EVALUATION OF LOW OR HIGH GLUCOSINOLATE RAPESEED MEALS IN EXPERIMENTS WITH GROWING PIGS AND POULTRY

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INTRODUCTION

In Europe three rapeseed meal (RSM) qualities with different glucosinolate and aglucone content are produced at present. Conventional (C) RSM is excluded from pig and poultry diets or fed only in small quantities. RSM of spring varieties with <30 mmol glucosinolates + aglucones/kg (double "zero" qualities, DQ) can replace at least half of the soya-bean meal (SBM) in the feed (RUNDGREN 1983). Feeding recommendations for RSM of newly bred winter varieties (N) with a glucosinolate content "between" CRSM and DQRSM are not available up to now.

In present experiments it was necessary to quantify the constituents of a CRSM and RSMN at first. In feed selection tests pigs should choose between diets with different glucosinolate content. In digestibility experiments RSM quantity was high to guarantee a high intake of non starch carbohydrates, including crude lignin. In feeding experiments with pigs SBM was completely replaced by RSM, in the chicken diet by the half. Due to RSM treatment the content of glucosinolates + aglucones ranged from 0.8 to 17 mmol/kg diet in the experiment with broiler chickens. The iodine dosage was varied, because iodine has had a greater effect on the thyroid than the glucosinolates (SCHÖNE et al. 1990b).

MATERIAL AND METHODS

The CRSM or the RSMN contained 407 or 414 g crude protein and 81 or 89 g crude lignin/kg dry matter (DM). The content of further crude nutrients and cell wall fractions (Van SOEST 1963) was described earlier (SCHÖNE et al. 1990c). The RSMN contained one third glucosinolates and aglucones (determination according to LANGE et al. 1986) of the CRSM (Fig. 1). In both meals the treatment with Cu and with myrosinase (extraction with cold water and 90 % ethanol from freshly ground Sinapis alba seed) lowered the glucosinolate and aglucone content to < 15 % of the initial content.

The animal experiments included a total of 80 pigs (Landrace x Large White) and 192 broiler chickens (Line Tetra B). In the digestibility experiments including 16 pigs (50 kg live weight) wheat barley diets - basal, 48 % SBM, 24 % CRSM, 24 and 48 % RSMN - and starch sugar diets - 48 % SBM, 48 % RSMN - were tested. In the feed selection experiments with 4x4 pigs and 5 periods with 5 d each pig received two diets from two troughs ad libitum. One diet was without RSM, one with increasing quantities of RSMN (1st period) or CRSM (2nd period). Thereafter the same percentage of both meals (3rd period) or of untreated versus Cu^{2+} treated RSM (4th and 5th period) were compared (for details see SCHÖNE et al. 1990a). The pig feeding experiment included 4 main groups with 12 animals each: CRSM, SBM pair fed to CRSM, RSMN, SBM pair fed to RSMN. In each group three subgroups with 4 pigs have been established:

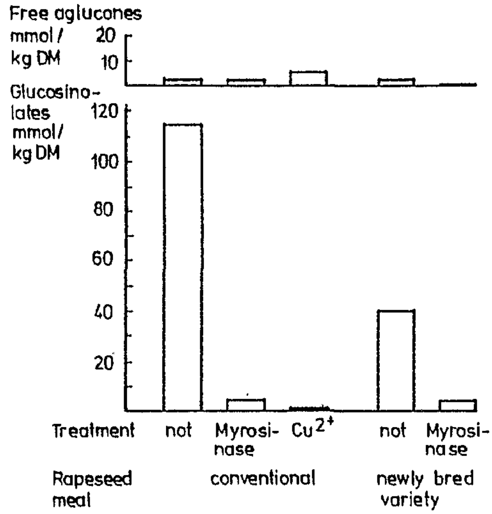

Fig. 1. Content of glucosinolates and free aglucones in rapeseed meals tested in the experiment with broiler chicks.
Cu^{2+} treatment: Soak 1 kg RSM with 2 l aqueos solution of 6.25 g $CuSO_4$ x $5H_2O$ and dry the mash at 60°C.
Myrosinase treatment: For 1 kg CRSM use myrosinase from 1 kg, for 1 kg RSMN that from 300 g seed of Sinapis alba. Soak 1 kg RSM with 2 kg suspension. Dry 24 h at 50°C and than by 60°C.

0, 0.0625 (only RSMN and SBM pair fed), 0.25 or 1 mg (only CRSM and SBM pair fed). The diets with 14 % SBM or 16 % RSM were isonitrogenous but not isocaloric (SCHÖNE et al. 1990c). The initial pig weight was 21 kg. When pigs of the SBM groups weighed 106 kg these and the pair fed animals of the RSM groups were slaughtered. After slaughtering the thyroids were weighed and the iodine content was analyzed (GROPPEL 1986). At Day 119 blood was sampled and the serum T_4 content was determined (JAHREIS et al. 1985).In the chick experiment maize diets (SCHÖNE et al. 1989) with 30 % SBM (487 g crude protein/ kg DM) or 12 % SBM + 16 % RSM (qualities and treatments in Fig. 1) were compared. Six groups with 16 animals received feed without supplementary iodine, 6 further groups received 0.5 mg supplementary iodine/kg diet. At slaughtering (46th day of life) blood and the thyroid were sampled for determining the organ weight and the serum T_4 and T_3 level. The results are given as the arithmetic mean (x) with standard deviation (SD). Different indices indicate significant differences.

RESULTS AND DISCUSSION

Apparent Digestibility of Organic Matter (OM) in Pigs

24 % RSM has not affected the OM digestibility comparing with the grain or SBM diet respectively (Tab. 1). Possibly in the distal colon the non starch carbohydrates of this diet can still be fermented or the passage is not so high (IMBEAH and SAUER 1989). The OM of both diets with 48 % RSMN, were significantly less digestible than the OM of the corresponding diets with 48 % SBM. Two third of the additional fecal OM excretion of the RSM fed animals could be detected as crude lignin (Fig. 2).

Table 1. Apparent digestibility of organic matter (OM), % (4 pigs/group)

Diet, solvent extracted meal	% of the diet	Period		Apparent OM digestibility % Diet	Solvent extracted meal
Barley wheat diet	0	I	x	85.1[a]	-
			SD	0.7	
- Soya-bean meal	48	I	x	85.6[a]	86.0[a]
			SD	2.0	4.1
- Conventional rapeseed meal	24	III	x	83.6[a]	78.9[ab]
			SD	1.3	5.5
- Rapeseed meal, newly bred variety	24	III	x	83.9[a]	80.1[ab]
			SD	0.7	4.8
	48	II[2)]	x	79,7[b]	73.2[b]
			SD	0.3	0.5
Starch sugar diet[1)]					
- Soya-bean meal	48		x	94.1[c]	92.0[c]
			SD	0.1	0.7
- Rapeseed meal, newly bred variety	48		x	85.5[a]	72.9[b]
			SD	1.3	2.7

1) 97.0 ± 0.4 % apparent OM digestibility of the cooked potato starch beet sugar constituent (HENNIG et al. 1986)
2) no consumption of the grain diet with 48% CRSM in Period II

Using the Rostock equation (1988) 73 % OM digestibility of RSM corresponds to 8.3 MJ net energy/kg DM. Some investigators gave similar estimates but the variation of energetic value of RSM published remains very high (RUNDGREN 1983). As a consequence of the present investigation results it is not possible to calculate a real energetic value using low RSM quantities in the diet.

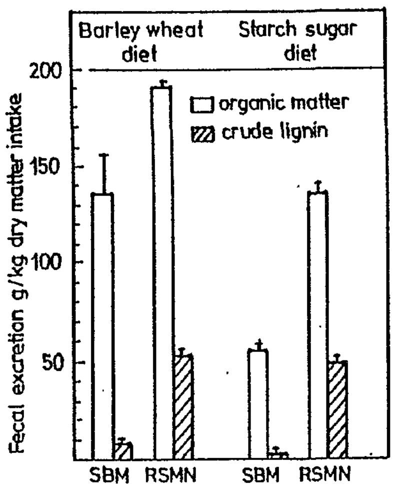

Fig. 2. Fecal excretion (x ± SD) of organic matter (OM) and crude lignin as g/kg dry matter intake from a grain and a starch sugar diet with 48 % soya-bean meal (SBM) or 48 % rapeseed meal of a newly bred variety (RSMN)

Feed Selection Experiments with Pigs

In each period pigs consumed both diets in a similar relation daily (SCHÖNE et al. 1990a). Thus the average relative intake is shown (Fig. 3). Feed with 1 % CRSM - given side by side with feed without glucosinolates (control) - was consumed only by 39 % ($P < 0.05$) of the total feed intake (2nd stage, SCHÖNE et al. 1990a). In the case of RSMN 2 % were necessary before the pigs lowered feed consumption (1st stage). Feed with > 4 % RSMN or CRSM, in comparison with the control, was consumed by < 30 or < 15 % of the total feed intake. Given a choice between CRSM and RSMN (3rd stage, Fig. 3) or between untreated RSM or RSM treated with Cu^{2+} (SCHÖNE et al. 1990a) the low glucosinolate RSM were significantly preferred. Pigs do not recognize < 0.5 mmol glucosinolates + aglucones/kg feed, at about 1 mmol they lower consumption and at 4 mmol they show an aversion.

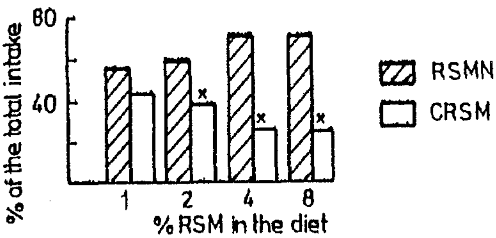

Fig. 3. Selection between diets with rapeseed meal of a newly bred variety and conventional rapeseed meal (% of the total intake, 4 pigs/group, 5 days)

Performance, Thyroid Hormone and Iodine Status of Pigs

The 16 % CRSM diet without supplementary iodine decreased feed intake and growth and led to remarkable iodine deficiency symptoms from the fifth week onwards. These pigs had to be repleted with iodine (SCHÖNE et al. 1990c). The 16 % RSMN diet without supplementary iodine also decreased performance and provoked iodine deficiency, however, not before Week 12. These animals were not repleted with iodine. An iodine dosage of > 0.0625 mg/kg feed did not affect the performance. The 8 animals which received RSMN consumed 13 % more feed (SCHÖNE et al. 1990c) and gained 20 % more weight (Tab. 2) than the CRSM groups, in the case that both diets were supplemented with iodine.

Comparing the SBM and RSM groups, pair fed, CRSM decreased the daily weight gain or increased the feed : gain ratio by 9 %. In the RSMN fed animals there was a 5 % lower performance than in the corresponding SBM group.

All diets without supplementary iodine decreased the serum T_4 level below the detection limit (10 nmol/l) and caused goitre with about 1 mg iodine in the total thyroid (Tab. 3). In the CRSM group even 1 mg supplementary iodine/kg feed - the sevenfold requirement (NATIONAL RESEARCH COUNCIL 1988) - can wether prevent goitre nor increase the T_4 level above 30 nmol/l serum. In the animals fed on RSMN the serum T_4 level of

Table 2. Live weight gain and feed efficiency of pigs (initial live weight 21.1 kg)

Feedstuff / Supplementary iodine		Soya-bean meal (pair fed)	Rapeseed meal Conventional (pair fed)	Rapeseed meal New breeding (pair fed)	Soya-bean meal (pair fed)
	Live weight gain, g/d				
Without[1)]	x	Repletion with iodine		452^{a}	469^{a}
	SD			98	101
With[2)]	x	594^{b}	544^{a}	654^{c}	686^{d}
	SD	37	40	34	32
	Feed : gain, kg/kg				
Without[1)]	x	Repletion with iodine		3.67^{ab}	3.36^{ab}
	SD			0.39	0.47
With[2)]	x	3.37^{a}	3.67^{b}	3.46^{ab}	3.30^{a}
	SD	0.17	0.27	0.16	0.09

1) 4 pigs 2) 2x4 pigs/group a <---> b, c <---> d: t-test for paired observations, iodine dosage 0.0625 - 1 mg/kg feed

Table 3. Serum T_4 level, weight and iodine content of the thyroid in pigs (4 animals/group)

Feedstuff / Supplementary iodine mg/kg diet		Soya-bean meal (pair fed)	Rapeseed meal Conventional (pair fed)	Rapeseed meal New breeding (pair fed)	Soya-bean meal (pair fed)
	Serum T_4 level, nmol/l				
Without	x	Repletion with iodine		$<10^{a}$	$<10^{a}$
0.0625	x			$<10^{a}$	14^{ab}
	SD				7
0.2500	x	41^{cd}	16^{ab}	45^{cd}	56^{d}
	SD	10	10	13	8
1.0000	x	39^{ec}	26^{be}		
	SD	17	15		
	Weight of the thyroid, mg/kg body weight				
Without	x	Repletion with iodine		1134^{a}	789^{abc}
	SD			617	610
0.0625	x			560^{a}	112^{b}
	SD			141	31
0.2500	x	91^{b}	302^{c}	152^{b}	114^{b}
	SD	33	101	56	28
1.0000	x	114^{b}	426^{ac}		
	SD	20	113		
	Iodine content of the thyroid, mg				
Without	x	Repletion with iodine		1.1^{a}	1.1^{a}
	SD			0.6	0.9
0.0625	x			1.7^{a}	2.7^{ac}
	SD			0.8	1.2
0.2500	x	7.2^{bd}	3.3^{cd}	3.5^{cd}	13.4^{e}
	SD	3.4	1.6	1.5	1.7
1.0000	x	31.0^{f}	12.1^{be}		
	SD	5.9	6.6		

1) The thyroid of 4 initially slaughtered pigs (23.4 ± 3.7 kg body weight) weighed 2.6 ± 0.7 g and contained 0.20 ± 0.06 mg iodine

the corresponding SBM group was reached with 0.25 mg supplementary iodine/kg feed.

From 0.25 mg/kg feed onwards the same iodine dosage caused a significantly higher thyroid iodine content in the SBM than in the RSM groups. The iodine content of the thyroid did not differ between both RSM groups with 0.25 mg supplementary iodine/kg feed. On the condition that > 99 % iodine is protein bound (TAUROG 1985) the lower glucosinolate + aglucone content via the RSMN (6 mmol/kg feed) might permit the thyroid to take in iodine and to release it as hormone.

The different thyroid iodine content of both SBM groups with 0.25 mg supplementary iodine/kg diet seems to be difficult to explain. The significantly lower thyroid iodine content of the SBM group on the lower feeding level (pair fed to CRSM) could result from a higher thyroid hormone requirement in energy or protein restriction respectively (INGRAM and EVANS 1980).

Effect of Treatment of Rapeseed Meals on Broiler Chicks

Table 4. Finishing weight, thyroid weight and serum thyroid hormone level of broiler chicks (46 d duration, initially 16 animals/group, 43 g body weight)

Rapeseed meal (RSM), treatment Supplementary iodine	No. of animals		Body weight kg	Thyroid weight mg/kg body weight	Serum level T_4 nmol/l	Serum level T_3 nmol/l
Without supplementary iodine						
Control	16	x	1.57[a]	325[a]	14.2[a]	2.0[ac]
		SD	0.13	234	5.0	0.6
Conventional RSM						
- not treated	15	x	1.44[ac]	747[b]	7.7[b]	2.5[b]
		SD	0.25	304	3.9	0.6
- Myrosinase	13	x	0.85[b]	1060[b]	<5.0[c1)]	2.5[b]
		SD	0.45	675		0.6
- Cu^{2+}	15	x	1.48[a]	681[b]	11.6[a]	2.7[b]
		SD	0.25	289	5.4	0.7
RSM, new breeding						
- not treated	16	x	1.54[a]	694[b]	8.5[ab]	2.3[ab]
		SD	0.17	312	6.2	1.1
- Myrosinase	14	x	1.27[c]	775[b]	5.3[bc]	2.7[b]
		SD	0.42	315	2.0	0.7
With 0.5 mg supplementary iodine/kg feed						
Control	16	x	1.60[a]	65[c]	19.7[de]	1.8[ac]
		SD	0.14	16	4.9	0.5
Conventional RSM						
- not treated	16	x	1.57[a]	199[d]	20.8[de]	1.9[ac]
		SD	0.15	55	5.5	0.7
- Myrosinase	15	x	1.57[a]	266[a]	18.8[e]	1.9[ac]
		SD	0.18	95	4.0	0.5
- Cu^{2+}	16	x	1.51[a]	78[c]	19.0[e]	2.2[ab]
		SD	0.23	20	3.7	0.7
RSM, new breeding						
- not treated	16	x	1.50[a]	126[e]	20.2[de]	1.6[c]
		SD	0.19	30	7.2	0.5
- Myrosinase	16	x	1.56[a]	196[d]	22.7[d]	1.9[ac]
		SD	0.20	53	4.3	0.8

1) detection limit

Myrosinase-treated RSM and a dietary iodine deficit caused a growth depression (Tab. 4) and a high morbidity. In this CRSM group 9 stunted animals showed leg injuries, incomplete feathering and swollen discoloured abdomens. In the RSMN group 4 animals were poorly developed, two of them had leg injuries. Chicks given untreated or the Cu^{2+} treated RSM without supplementary iodine showed hypothyroid goitre but without growth depression. In feed without supplementary iodine even a low glucosinolate dosage strongly enlarged the thyroid. Iodine could only partially prevent the increased thyroid weight of the chicks fed RSM. In the RSM groups with supplementary iodine the chicks which received myrosinase treated RSM, particularly CRSM, had the heaviest thyroids.

In accordance with findings in previous experiments with chicks (SCHÖNE et al. 1989) or pigs (LÜDKE and SCHÖNE 1988) the Cu^{2+} treatment combined with supplementary iodine "normalized" the thyroid weight. The serum T_4 content reflected the iodine supply. Differences between the RSM were only indicated when feed without supplementary iodine was given. In comparison to the untreated RSM the RSM treated with Cu^{2+} increased that with myrosinase decreased the serum T_4 level significantly.

In RSM soaked with $CuSO_4$ solution and frozen dried more than 1/3 of the initial glucosinolates were detected as 2-hydroxy-3-butenylnitril (LANGE et al. unpublished results)). In RSM soaked with myrosinase solution and frozen dried it were 1/5 as L 5-vinyloxazolidin-2-thion and 1/10 as 2-hydroxy-3-butenylnitril. Possibly hot air drying of the wet Cu enriched RSM decomposed the nitril (Fig. 1). A heating of the myrosinase treated RSM could cause the thiourea formation from aglucones and rapeseed protein (KUJAWA et al. 1989).

REFERENCES

GROPPEL, B. 1986. Jodmangelerscheinungen, Jodversorgung und Jodstatus des Wiederkäuers (Rind, Schaf, Ziege). Diss. zur Prom. B, Karl-Marx-Universität Leipzig.

HENNIG, A., SCHÖNE, F., LÜDKE, H., PANNDORF, H. und GEINITZ, D. 1985. Untersuchungen zum Vitamin-A-Bedarf des wachsenden Schweines. 2. Mitt.: Der Einfluß der Vitamin-A-Versorgung auf die Vitamin-A-Konzentration der Leber und des Plasmas von Ferkeln und Mastschweinen. Arch. Tierernähr. 35: 19-31.

IMBEAH, M. and SAUER, W. 1989. Rate of passage studies with pigs fed soybean meal and canola meal diets supplemented with three different fat levels. Univ. Alberta: The 68th Annual Feeders`Day Report. 43

INGRAM, D.L. and EVANS, S.E. 1980. Dependence of thyroxine utilization rate on dietary composition. Brit. J. Nutr. 43: 525-531.

JAHREIS, G., HESSE, V., PLENERT, W., HENNIG, A., SCHÖNE, F. and LÜDKE, H. 1985. Influence of phytogenic substances with thyreostatic effects in combination with iodine in the ration on the thyroid hormone and somatomedin level in pigs. J. Exper. Clin. Endocrinol. 85: 183-190.

KUJAWA, M., SCHNAAK, H., LEWERENZ, H.-J., und MACHOLZ, R. 1989. Glucosinolate - Analytik, Toxizität, Bewertung. Int.

Symp. "Aktuelle interdisziplinäre Probleme des Jodmangels, der Jodprophylaxe, des Jodexzesses und antithyreoidaler Substanzen". Karl-Marx-Stadt. 90-93.

LANGE, R., PETRZIKA, M. und LINOW, F. 1986. Zur Kenntnis der Schwefelverbindungen in Raps- (Brassica napus) Varietäten und Verarbeitungsprodukten. 1. Mitt.: Extraktion, Reinigung und gaschromatographisch-massenspektrometrische Erfassung der Glucosinolate. Die Nahrung. 30: 1035-1037.

LÜDKE, H. and SCHÖNE, F. 1988. Copper and iodine in pig diets with high glucosinolate rapeseed meal. 1. Performance and thyroid hormone status of growing pigs fed a diet with copper sulphate solution treated or untreated rapeseed meal and supplements of iodine copper or a quinoxaline derivative. Anim. Feed Sci. Technol. (Elsevier) 22: 33-43.

National Research Council (NRC). 1988. Nutrient Requirements of Swine. 9. Aufl. Nat. Acad. Sci. Washington D.C.

Rostocker Futterbewertungssystem. 1988. 6. Aufl. VEB Deutscher Landwirtschaftsverlag Berlin.

RUNDGREN, Margareta. 1983. Low-glucosinolate rapeseed products for pigs - a review. Anim. Feed Sci. Technol. (Elsevier) 9: 239-262.

SCHÖNE, F., HENNIG, A. und LANGE, R. 1990a. Auswahl rapsextraktionsschrothaltigen Futters mit unterschiedlichem Glucosinolatgehalt durch wachsende Schweine. Agribiol. Res. 43: 260-270.

SCHÖNE, F., JAHREIS, G., LANGE, R., SEFFNER, W., GROPPEL, B. HENNIG, A. and LÜDKE, H. 1990b. Effect of varying glucosinolate and iodine intake via rapeseed meal diets on serum thyroid hormone level and total iodine in the thyroid in growing pigs. Endocrinol. Exper. 24: 415-427.

SCHÖNE, F., JAHREIS, G. und MEIXNER, B. 1989. Fütterung von mit Kupferionen behandeltem Rapsextraktionsschrot an Broiler unter Berücksichtigung der Jodversorgung. Die Nahrung. 33: 221-223.

SCHÖNE, F., LANGE, R., LÜDKE, H., BRAUTZSCH, R. und HENNIG, A. 1990c. Prüfung von Extraktionsschroten aus Winterrapssaat mit unterschiedlichem Glucosinolatanteil am Schwein unter Berücksichtigung der Jodversorgung. 1. Charakterisierung der Rapsextraktionsschrote und Mastergebnisse. Arch. Anim. Nutr., Berlin. 40: 869-882.

TAUROG, A. 1985. Hormone synthesis: Thyroid iodine metabolism. In: INGBAR, S.H., L.E. BRAVERMAN: Werner's The Thyroid. Fifth Edition. J.B. Lippincott Comp. Philadelphia. 53-97.

VAN SOEST, P.J. 1963. Use of detergents in the analysis of fibrous feeds. II. Rapid method for the determination of fiber and lignin. Assoc. Off. Agr. Chem. J. 46: 829-835.