Quality demands for present and future optimal nutritional value of rapeseed for feed purposes

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Abstract

The amino acid composition in rapeseed proteins is well balanced and comparable with fishmeal for feed to monogastric animal production and protein protected rapeseed meal is well recognised as protein feed for dairy cattle. However, especially processing conditions and two groups of seed constituents are associated with limitation in rapeseed protein utilization in monogastrics; the content and structural types of glucosinolates and the dietary fibres. The problems with glucosinolates are associated with increased thyroid growth caused by goitrin produced from progoitrin, and the thiocyanate ion produced from indole-3-ylmethylglucosinolates. At too high concentration these compounds causes decreased protein utilization, reduced feed intake and decreased growth rate. Also the quality of cow milk can be affected mainly due to reduced iodine content, but some glucosinolate degradation products can also be transferred into milk. The high content of dietary fibre in rapeseed meal cause reduced digestibility of energy and protein. Double low rapeseed varieties are today only used in restricted amounts to monogastric animals. Therefore, it is still relevant to breed for lower glucosinolate content and optimize the technical processes in order to improve the nutritional value of rapeseed meal. This review gives an update of different initiatives performed in order to increase the nutritional value of rapeseed meal for feed purposes. Another issue important to discuss in order to efficiently optimize future utilization of rapeseed meal is an increased cooperation between plant breeders, rapeseed growers, processing industries, nutritionists and biochemistry researchers in order to fulfil the goal.

Introduction

Double low rapeseed or canola is a very important oil and protein crop, due to its high yield and high nutritive quality of both oil and protein. However, the content of anti-nutrients, as glucosinolates, aromatic choline esters, phytate and dietary fibres, restricts the use of rapeseed meal to sensitive animals.

The major antinutritional factor in rapeseed is the glucosinolates, while dietary fibres including lignin are the second most important components, being the main cause of lowering the nutritional value of protein and energy in rapeseed compared to soybean meal.

Glucosinolates

The glucosinolates in rapeseed can be divided into two groups. The first group is the aliphatic glucosinolates derived from methionine and include the major goitrogenic glucosinolate progoitrin and gluconapin. The other group is the indole glucosinolates derived from tryptophane and include the thermo labile 4-hydroxyglycobrassicin. The aliphatic glucosinolates can by plant breeding be reduced to levels close to zero. The indole glucosinolates have not been reduced by plant breeding and contribute with 2-4 μmoles/g seed in most varieties. The aliphatic glucosinolates cause without doubt the most negative antinutritional effects on the animals, whereas the importance of the indole glucosinolates is still questioned (Sørensen, 1990; Bell, 1993).

Glucosinolates are sensitive to degradation by either enzymatic or technical processes. It is generally agreed that enzymatic degradation of glucosinolates should be avoided due to enhanced negative effect of enzymatic produced glucosinolate degradation products.

Effect of glucosinolates and heat treatment on nutritional value

Various technical treatments have been investigated in order to reduce glucosinolate content and increase nutritional value of rapeseed meal. Inactivation of myrosinases by heat treatment is so far one of the most efficient ways to improve the nutritional value of rapeseed. Jensen et al. (1995a) performed a laboratory-scale toasting experiment with steam toasting at 100 °C of rapeseed meal for various time. The main effect of toastning was a reduction in the concentration of intact glucosinolates, but also the concentrations of carbohydrates and lysine were reduced by heating (Table 1). The decrease in glucosinolates and carbohydrates correspond almost to the decrease in lysine, when expressed on molar basis, and it is likely that this decrease is caused by reactions between the

nucleophilic ε-amino group on lysine and some of the glucosinolate breakdown products and/or reducing carbohydrates (Maillard reactions). This mechanism was further supported by the concurrent decrease in protein solubility.

Table 1. Effect of heat treatment on chemical composition and nutritional value of rapeseed meal.

Heat time, min	0	15	30	60	120	P-value
Chemical composition						
Glucosinolates, µmol/g	16.2	12.3	8.7	4.9	0.8	
Carbohydrates. g/kg[a]	115	-	111	-	105	
Lysine. g/16 g N	5.93	-	5.72	-	4.91	
Protein solubility. g N/100 g[b]	85	81	61	52	40	
Nutritional value of protein (rat trials)[c]						
True digestibility. %	77.0	73.9	72.1	72.8	71.2	<0.01
Biological value. %	71.2	71.1	71.3	68.3	65.8	<0.01
Net protein utilisation. %	62.9	61.8	61.4	58.6	56.3	<0.01

a) Sum of fructose, glucose, sucrose, raffinose and stachyose measured by HPLC
b) Nitrogen soluble in 0.2 N NaOH
c) Rat trials performed with a 1:1 mixture of protein from rapeseed and wheat gluten in order to ensure lysine to be the first limiting amino acid.

In another experiment, rapeseed meal from four different double low rapeseed varieties with different glucosinolate content was tested for nutritional value both after a mild heat treatment (95 °C for 25 min) in order to inactivate myrosinase and lipoxygenase prior screw pressing with a pilot plant scale Reinartz oil press, or exposed to an additional heating at 107 °C for another 25 min.
Feed containing 25% of rapeseed meal was formulated according to common practice with respect to nutrients, energy content and amino acids for broilers and piglets. Details regarding the feeding experiments has previous been described (Jensen et al., 1995a,b; Liu et al., 1995). Analyses of glucosinolates were performed by HPLC of desulfoglucosinolates as described by Sørensen (1990).
The glucosinolate content in the pressed rapeseed meal of the four different varieties and in their respective autoclaved meal samples is presented in table 2.

Table 2. Glucosinolate content in four rapeseed meal samples before (1-4) and after heat treatment (1h-4h).

Sample	µmol/g meal PRO[1]	GNP[2]	GBC[3]	4-HG[4]	GLB[5]	Total
1	1.5	0.6	0	1.3	0.1	3.4
2	8.3	1.7	0.3	1.7	0.1	12.2
3	11.1	2.6	0.9	2.9	0.7	17.9
4	21.6	8.5	2.9	2.7	0.3	36.0
1h	1.3	0.4	0	0.3	0.1	2.0
2h	6.8	1.4	0.3	0.6	0.1	9.2
3h	8.4	2.1	0.8	0.9	0.3	12.5
4h	14.4	5.7	2.0	0.7	0.2	23.0

[1] Progoitrin, [2] Gluconapin, [3] Glucobrassicanapin, [4] 4-Hydroxyglucobrassicin, [5] Glucobrassicin

On average one third of the glucosinolates were degraded by the second heat treatment. 4-Hydroxyglucobrassicin was the most heat sensitive glucosinolate with an average degradation of 71%, while the aliphatic glucosinolates on average only were degraded 20-25%.
Feed consumption and weight gain decreased with increasing glucosinolate content in the rapeseed meal fed to the broilers, irrespective of heat treatment, but feed utilization was unaffected. For the piglets feed utilization increased with increasing glucosinolate content in the feed for the varieties exposed to the mild heat treatment, whereas no difference was observed between varieties exposed to the longer heat treatment.
The negative effects of the glucosinolates on production parameters were accompanied by an enlargement of liver and thyroid as well as production of the hormone T3 by the thyroid (Table 3).

Table 3. Effect of glucosinolate content and heat treatment on size of liver and thyroid, and production of the hormone T3 in broilers and piglets

Sample	Liver g/kg			Thyroid mg/kg			T_3 nmol/l		
	Rats	Broilers	Piglets	Rats	Broilers	Piglets	Rats	Broilers	Piglets
1	43[b]	19	30[b]	89[b]	83[b]	119[b]	7.82[ab]	2,17	2,16
2	47[ab]	22	32[b]	92[b]	124[ab]	137[b]	9.58[a]	2,30	2,90
3	52[a]	21	31[b]	128[a]	169[a]	167[ab]	7.60[ab]	2,27	3,01
4	54[a]	21	37[a]	116[ab]	177[a]	192[a]	4.92[b]	1,68	2,59
P-value	0.003	0.08	0.006	0.005	0.001	0,01	0.01	0,3	0,2
1h	42[b]	19[b]	27	65[b]	85	100	8.03	1,73[b]	2,95
2h	47[ab]	21[ab]	27	83[b]	107	105	7.73	2,61[a]	2,58
3h	51[a]	24[a]	28	144[a]	125	105	7.95	2,53[a]	3,01
4h	55[a]	24[a]	30	138[a]	128	117	6.57	2,77[a]	3,02
P-value	0.001	0.001	0.2	0.002	0.06	0.4	0.5	0,001	0,8

The present study shows that meal from rapeseed varieties with a glucosinolate content less than 10 µmol glucosinolate/g seed is of a higher nutritive value for broilers and pigs than meal from rapeseed varieties with 15-20 µmol glucosinolate/seed.

Digestibility of rapeseed meal
The relative low digestibility of protein and energy in rapeseed meal is attributed to the high content of dietary fibres and dietary fibre associated protein. Especially the hull has a high proportion of indigestible dietary fibres and dietary fibre associated protein (Jensen et al., 1990; Jensen et al., 1995 b). Different rapeseed samples showed a variation in lignin content from 47-115 g/kg oil free meal, while the total content of dietary fibre varied from 245-517 g/g oil free meal. The dietary fibre (r = -0.471), lignin content (r = -0.735) and hull content (r = -0.398) decreased with increasing seed size.
Amino acid composition of the hulls and hull free meal revealed that 7-12% of total lysine and 8-14% of total threonine are located in the hulls. In addition hydroxy-proline make up 7-11% of the protein in the hulls, indicating a common occurence of ester linkages between protein and dietary fibre constituents.
In agreement with these findings the digestibility of protein and energy found in digestibility trials with rats were negatively correlated to the hull and lignin content (-0.757; -0.699; -0.681 and –0.696; P<0.05) (Jensen et al., 1995 b).

Conclusion
The present experiments revealed a clear effect of heat treatment on glucosinolate content, lysine content, protein solubility and nutritional value of rapeseed meal. The results thus underline the importance of combining low glucosinolate varieties with an optimal heat treatment of rapeseed meal in order to maximize the nutritional value of rapeseed meal.
Regarding seed size it is clear that there is an appreciable variation in the hull proportion between seeds, which is largely dependent on seed size. Therefore a selection towards large seed and varieties with a low hull content, will be nutritional beneficial with respect to increased digestibility of nutrients and thus diminished excretion of nutrients to the environment.

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