	76.7	7.5
2	44.3	74.4	7.3	73.8	8.4
3	43.6	73.8	8.4	74.8	7.1
4	43.6	73.5	8.6	74.0	9.1
5	43.5	73.7	8.4	74.9	8.2

*) 1-15, 15 best.

No difference in final weight was observed, whether the mink were fed 7.5% or 15% NRM in the diet. Addition of sugar beet molasses did not show any positive effect on the growth rate of the mink.

The post mortem examinations of animals fed NRM revealed no lessions, neither at the macroscopic level nor by the histological examinations of rats and mink (Henriksen, 1989). The weights of the organs showed no difference between the different groups.

DISCUSSION

Novo rapeseed meal (NRM) is a product without hulls and with a high content of protein, a relatively high lipid content and a relatively high content of IDF. The balance trials with young growing rats revealed that NRM is a protein source of high nutritional value. The untreated syrup fraction may also prove beneficial for some purposes. The hull fraction on the other hand has only limited interest as feed to monogastric animals owing to a very low digestibility (Bille et al., 1983). The digestibility of NRM can be improved and this possibility seems to be closely connected to the insoluble dietary fibre (IDF) (Bjergegaard et al., 1991).

The high BV (98.3%) obtained with the mixture of NRM + pea supplement with amino acids show that the concentrations of glucosinolates, products thereof and other antinutritional compounds are very low (Bjerg et al., 1989; Michaelsen et al., 1991a).

The energy- and N-balance trials with broilers revealed that up to 12% NRM can be included in the diets to broilers without causing problems. Inclusion of 18% NRM in the diet decreased voluntary feed intake considerably. The digestibility of dry matter and gross energy decreased also significantly at this level, but the protein utilization and the feed conversion ratio were not affected. This indicate that no negative effects of glucosinolates or other antinutritional compounds occurred. The only problems remaining by using too high amounts of NRM in broiler diets are thus the dietary fibres and the negative effect on palatability.

Production and balance trials with NRM to piglets revealed decreasing digestibility of protein and energy with increasing levels of NRM in the diets. TD was affected more than DE, but both parameters correlated well with the IDF content (Bjergegaard et al., 1991). The negative effect of NRM on feed consumption and thereby weight gain, also observed by other as a result of using rapeseed meal in the diets (Baidoo et al., 1987a & b; Gill and Taylor, 1989), can not be a result of effects from glucosinolates/glucosinolate products. Addition of Flavodan to NRM reduced also the problems with voluntary feed intake.

The results obtained with NRM to mink showed that this protein source improved the fur quality (Henriksen et al., 1987) and even the high levels of NRM used in the diets did not cause any nutritional problems. The series with addition of sugar beet molasses did not increase the growth rate of the mink. Energy- and N-balance trials with rats, in which sugar beet molasses were added to NRM and fed to young growing rats gave the same conclusion. It may be possible to obtain a positive effect on the growth rate if the right source of low molecular weight compounds is chosen. If the glucosinolate problem in the rape syrup can be solved, a beneficial effect from this source might be obtained. The slightly lower final weight observed for the male mink fed NRM may be explained by the lower lysine content in the rapeseed diets, as the lysine can be critical for the BV of rapeseed protein. Finally, the trials showed that NRM was superior to heat treated rapeseed and pea, in accordance with previously reported data concerning the quality requirements to rapeseed products which can be used in mink diets without causing problems (Bjerg et al., 1987a; Henriksen et al., 1987).

Compared to traditionally used methods of oilseed rape processing, the new method results in a limited degradation of glucosinolates. The problems caused by these harmful degradation products in rapeseed oil and meal are thus reduced correspondingly.

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