

Effects of thermal processing on digestibility and protein utilization of rapeseed meal of medium and low glucosinolate type in diets for growing pigs

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Abstract. The nutritive value of rapeseed meals (RSM) from *Brassica campestris*, 0 and 00-cultivars, with medium (25—55 µg/g defatted meal) and low (<25 µg/g) level of glucosinolates (GL), normal solvent extracted meal or thermal treated in order to decrease protein ruminal degradability (Öpex-process) or followed also by treating for GL-reduction, was investigated in three digestibility and balance trials with growing pigs. The GL-reduction treatment used removed 0.68 of the original GL, while Öpex treated RSM's had 0.33 to 0.45 lower total GL-content than untreated RSM's. The various cultivars or differently processed RSM's were close to each other in their proximate composition. However, thermal treated 0-RSM had a slightly reduced lysine content compared to untreated meal. The efficient degradability of dry matter in the untreated RSM's was on average 0.532 and that of the Öpex-treated 0.485. The digestibility of CP in different RSM's varied from 0.677 to 0.842 with no significant difference between 0 and 00-RSM's or to the RSM treated for GL-reduction ($P > 0.05$), although 00-RSM's tended to have higher OM and CP digestibilities compared with 0-RSM; pooled mean values being 0.638 vs. 0.715 for OM and 0.715 vs. 0.775 for CP. RSM treated for ruminant escape protein had the same or better digestibility than untreated RSM; pooled average values being 0.669 vs. 0.680 for OM and 0.746 vs. 0.757 for CP. This observation has practical importance since the same treatments of RSM could be employed for meals to be used in diets of both ruminants and pigs. In these experiments, the protein utilization was efficient and differences between the dietary treatments were small and insignificant. Heat treatment (Öpex) did not decrease protein utilization despite a small reduction in lysine content.

Index words: rape seed meal, glucosinolate, thermal processing, digestibility, pig

Introduction

Production of rapeseed is one of the most readily available means of increasing the domestic supply of protein of high biological

value in Finland. The harvested seed is rich in oil and protein, the former being increasingly used for human consumption. Production of rapeseed oil for fuel purposes is also under evaluation, which means increased oil

seed meal supply as a protein source for animal feeding. Removal of the oil leaves rape seed meal (RSM) containing 350–400 g/kg crude protein with an amino acid balance that compares well with that of soybean meal. Whilst RSM is currently included in ruminant rations with promising response (TUORI *et al.* 1989, unpubl. HUHTANEN *et al.* 1991), the use in pig and poultry rations has not been realised because of the presence of a number of undesirable factors. However, many investigations have shown RSM as a potential replacement for e.g. soybean meal (KIISKINEN 1984, NÄSI *et al.* 1985).

Rapeseed meal has some antinutritional factors and toxic constituents which restrict the utilization of RSM as feed for pigs. The main factors responsible for lowering the nutritive value are the hulls with a high fibre content of the rapeseed, the glucosinolates (GL), tannins, rapeseed gums, myrosinase and phytic acid (FENWICK and CURTIS 1980, BELL 1984).

The most important factor limiting the potential RSM as a protein supplement in pig feeding is the presence of glucosinolates (RUNDGREN 1983). These compounds are broken down by the enzyme myrosinase into toxic, goitrogenic substances which cause metabolic disturbances and depress food intake and growth rate. Some of these are goitrogenic and others are potentially hepatotoxic, whilst the majority are volatile and have a strong bitter taste (BELL 1984). Plant breeding has managed to develop varieties with lower levels of GL. Meals prepared from rapeseed varieties with low or medium contents of GL are finding increasing acceptance as a protein source in pig diets and are being used as replacements for soybean meal (SBM) (THOMKE 1984, NÄSI *et al.* 1985, ROWAN and LAWRENCE 1986).

An improvement in the nutritional quality of RSM would be expected from a reduction in the glucosinolate content. In addition, a variety of processes have been reported for the removal of glucosinolates from rapeseed products. Such processes, generally termed detoxification, involve chemical, microbiolog-

ical or physical treatments alone, or in combination (FENWICK *et al.* 1986).

The fibre content of RSM is almost double that of SBM which lowers the nutrient digestibility and energy value. Rapeseed contain hulls 165–187 g/kg, on dry matter basis (APPELQVIST and OHLSON 1972). After oil extraction, the resulting meal contains about 300 g/kg of hulls. Rapeseed hulls contain about 200 cellulose, 230 lignin, 90 pectin, 200 protein and 50 ash g/kg, but very little free carbohydrates or lipids. Pectins, cellulose and arabinose-based carbohydrates are dominant carbohydrates in hull-free RSM and these are not regarded as being readily digested by enzymes secreted by the intestine of pig. Insoluble fibre tends to increase transit time and form an insulating coat on the digestible nutrients, thus reducing the nutrient supply. Soluble fibres slow down the transit time, but their gelling, ion-exchange and absorbing characteristics retard digestion and absorption. The breeding work directed towards reduction of hull content may also make RSM more suitable for pig feed. Attempts to dehull rapeseed have been directed toward the same goal.

Proper processing is of great importance to the nutritional value of rapeseed meals for pig diets, and heat treatment in oil extraction and meal toasting inactivates some antinutritional factors in RSM. Heat treatment and hydrothermal processing can be used to rupture the cell wall matrix and modify the chemical structure of the constituents in order to render them more susceptible to enzyme degradation in the small intestine, thus improving the digestibility and utilization of the nutrients, especially amino acids (NÄSI 1991).

The first objective of the present study was to compare the nutrient digestibility of rapeseed meals with various levels of glucosinolates of different varieties before and after processing for GL-reduction. The second objective was to elucidate the effect of thermal processing used in order to decrease protein ruminal degradation on the nutritive val-

ue of rapeseed meals as protein supplement in pig nutrition.

Material and methods

The rapeseed meals used in Expt. I, prepared from medium glucosinolate variety 0-type (*Brassica campestris*), were: 1.) normal solvent-extracted 0-RSM (cv. Emma), 2.) same as 1) but heat-treated (Öpex), to yield a low-degradable rape seed protein for ruminants. The RSM's, prepared from medium or low glucosinolate varieties, in Expt. II. were: 1.) normal solvent-extracted 0-RSM (Emma), 2.) same as 1) but heat-treated (Öpex) 3.) heat-treated (Öpex), low rumen degradable 00-RSM (cv. Esko), 4.) normal solvent-extracted 00-RSM followed by a process of reduction of glucosinolates (Öljynpuristamo Oy, Helsinki) and in Expt. III 1.) normal solvent-extracted 00-RSM (cv. Esko) and 2.) same RSM as 1.) but heat-treated (Öpex), for low rumen degradable protein.

Öpex process (Öljynpuristamo Oy, Helsinki) is a pressurized heat-moisture treatment, where a sequence of cell rupturing pressure is added to achieve a rapid protein denaturation of the surface molecules. The process is a programmed semi-batch treatment. It also eliminates a part of the antinutritional compounds in the meal as well as producing rumen low-degradable protein. Ferrous sulphate was used as a supplement at a level of 1.0 g/kg meal during toasting to reduce the GL content.

In the first digestibility and balance trial, the normal and Öpex processed 0-RSM's were used at the inclusion level of 202–212 g/kg as protein supplements in isonitrogenous, 160 g/kg diet crude protein (CP) barley-based diets. In the second digestibility and balance trial, the variously processed 0- and 00-RSM's were used at the inclusion level of 200 g/kg as protein supplements in four isonitrogenous, 152 g/kg CP, barley-based diets adjusted with barley protein. The third trial comprised assays of normal and Öpex 00-RSM's at inclusion levels of 203 and 192 g/kg providing diets with 160 g/kg CP.

The first experiment was made with six castrates from 89 to 109 kg of live weight with a switch over experimental design and a basal diet assay made separately. The second experiment, in which pigs were at the live weight from 28 to 74 kg, had a 6 × 6 Latin square design including a basal diet assay simultaneously. The third trial was made with four pigs of weight between 66 and 89 kg using a switch over design. Each period comprised 6 days of adjustment and 6 days of total faeces and urine collection.

The coefficients of the apparent digestibility of the nutrients and the nitrogen balance were calculated for each diet and, using the difference method, for each RSM. Assay procedures were similar to those reported by NÄSI (1984), but crude fat was determined after acid hydrolysis. The glucosinolate content was analyzed with high-performance liquid chromatography which separates and quantifies individual components of GL. The degradability of the organic matter in the RSM's was tested by the method of ØRSKOV and McDONALD (1979).

Results and discussion

The total GL levels ($\mu\text{mol/g}$ defatted meal) of the RSM's made from cv. Emma, a medium GL 0-type, were between 16 and 55. The 00-RSM's made from cv. Esko, a low GL 00-type contained from 7 to 22 μmol of total GL (Table 1). The individual components of GL in relation to others did not vary between varieties. The GL-reduction treatment was reduced to 0.32 of the original total GL-content compared to untreated. The GL-level of Öpex-treated 0-RSM's was 0.55 of the normal untreated meals. Correspondingly Öpex-treated 00-RSM's had a level of 0.67 of the original. No difference in destroying various GL-components were found in present study, they decreased equally in relation to the total content. Lower responses have been reported by AUMAITRE et al. (1989) who found microwave treatment decrease the total GL content in RSM by 0.07, while extrusion has removed 0.19 of these antinutritive factors, principal-

ly procoitrin (AUMAITRE et al. 1989). Extrusion has been shown to inactivate myrosinase efficiently but has had relatively little effect on glucosinolate content, unless chemicals were added before extrusion (FENWICK et al. 1986). They also found that the combination of alkali and ferrous sulphate produces a decrease in total GL-content to 0.80. This later figure is at the same level as shown in present trial using ferrous sulphate supplementation during toasting the meal.

The chemical composition of the experimental feeds and their calculated feed values are presented in Table 1. Only small differences were found in the proximate composition of the processed RSM's. Oil was left in meal in solvetizing 101–125 g/kg to increase the energy density of RSM. The different RSM's were close to each other in their amino acid composition. However, the RSM

treated for ruminants had a slightly lower lysine and available lysine content compared to the untreated normal meal. Excessive heat treatment during processing can lead to the destruction of amino acids and the formation of biologically unavailable amino acid carbohydrate complexes, which was noticed by NÄSI et al (1985) and NÄSI (1991). The mean efficient degradability of the dry matter in untreated RSM's was 0.532 (s.d. 0.0129) and somewhat lower in Öpex-treated RSM's, on average 0.485 (s.d. 0.0217). TUORI (1991, unpublished) found similar degradabilities of the RSM's with equal processing as in present study, but the process of RSM for lower rumen degradability with the Öpex-treatment did not show any response in milk production in that study.

The digestibility of crude protein in the different RSM's varied from 0.677 to 0.842

Table 1. Chemical composition and calculated values of the experimental feeds (Experiments 1, 2 and 3).

	Experiment		Experiment 2				Experiment 3		Barley
	0—RSM		0—RSM		00—RSM		00—RSM		
	Norm	Öpex	Norm	Öpex	Öpex	Glucos. reduct.	Norm	Öpex	
Total glucosinolates									
µmol/g defatted meal	55	25	28	16	13	7	22	16	
Gluconapin	15	7	8	6	4	2	6.3	4.6	
Glucobrassicinapin	14	7	8	4	3	1.5	4.1	2.8	
Progoitrin	18	9	10	5	4	2	8.0	5.9	
Napoleiferin	4	2	2	1	1	1.5	0.9	0.7	
Others	0	0	0	0	1	1	3.0	1.8	
Crude protein, g/kg DM	361	353	336	340	335	331	325	337	130
Ether extract »	100	118	107	101	106	119	125	107	37
Crude fibre »	130	130	124	125	121	123	125	123	47
Nitrogen free extract »	335	325	353	352	354	344	349	354	759
Neutr. deterg. fibre »	243	240	256	267	249	236	257	265	187
Acid deterg. fibre »	176	173	183	187	176	166	170	172	42
Acid deterg. lignin »	77	73	74	76	66	58	74	72	—
Lysine, g/160 g N	56	54							41
Threonine »	44	44							35
Methionine »	23	24							19
Cystine »	23	23							24
Available lysine »	53	50							40
FU/kg DM	0.84	0.86	0.73	0.71	0.89	0.90	0.95	0.98	1.14
Kg/FU	1.32	1.31	1.57	1.45	1.28	1.28	1.05	1.02	1.03
DCP, g/kg DM	265	235	234	230	250	234	262	284	68
ME, MJ/kg DM	12.7	13.0	12.3	12.0	13.5	13.0	13.78	14.31	14.71
Efficient degradability DM	0.549	0.514	0.523	0.462	0.477	0.523	0.534	0.488	

(Tables 2—4). The 00-RSM's tended to have higher organic matter and crude protein digestibilities compared to 0-RSM's; pooled mean values being 0.638 vs. 0.715 for OM and 0.715 vs. 0.775 for CP, respectively. The treatment for GL-reduction did not have any response to protein digestibility. This is in agreement with the results of SAUER and CICHON (1980), who found no significant differences in the ileal apparent digestibility of essential amino acids between a high and two low GL-RSM. The Öpex-treated 00-RSM had significantly higher protein digestibility ($P < 0.001$) than other RSM's in Expt. 2. RSM's treated for ruminant escape protein had the same or better digestibility than untreated RSM's; pooled average values being 0.669 vs. 0.680 for OM and 0.746 vs. 0.757 for CP, respectively. This observation has practical importance since the same lots can be used for both ruminants and monogastrics. In Expt. 1 and 3, values of digestion were slightly higher which is to be expected because the pigs were older and made more efficient use of high fibre contents of RSM than younger pigs. Similarly, improvement of CP digestibility by 0.09 units and the ME content by 0.7 MJ per kg DM in sows was demonstrated when compared the results on growing pigs (JUST et al. 1983).

Carbohydrate digestibility of all the lots of

RSM's investigated was rather low. However, 00-RSM's tended to show higher digestibility of organic matter, crude fibre and nitrogen free extracts compared to 0-RSM's, but the differences were not statistically significantly ($P > 0.05$). RUNDGREN et al. (1985) also found lower carbohydrate and OM digestibilities for summer HG-RSM in comparison to LG-RSM. The dietary fibre in RSM represents the unavailable part of the diet, which reduces the digestibility of energy and amino acids. Degradation of the structural polysaccharides in rapeseed fibre and the cell wall matrix by physical or other means promotes the release of intracellular nutrients especially that of protein in the small intestine for digestion and absorption (NÄSI 1991). A small insignificant trend to improved NDF digestibility of RSM followed after Öpex-process was noticed.

The present digestibility data of various RSM tested in pigs are in agreement with the recent literature, which shows a superiority in the nutritive value low glucosinolate (LG)-compared with high glucosinolate (HG)-RSM (BOURDON and AUMAITRE 1990). The average digestibility value of CP of LG-RSM has been 0.79 versus 0.73 for HG-RSM and corresponding average values for content of ME for two RSM-types were calculated to be 13.1

Table 2. Digestibilities of processed rapeseed meals and protein utilization of the diets (Experiment 1).

	0-RSM		SEM	Statist. signif.
	Normal	Öpex		
Organic matter	0.645	0.656	0.0039	NS
Crude protein	0.736	0.748	0.0059	NS
Ether extract	0.623	0.597	0.0073	NS
Crude fibre	0.321	0.362	0.0140	NS
Nitrogen free extract	0.677	0.699	0.0091	NS
Neutr. deterg. fibre	0.239	0.298	0.0165	NS
Acid deterg. fibre	0.182	0.212	0.0118	NS
N intake, g/d	72.2	71.8	0.30	NS
N excr. in faeces, g/d	14.5	14.2	0.19	NS
N excr. in urine, g/d	32.2a	30.7b	0.21	$P < 0.05$
N retained, g/d	25.6	26.9	0.33	NS
of intake	0.354b	0.375a	0.0036	$P < 0.05$
of absorbed	0.444b	0.467a	0.0043	$P < 0.05$
Urea excr. in urine, g/d	55	52	—	—
Biological value	0.529	0.550	0.0040	$P < 0.05$

and 11.3 MJ per kg DM, respectively (RUNDGREN 1983). Danish experiments performed according to the regression technique on three different batches of LG-RSM resulted in an estimated average of the CP digestibility of 0.73 and of the ME value of 11.9 MJ per kg DM (JUST et al. 1983).

In these experiments, the differences in protein utilization between the dietary treatments were very small. Results of protein utilization

in Expt. 1. were poorer than in Expt. 2, but the protein intake was excess to the requirements and pigs were also heavier in that trial. Damages in protein quality were not caused by the thermal treatment in the Öpex process, according the present data. Usually heat treated meals, processed for rumen escape protein, are lower in protein value for pigs compared to untreated (NÄSI et al. 1985, CHANG et al. 1987), probably due to excessive heat which

Table 3. Digestibilities of processed rapeseed meals and protein utilization of the diets (Experiment 2).

	0—RSM		00—RSM		SEM	Statist. signif.
	Normal	Öpex	Öpex	Glucos. reduct.		
Organic matter	0.630	0.619	0.703	0.660	0.031	NS
Crude protein	0.696b	0.677b	0.746a	0.706b	0.007	P < 0.001
Ether extract	0.656	0.624	0.670	0.678	0.036	NS
Crude fibre	0.336	0.332	0.497	0.389	0.061	NS
Nitrogen free extract	0.649	0.650	0.730	0.692	0.053	NS
Neutr. deterg. fibre	0.335	0.408	0.526	0.400	0.069	NS
Hemicellulose	0.620	0.748	0.871	0.718	0.112	NS
Cellulose	0.440	0.512	0.630	0.510	0.064	NS
N intake, g/d	50.5	50.6	50.4	50.0	0.39	NS
N excr. in faeces, g/d	13.6	14.1	12.8	13.2	0.35	NS
N excr. in urine, g/d	13.8	14.1	14.0	14.1	0.59	NS
N retained, g/d	23.1	22.4	23.6	22.7	0.68	NS
of intake	0.458	0.444	0.474	0.453	0.014	NS
of absorbed	0.634	0.620	0.637	0.621	0.017	NS
Urea excr. in urine, g/d	27.4	28.8	30.1	24.8	1.40	NS
Biological value	0.705	0.693	0.706	0.694	0.016	NS

Table 4. Digestibilities of processed rapeseed meals and protein utilization of the diets (Experiment 3).

	00—RSM		SEM	Statist. signif.
	Normal	Öpex		
Organic matter	0.729	0.769	0.055	NS
Crude protein	0.807	0.842	0.025	NS
Ether extract	0.604	0.645	0.053	NS
Crude fibre	0.328	0.370	0.083	NS
Nitrogen free extract	0.769	0.796	0.075	NS
Crude carbohydrate	0.714	0.750	0.077	NS
Neutr. deterg. fibre	0.278	0.381	0.1131	NS
Acid deterg. fibre	0.103	0.185	0.0940	NS
N intake, g/d	54.5	54.6	0.04	NS
N excr. in faeces, g/d	11.8	11.1	0.05	NS
N excr. in urine, g/d	21.0	21.3	0.78	NS
N retained, g/d	21.7	22.2	0.43	NS
of intake	0.400	0.410	0.0077	NS
of absorbed	0.510	0.510	0.0122	NS
Urea excr. in urine, g/d	29.6	39.7	3.96	NS
Biological value	0.592	0.593	0.0122	NS

destroys essential amino acids. An improvement in the nutritive quality of RSM would be expected from a reduction in their GL-content, but the treatment for GL-reduction in this study did not show in the protein utilization. The effect of extraction of RSM with hot 0.70 ethanol and with water has improved net protein utilization in rats significantly compared to untreated RSM (FOWLER et al. 1987). Performance was also higher in pigs fed RSM washed with cold water extraction. BILLE et al. (1983) concluded that only minor or no physiological effects in protein utilization in rats were observed at low levels of isolated glucosinolates similar to double low RSM, which is in line with the present observations.

In the present study, where fairly high rape

seed meal supplements from cultivars of medium and low GL contents in barley meal diets were used in pig feeding, it can be concluded that RSM is a suitable protein source in supplementing grain protein. Double low cultivar tended to be slightly higher in nutritive value than 0-RSM. The thermal (Öpex process) used to decrease ruminal degradation of RSM protein and organic matter, did not decrease protein utilization so that the same process could be used for RSM used in diets for ruminants and for pigs. From a practical point of view it is also important to retain as high a protein intestinal digestibility as possible, according to the results of the present assay. Processes directed to the decrease glucosinolate content of RSM, did not improve digestibility of nutrients nor protein utilization.

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SELOSTUS

Kuumennuskäsittelyn vaikutus eri glukosinolaattipitoisten rypsirouheiden sulavuuteen ja valkuaisen hyväksikäyttöön lihasikojen ruokinnassa

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Tutkimuksessa selvitettiin kuumennuskäsittelyn ja glukosinolaattien vähentämisen vaikutusta 0- ja 00-rypsirouheiden sulavuuteen ja valkuaisen hyväksikäyttöön kasvavilla lihasioilla. Tutkimus käsitti kolme sulavuus- ja tasekoetta, joissa käytettiin kokonaiskeruumenetelmää. Tutkittavina lajikkeina olivat 0-rypsi Emma ja 00-rypsi Esko, joissa glukosinolaattien kokonaismäärä oli 16—55 ja 7—22 $\mu\text{mol/g}$ rasvatonta rouhetta. Rouheet olivat normaalisti uuttamalla tuotettuja ja kuumennuskäsittelynä oli Öpex-prosessi, jolla alennettiin rouheiden valkuaisen pötsihajoavuutta. Glukosinolaattien vähentäminen tehtiin käyttäen rautasulfaattikäsittelyä. Rouheet olivat kemialliselta koostumukseltaan lähellä toisiaan. Öpex-käsittely alensi hieman lysiinipitoisuutta käsittelemättö-

mään verrattuna. Rouheiden raakavalkuaisen sulavuus vaihteli 0.677 ja 0.842 välillä. 00-rouheet olivat sulavuudeltaan hieman parempia kuin 0-rouheet: orgaaninen aine keskimäärin 0.638 vs. 0.715 ja vastaavasti raakavalkuainen 0.715 vs. 0.775. Glukosinolaattien poistaminen ei vaikuttanut sulavuusarvoihin. Öpex-käsitellyt rouheet sulivat yhtä hyvin tai hieman paremmin kuin käsittelemättömät rouheet: orgaaninen aine keskimäärin 0.669 vs. 0.680 ja vastaavasti raakavalkuainen 0.746 vs. 0.757. Tällä havainnolla on käytännön merkitystä, koska samalla tavalla käsiteltyjä rouheita voidaan käyttää rehuna sekä märehittäjille että yksimahaisille. Valkuaisen hyväksikäytössä ei ollut eroja eri rouheiden tai erilaisten käsittelyiden välillä.