EFFECTS OF LOW OR HIGH GLUCOSINOLATE RAPESEED MEALS ON GROWTH, THYROID HORMONE, VITAMIN A AND TRACE ELEMENT STATUS OF PIGS

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INTRODUCTION

The degree of thyroid impairment of animals fed rapeseed meal (RSM) depends on the glucosinolate and aglucone content as well as the supplementary iodine in the diet. Findings, like a depressed growth and an affected zinc (ANDERSON et al. 1976, ANKE et al. 1984) or vitamin A status (SCHÖNE et al. 1989) may be related to the antithyroid effect or they are specific for RSM constituents other than glucosinolates. As a third possibility the metabolic disturbances indicate interactions between these criteria itself.

In a first experiment antithyroid effects were produced by a lack of iodine, by conventional (C) RSM or by methimazol (MMI), methylthiouracil (MTU) or SCN^-. The RSM was treated with mustard (Sinapis alba) seed, because the myrosinase effect on the feed value of RSM seems unclear (BACHMANN 1985). In the second experiment a treatment of CRSM and RSM of a newly bred winter variety (N) with copper sulphate (LÜDKE and SCHÖNE 1988) decreased the glucosinolate and aglucone content decisively.

MATERIAL AND METHODS

The crude nutrient, glucosinolate and aglucone content of RSM and the diets and the analytic methods used were published (SCHÖNE et al. 1990a).

In case of the myrosinase treatment 900 g CRSM were mixed with 100 g freshly ground mustard seed and 1 l water. The mash was dried at 50°C for 12 h and at 60° thereafter. The same quantity cooked and dried (myrosinase inactive and sinalbin free) mustard seed was added to realize the same nutrient content of the "untreated" RSM. The myrosinase treated CRSM contained 67 mmol glucosinolates and 6 mmol free aglucones/kg dry matter (DM).

The Cu^{2+} treatment lowered the glucosinolate and aglucone content af both RSM to <15 % of the initial value (Table 1).

Experiment 1 (duration 56 d) was carried out with a total of 51 pigs (initial weight 22 kg) in 6 groups. The control group (6 pigs) had no antithyroid compounds in the diet. The other groups (9 pigs each) received 250 mg MMI (2), 1000 mg MTU (3), 1000 mg SCN^- (4), 72 g RSM + 8 g myrosinase-inactive mustard seed (5) or 72 g RSM treated with 8 g myrosinase-active mustard seed (6)/kg feed. In subgroups with 2 (control) or 3 animals the iodine dosage/kg feed amounted to 0, 0.125 (requirement) or 0.5 mg.

Experiment 2 (duration 119 d) was carried out with a total of 45 pigs (initial weight 20 kg) in 5 groups. SBM was isonitrogenously replaced by CRSM or RSMN, both untreated or treated with Cu^{2+}. In subgroups with 3 animals the iodine dosage/kg feed amounted to 0, 0.125 or 0.25 mg.

In Experiment 1 at Day 28, and at the end of Experiment 2 blood was sampled. The determination of the serum T_4, Vitamin A, Cu, Fe and Zn level was described earlier (SCHÖNE et al. 1989, 1990b). In Experiment 2 the thyroid was weighed and the iodine content of the organ was analyzed (GROPPEL 1986).

Table 1. Content of glucosinolates and glucosinolate degradation products in rapeseed meals (mmol/kg dry matter)

	Conventional		Newly bred	
	Non treated	Treated with Cu^{2+} 1)	Non treated	Treated with Cu^{2+} 1)
Glucosinolates	112.1	13.6	40.3	2.3
- Gluconapin	32.7	4.7	11.9	0.7
- Glucobrassicanapin	4.5	0.6	2.2	0.1
- Progoitrin	68.6	7.4	21.9	0.8
- Pronapoleiferin	4.3	0.6	1.7	0.3
- Indolylglucosino-lates	2.0	0.3	2.6	0.4
Aglucones, free	23.7	4.0	7.7	2.2
- 3-Butenylisothio-cyanat	5.8	0.1	n.d. 2)	0.1
- 2-Hydroxy-3-bute-nylnitril	17.9	3.2	7.7	1.7
- Others	n.d. 2)	0.7	n.d. 2)	0.4
Glucosinolates + aglucones	135.8	17.6	48.0	4.5

1) Dilute 6.25 g $CuSO_4 \times 5\ H_2O$ in 0.5 l hot water, soak 1 kg RSM with the solution in a feed mixer and dry the mash to constant weight at 60 °C.
2) Not detectable, <0.1 mmol/kg dry matter.

The data were evaluated by analysis of variance with 2-way classification and the tests of FISHER, DUNCAN and STUDENT (SACHS 1984). The results are given as the arithmetic mean ($\bar{x}$) with standard deviation (SD). Different indices indicate significant differences.

RESULTS AND DISCUSSION

Comparison of Rapeseed Meals with Antithyroid Drugs

MMI and MTU decreased the serum T_4 level below the detection limit (<10 nmol l^{-1}), impaired the growth (Tab. 2) and changed body proportions and skin. The iodine supplementation was without effect.

The diets without supplementary iodine lowered the serum T_4 level below 10 nmol l^{-1}, but clinical hypothyroidism happened only in the group with SCN^- or myrosinase treated RSM in the feed.

In the control group an iodine dosage above 0.125 mg/kg feed had no effect on the serum T_4 level. In the groups with SCN^- or RSM - particularly myrosinase treated RSM - even 0.5 mg supplementary iodine/kg feed could not increase the serum T_4 up to the level of the control pigs.

The serum Cu level did not differ between the groups ($\bar{x}$, range 1.7 - 2.5 mg l^{-1}). In clinical hypothyroidism - independently if caused by MMI and MTU or by SCN^- and myrosinase treated RSM without supplementary iodine - the serum Fe as well as the vitamin A level were increased, but the serum Zn level was decreased (Tab. 3). In contrast to both trace elements the iodine did not normalize the serum vitamin A level of the RSM fed pigs.

The Fe utilization for hemoglobin synthesis seems to be reduced or the hemolysis is higher in hypothyroid pigs (BERKOW and TALBOTT 1977). Possible explanations for the impaired Zn status were published (SCHÖNE et al. 1990b). The serum vitamin A level is well regulated by a binding protein, which is excreted

Table 2. Live weight gain and serum T_4 content in Experiment 1 (control: 2 pigs/group, others: 3 pigs/group, initial weight 22.4 kg)

Antithyroid compound		Without	Methimazol	Methylthiouracil	SCN^-	Glucosinolates + aglucones via conventional rapeseed meal, non treated	Glucosinolates + aglucones via conventional rapeseed meal, myrosinase treated
Dosage/kg feed		-	250mg	1000mg	1000mg	9.5mmol	5.1mmol
Supplementary Iodine mg/kg feed							
Live weight gain, 1 - 56 d, g/d							
Without	x	556^{ad}	384^{bc}	237^{b}	346^{bc}	438^{ac}	347^{bc}
	SD	29	120	10	113	77	6
0.125	x	600^{de}	249^{b}	277^{b}	712^{ef}	562^{ad}	514^{ad}
	SD	26	28	80	43	91	13
0.500	x	583^{ade}	296^{b}	247^{b}	801^{f}	615^{de}	524^{ad}
	SD	6	113	37	55	38	125
Serum T_4 content, Day 28, nmol l^{-1}							
Without	x	$<10^{a}$	$<10^{a}$	$<10^{a}$	$<10^{a}$	$<10^{a}$	$<10^{a}$
0.125	x	37^{b}	$<10^{a}$	$<10^{a}$	$<10^{a}$	17^{cd}	$<10^{a}$
	SD	1					
0.500	x	36^{b}	$<10^{a}$	$<10^{a}$	26^{c}	25^{c}	15^{d}
	SD	9			7	5	4

Table 3. Trace element and vitamin A content of the serum in Experiment 1 (Day 28, control: 2 pigs/group, others:3 pigs/group)

Antithyroid Compound		Without	Methimazol	Methylthiouracil	SCN^-	Glucosinolates + aglucones via conventional rapeseed meal, non treated	Glucosinolates + aglucones via conventional rapeseed meal, myrosinase treated
Dosage/kg feed		-	250mg	1000mg	1000mg	9.5mmol	5.1mmol
Supplementary Iodine mg/kg feed							
Fe mg l^{-1} serum							
Without	x	1.2^{ad}	2.3^{b}	2.3^{b}	2.2^{bc}	1.6^{cd}	1.8^{bc}
	SD	0.1	0.2	0.4	0.5	0.1	0.2
0.125	x	0.9^{a}	1.7^{ac}	2.1^{bc}	1.2^{a}	1.0^{a}	1.0^{a}
	SD	0.1	0.4	0.2	0.1	0.2	0.3
0.500	x	0.8^{a}	2.0^{bc}	1.7^{cd}	1.0^{a}	0.9^{a}	1.1^{a}
	SD	0.2	0.3	0.4	0.3	0.1	0.1
Zn mg l^{-1} serum							
Without	x	1.1^{a}	0.7^{b}	0.6^{b}	0.7^{bc}	0.7^{bc}	0.7^{bc}
	SD	0.1	0.1	0.1	0.1	0.1	0.1
0.125	x	1.0^{ac}	0.6^{b}	0.6^{b}	1.2^{a}	1.1^{a}	0.8^{b}
	SD	0.1	0.1	0.1	0.2	0.1	0.1
0.500	x	1.2^{a}	0.7^{bc}	0.6^{bc}	1.5^{d}	1.3^{ad}	1.1^{a}
	SD	0.2	0.1	0.2	0.2	0.3	0.1
Vitamin A µmol l^{-1} serum							
Without	x	$0,77^{ad}$	1.12^{bc}	1.17^{bc}	0.98^{ab}	1.32^{c}	1.11^{bc}
	SD	0.21	0.15	0.12	0.03	0.22	0.15
0.125	x	0.45^{de}	1.11^{bc}	1.25^{bc}	0.79^{af}	0.76^{ad}	0.76^{ad}
	SD	0.16	0.05	0.25	0.11	0.14	0.08
0.250	x	0.42^{ef}	1.03^{abc}	1.01^{ab}	0.61^{df}	0.82^{a}	0.80^{a}
	SD	0.06	0.12	0.28	0.16	0.09	0.06

by the kidney. The ultrastructural findings of the kidney of goitrin exposed rats (LEWERENZ et al. 1989) may indicate a RSM mediated disturbed excretory function.

Treatment of Rapeseed Meals with Cu^{2+}

Because an effect of the iodine dosage on performance of pigs was not detectable at any time, these results are only given for the main groups (diets) in Fig. 1 and Table 4. The CRSM lowered feed intake and live weight gain significantly. At the end of the experiment after 17 weeks, these animals had a 37 % lower body weight than the control animals fed on SBM (Fig. 1).

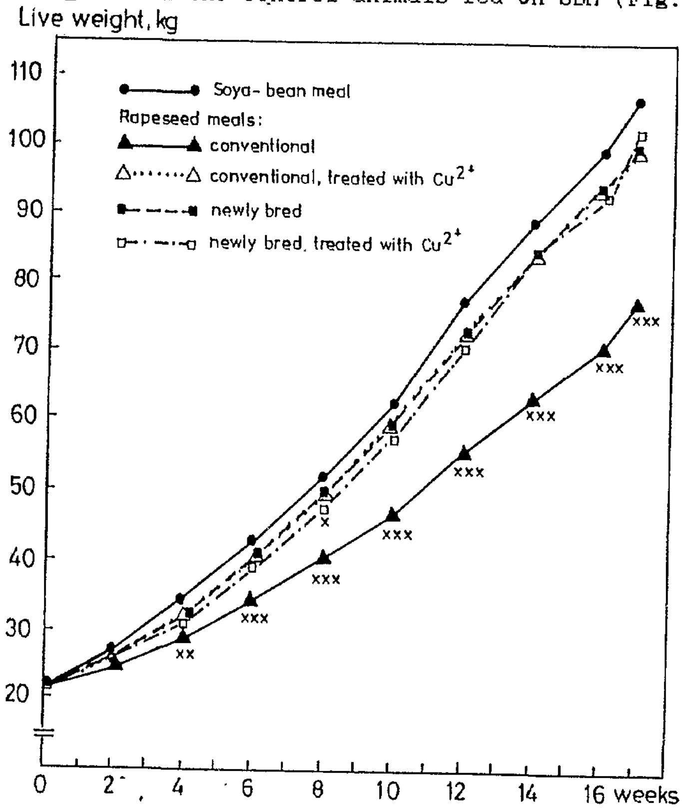

Fig. 1. Replacing soya-bean meal (SBM •——•) by conventional non treated (▲——▲) or Cu^{2+} treated (△······△) rapeseed meal (RSM) and non treated (■– – –■) or Cu^{2+} treated (□–·–·–□) RSM of a newly bred variety: effects on growth of pigs (kg live weight). Results are expressed as group means of 9 pigs and significant differences from the SBM diet are indicated x) $P < 0.05$, xx) $P < 0.01$, xxx) $P < 0.001$.

Estimating the same live weight range there was an 11 % higher ($P < 0.05$) feed gain ratio of the animals fed on CRSM than in the control (Tab. 4).

The three diets with the RSM, whose glucosinolate content has been reduced by breeding or by Cu^{2+} treatment were consumed to a similar extent like the control diet. In comparison with the SBM diet (control) a 4 % lower net energy content of RSM diets reduced live weight gain and feed efficiency by 7 %.

Table 4. Feed intake, live weight gain and feed : gain ratio in Experiment 2 in the live weight range 21 - 78 kg (9 pigs/group)

Feedstuff		Soya-bean meal	Rapeseed meal			
			Conventional		Newly bred	
Treatment		–	–	Cu^{2+}	–	Cu^{2+}
Duration d	x	84	119	91	91	91
Feed intake kg/d	x	2.08^{a}	1.64^{b}	2.08^{a}	2.07^{a}	2.09^{a}
	SD	0.16	0.15	0.19	0.16	0.20
Live weight g/d	x	684^{a}	487^{b}	638^{a}	640^{a}	635^{a}
	SD	77	59	91	38	76
Feed : gain kg/kg	x	3.05^{a}	3.38^{b}	3.28^{b}	3.24^{b}	3.30^{b}
	SD	0.17	0.22	0.17	0.14	0.15
Net energy fat[1)]	x	26.9	28.6	27.7	27.4	27.9
MJ/kg gain	SD	1.5	1.9	1.4	1.2	1.3

1) not significant

Under consideration of the iodine dosage 0.5 and 2.4 or 6.6 and 18.8 mmol glucosinolates + aglucones/kg feed via Cu^{2+} treated RSMN and CRSM or untreated RSMN and CRSM affected the thyroid status (Table 5). In the group with 16 % untreated CRSM even the highest iodine dosage could not prevent goitre formation. The serum contained < 25 nmol T_4/l and a low iodine content of the thyroid persisted. In the diet with 16 % untreated RSMN 0.25 mg supplementary iodine/kg were needed to reach the serum T_4 level of the control. In this case the thyroid weight was still to high.

Table 5. Serum T_4 content, weight and iodine content of the thyroid in Experiment 2 (3 pigs/group, after 119 days)

Feedstuff		Soya-bean meal	Rapeseed meal			
			Conventional		Newly bred	
Treatment Supplementary iodine mg/kg diet		–	–	Cu^{2+}	–	Cu^{2+}
		Serum T_4 content nmol l^{-1}				
0.0625	x	44^{ade}	<10^{b}	31^{cd}	25^{cfg}	40^{adf}
	SD	4		5	3	7
0.1250	x	52^{ae}	13^{bg}	50^{aeh}	35^{cdh}	52^{ae}
	SD	15	6	19	4	5
0.0250	x	58^{e}	22^{bc}	51^{aeh}	56^{ae}	56^{ae}
	SD	14	2	14	6	9
		Thyroid weight mg/kg body weight 1)				
0.0625	x	147^{ad}	1010^{c}	285de	367^{be}	164^{ad}
	SD	89	268	118	116	60
0.1250	x	109^{a}	498^{b}	253^{aed}	344^{bed}	107^{a}
	SD	10	77	178	183	17
0.2500	x	110^{a}	807^{c}	117^{a}	203^{d}	99^{a}
	SD	16	196	8	14	33
		Total iodine content of the thyroid mg1)				
0.0625	x	5.0^{ae}	5.2^{abe}	3.5^{ae}	4.2^{ae}	4.9^{ae}
	SD	2.2	4.0	1.4	1.6	1.5
0.1250	x	11.3^{bc}	4.4^{ae}	8.4^{abce}	4.2^{ae}	9.9^{bc}
	SD	2.2	0.9	4.4	2.6	3.2
0.2500	x	23.9^{d}	2.7^{e}	13.1^{c}	10.1^{bc}	14.0^{c}
	SD	6.3	2.5	3.8	3.1	5.3

1) The thyroid of 4 initially slaughtered pigs (24.9 ± 3.9 kg body weight) weighed 3.1 ±1.0 g and contained 0.85 ± 0.26 mg iodine.

The thyroid weight was normalized (< 120 mg/kg body weight) after inactivating glucosinolates by Cu^{2+} and when 0.25 mg iodine/kg feed was added. In these pigs, however, the thyroid contained significantly less iodine than in the control group with the same iodine dosage.

The iodine dosage had no effect on the further investigation criteria used, that's why the results are given only for the main groups (Tab. 6). In accordance with Experiment 1 an increasing glucosinolate content raised the vitamin A and lowered the Zn level of the serum. In rats a diet with 20 % low glucosinolate RSM decreased the serum Zn level significantly (KEITH and BELL 1987). The decreased serum Cu level of the pigs fed untreated CRSM agrees with previous findings (SCHÖNE et al. 1990b), however, it may not result from an impaired thyroid function (see Experiment 1). In agreement with Experiment 1 the serum Fe level of pigs which received the untreated RSM and additional iodine was not affected. The higher serum Fe level of the Cu groups may result from hemolysis.

Table 6. Trace element and vitamin A content of the serum in Experiment 2 (9 pigs/group, blood sampling after 119 days)

Feedstuff			Soya-bean meal	Rapeseed meal Conventional		Newly breed	
Treatment			–	–	Cu^{2+}	–	Cu^{2+}
Cu	mg l^{-1}	x	2.5^{a}	1.8^{b}	2.0^{bc}	2.3^{ac}	2.2^{abc}
		SD	0.4	0.6	0.4	0.3	0.3
Fe	mg l^{-1}	x	1.3^{a}	1.4^{a}	1.9^{b}	1.2^{a}	2.0^{b}
		SD	0.2	0.2	0.7	0.3	0.8
Zn	mg l^{-1}	x	1.2^{ac}	0.8^{b}	1.3^{c}	1.0^{bd}	1.1^{ad}
		SD	0.1	0.2	0.2	0.1	0.2
Vitamin A	µmol l^{-1}	x	0.58^{a}	0.92^{b}	0.66^{a}	0.72^{a}	0.58^{a}
		SD	0.12	0.31	0.10	0.12	0.17

CONCLUSIONS

Irrespective of the iodine dosage MMI or MTU suppressed absolutely the thyroid - consequences : deficiency symptoms, impaired growth, diminished Zn level and increased Fe and vitamin A level of the serum. Similar disturbances were produced with SCN^- or RSM treated with myrosinase, however, in diets without supplementary iodine only. CRSM, particularly that treated with myrosinase , depressed the feed intake, the growth and the thyroid hormone status and increased the serum vitamin A level. RSMN, Cu^{2+} treated RSM or SCN^- were tolerated without feed intake depression, but the iodine requirement was higher. Growing pigs may receive up to 2.4 mmol glucosinolates + aglucones/kg diet. Prerequisite is an iodine dosage of about 0.25 mg/kg diet.

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