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INFLUENCE OF DIETS WITH RAPESEED MEAL CONTAINING VARYING AMOUNTS OF GOITROGENIC COMPOUNDS OR IODINE ON PERFORMANCE, IMMUNE RESPONSE AND SOME BLOOD SERUM PARAMETERS IN GROWING PIGS

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Abstract

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In two feeding trials with 74 growing pigs from 20 to 100 kg live body mass, diets containing 8 % untreated rapeseed meal - solvent extracted - (RSM) were compared with RSM whose content of goitrogenic compounds was reduced by the treatment with copper ions (Cu^{2+}). The RSM diets were given without iodine supplementation or supplemented with 0.0625 to 1 mg J/kg. The control animals received a soybean meal (SBM) diet with 0.125 mg J/kg feed. The application of the RSM diet without iodine supplementation lowered the serum T_4 level, feed intake and growth. The thyroid hormone deficit also occurred when Cu^{2+}- treated RSM was fed, but without the performance depression. In both diets, a lack of iodine decreased the serum antibody titers to two of three antigens administered. Hypothyroidism did not affect the serum protein, albumin and globulin level, but the serum urea level was increased ($P < 0.05$), the content of inorganic P decreased ($P < 0.05$). The depression of immune response and growth in hypothyroid animals resulted from an impaired protein synthesis or an unfavourable relation synthesis-catabolism. There was no effect of the reduced feed intake of the pair fed animals (littermates that received the same feed quantity as the iodine deficiency animals but with iodine supplementation) on the immune response and some clinical-chemical parameters. Therefore the pathophysiology of hypothyroidism cannot be simply explained by the food consumption impairment.

Iodine deficiency, hypothyroidism, protein metabolism, serum, antibody titers, urea, inorganic P.

Rapeseed meal (RSM) contains more than 35 % high quality protein. Due to the content of glucosinolates and their degradation products, sinapine, phytate and lignin (Bell 1984) pigs and poultry are fed RSM from winter varieties (high glucosinolate rapeseed meal, HGRSM) in small amounts only. By means of different treatments, the goitrogenic or toxic compounds of HGRSM can be eliminated and fed in amounts similar to the RSM of low glucosinolate summer varieties (low glucosinolate rapeseed meal, LGRSM). The microbial fermentation of a mixture of RSM and root crops is best known and easy to practise (Nehring 1950; Ohff et al. 1978). According to recently published findings (Schöne et al. 1986a), however, the goitrogenic noxes of RSM are insufficiently decomposed when ensile with raw potatoes. Gestating and lactating sows, which were fed the silage, particularly together with an alimentary iodine deficiency, were characterized by hypothyroidism and a poor farrowing performance.

Many investigations showed that the impaired feed intake and growth due to RSM feeding are associated with hyperplasia and hypertrophy of the thyroid gland (Groppel and Körber 1985). The T_4 level of the blood serum was depressed, particularly in the case of iodine deficiency or too high a quantity of goitrogenic compounds in the ration and in young animals (Schöne et al. 1986c). It is not known how far the feed intake depression caused by RSM affects the thyroid gland and other organs. Therefore, littermates received the same quantity of diet containing 8 % RSM in one case with and in another without iodine supplementation in our experiments. Under these pair-fed conditions, the inclusion of the immune response as a criterion of investigation seemed particularly important:

a) There are no data on the effect of an iodine deficit or goitrogenic exposure on the immune response (Chandra and Dayton 1982).
b) In most existing investigations into the immune status in vitamin or trace element deficiency, no distinction was made between the effect caused by depressed feed intake (energy and protein deficit) and the micronutrient deficiency as such.

More attention must be paid to the extrathyroidal effects of goitrogenic or antinutritive compounds of RSM (Bell 1984; Fenwick et al. 1983). Investigations into the manifold metabolic effects on the performance and health of animals are of importance since the glucosinolates and their in vivo degradation are still insufficiently investigated (Schöne and Paetzelt 1985).

In the present investigations, the effect of the reduction of goitrogenic RSM compounds (oxazolidinethiones OT; isothiocyanates, ITC) caused by copper ions (Cu^{2+}) (Bell et al. 1967; Lüdke et al. 1985a) on the animal was to be examined, with the influence of the iodine supply being taken into consideration as well.

Materials and Methods

The RSM (solvent extracted) used in trial 1 contained 0.25 % ITC and 1.37 % OT in the dry matter. 0.38 % ITC and 1.19 % OT were analyzed in the RSM dry matter of trial 2 by means of Young's and Wetter's method (1967) modified by Ohff et al. (1978). After the infiltration of RSM with a copper sulphate solution (12.5 g $CuSO_4$ x 5 H_2O ad 0.5 l H_2O/kg RSM during 24 hours) and subsequent drying, OT and ITC were not detectable in trial 2 (Lüdke and Schöne 1988). In both feeding trials, the experimental diet containing 8 % RSM, 7 % soybean meal (SBM), 43 % wheat, 40 % barley and 1 % mineral and 1 % vitamin premix was compared with a control diet consisting of 12.5 SBM, 46 % barley, 39.5 % wheat, and 1 % mineral as well as 1 % vitamin premix. The experimental diet contained 15.5 % crude protein, the control diet 15.0 %. Depending on trial and diet, the P content differed: In trial 1, 4.5 and 4.1 g P, resp. were analyzed in the experimental and control diet. In trial 2, the P content amounted to 5.7 and 5.0 g, resp. The feed content of further nutrients, including iodine, as well as the analysis methods are published by Schöne et al. (1988).

Trial 1 was carried out during 97 days with 4 x 6 crossbred pigs (Landrace x Large White) with an initial weight of 21 kg. Six animals were fed the RSM diet without iodine supplementation. Littermates of the same initial weight and sex received the same feed quantity (but supplemented with iodine) which the corresponding iodine-deficient animal had eaten the day before (pair fed). Pigs of two other groups were fed ad libitum the RSM or SBM diet supplemented with 1 or 0.1 mg J/kg.

Trial 2 was carried out during 104 days with 50 crossbred pigs (Landrace x Large White) with a mean initial body mass of 20 kg. Groups of 22 pigs received untreated RSM or RSM treated with Cu^{2+} (declaration RSM Cu^{2+}). The control diet was administered to 6 pigs. The iodine supplementation of the diets corresponded with the results of former experiments (Lüdke et al. 1985a; Schöne et al. 1986c): 0.125 mg I/kg in the SBM diet, between 0 and 1 mg I/kg in the RSM diet, between 0 and 0.5 mg I/kg in the RSM Cu^{2+} diet.

Investigation criteria, samples and analyses

The body mass and the feed quantity taken in were determined every two weeks. Thyroid gland and liver were weighed after slaughter. Blood was sampled (after a 12-hour feed withdrawal) from the v. cava cranialis or v. jugularis after 5, 10 and 13 weeks in experiment 1 and after 4, 10 and 15 weeks in experiment 2. The serum T_4 and T_3 content was analyzed according to Jahreis et al. (1985). Urea and inorganic P of the serum were determined enzymically and colorimetrically (AB2, GDR 1983).

The analysis of protein, albumin and α, β and γ globulin in the blood serum was carried out by means of the biuret method and paper electrophoresis only at the end of trial 2. The immune response to 3 antigens was detected (Table 1).

In trial 1, 5 animals per group were vaccinated after 70 days, 18 days before blood sampling. In experiment 2, 42 animals were vaccinated after 90 days, 15 days before blood sampling. The non-vaccinated animals served as control to find out if an immune response had occurred or not. The serum antibody concentration is given semi-quantitatively. The values are the $-\log_2$ of the highest positively reacting serum dilution. Sera which did not react even at the initial dilution of 1 : 2 are designated 0.

Table 1

Antigens and antibody detection in blood serum

Vaccine, quantity and application	Antigens, antibodies to	Antibody detection
Salmovac "Dessau" R (adsorbatevaccine) 2 ml s.c. at the neck	H-or flagellum antigen and lipopolysaccharid (LPS) from salmonella dublin	Widalmethod (Hallmann and Burkhardt 1974)
Human Gamma Globulin "Dessau" R 2 ml s.c. at the neck	Human Gamma Globulin (HGG)	passive hemagglutination using a 0.2 % sheep erythrocytes suspension in the microtitrator according to Takatsy (Ziska 1976)

Statistical methods

The results are given as the arithmetic mean ($\bar{x}$) and standard deviation (s). The antibody titers were tested non-parametrically according to MANN and WHITNEY's U-test.

The effects of rations (trials 1 and 2) and of feed intake (trial 2) on the other criteria were examined with STUDENT's t-test.

The variance analysis with the 2-way classification and the SCHEFFE test (Weber 1972) were used in trial 2.

Results

Trial 1

Even in the first weeks, the feeding of the RSM ration led to a thyroid hormone deficit associated with impaired feed intake and growth. Clinical symptoms of iodine deficiency in the form of cretinism and myxedema were observed in this group from the 7th week onwards. Compared to the control, the thyroid mass was increased by factor 6, the liver mass by factor 2 at the end of the trial (Table 2).

Table 2

Feed intake, growth, thyroid hormone status and mass of the thyroid and liver of fattening pigs at the end of trial 1 (6 animals per group, duration 97 d, initial body mass 21 kg)

		Rapeseed meal		Soybean meal		Significance P<0.05		
Iodine supplementation		-	+	-	+	Iodine	feed intake level	diet
Feed intake level		ad libitum	pair fed	ad libitum	ad libitum			
Feed intake kg/d	$\bar{x}$	1.24	1.24	2.13	2.61	-	*	*
	s	0.15	0.15	0.09	0.17			
Body mass gain g/d	$\bar{x}$	327	337	613	733	-	*	*
	s	76	72	66	60			
Final body mass kg	$\bar{x}$	52	53	80	92	-	*	*
	s	8	8	6	5			
Thyroid mass mg/kg body mass	$\bar{x}$	952	253	207	152	*	-	*
	s	367	38	65	13			
Liver mass g/kg body mass	$\bar{x}$	26	20	17	13	*	*	*
	s	3	2	2	1			
Serum-T_4-level nmol/l	$\bar{x}$	<10	54	56	52	*	-	-
	s		22	18	11			
Serum-T_3-level nmol/l	$\bar{x}$	0.67	0.93	1.04	1.64	*	-	*
	s	0.30	0.16	0.21	0.24			

The body mass gain of pigs supplied with iodine, but limited to the feed intake level of deficient animals (pair fed) was only slightly increased ($P > 0.05$). Even if the RSM diet was supplemented with iodine amounts which exceeded the requirement by several times, the performance of control animals was not achieved.

The serum T_4 level did not differ between the groups supplied with iodine. The serum T_3 level, however, was about 40 % lower than in the control group with 0.1 mg iodine supplementation/kg feed when the RSM diet with 1 mg iodine supplementation was fed.

In the case of iodine or thyroid hormone deficiency, the antibody titers were depressed by 1 to 3 stages compared to animals fed the iodine-supplemented RSM diet (Table 3). An influence of the feed intake level on the immune response was not detected. Compared to the control animals (SBM diet), the serum of the animals fed RSM contained significantly more antibodies to the LPS and HGG antigen. The comparison of 4 non-vaccinated pigs with 20 vaccinated ones shows that the strongest immune response with a difference of 6 titer stages occurs for HGG. Due to the low number of animals, however, these values are not presented here.

Table 3

Serum antibody titers (-log 2) after 10 weeks, 18 d after administration of antigens (trial 1, 5 vaccinated animals per group)

		Rapeseed meal			Soybean meal	Significance $P<0.05$		
Iodine supplementation		-	+	-	+	Iodine	feed intake level	diet
Feed intake level		ad libitum	pair fed	ad libitum	ad libitum			
H-antigen[1]	x̄	2.2	3.2	4.0	3.0	-	-	-
	s	2.3	1.1	2.0	1.4	*	-	*
Lipopolysaccharid[1]	x̄	6.0	8.6	7.8	5.4	*	-	*
	s	2.2	1.1	0.8	1.8			
Human-gamma-globulin	x̄	8.2	9.0	8.0	4.8	-	-	*
	s	2.5	0.7	1.2	2.9			

1) from Salmonella dublin

Table 4

Serum urea level in trial 1 (mmol/l, 6 animals per group)

		Rapeseed meal			Soybean meal	Significance $P<0.05$		
Iodine supplementation		-	+	-	+	Iodine	feed intake level	diet
Feed intake level		ad libitum	pair fed	ad libitum	ad libitum			
Week								
5	x̄	5.4	4.8	3.8	4.4	*	*	*
	s	0.7	0.9	0.3	0.7			
10	x̄	5.6	4.2	4.4	6.4	*	-	*
	s	0.7	1.4	1.3	1.6			
13	x̄	5.8	4.2	5.5	5.5	*	*	-
	s	1.0	0.6	1.7	1.5			

Under the conditions of iodine deficiency, the urea level of the serum was significantly increased at all 3 times of blood sampling (Table 4). The protein and energy supply diminished by 1/4 after 5 weeks of trial compared to the ad libitum level increased the urea content of the serum of restrictively fed animals (pair-fed group). In the case of stronger and longer nutrient restriction, however, the urea level of the serum was lowered in this group after 10 ($P>0.05$) and 15 ($P<0.05$) weeks. Compared to the iodine supplemented RSM diet fed ad libitum, the pigs fed the SBM diet (though at a higher feed intake level) had significantly more urea in the serum after 5 and 10 weeks.

The serum level of inorganic P was significantly decreased in the highly hypothyroid animals (Table 5). The feed intake level did not influence the P level. In the first third and at the end of trial, the pigs fed RSM tended to have a higher serum P level than control animals (in correspondence with the higher P content of the diet).

Table 5

Serum level of inorganic P in trial 1 (mmol/l, 6 animal per group)

		Rapeseed meal		Soybean meal		Significance $P<0.05$		
Iodine supplementation		-	+	-	+	Iodine	feed intake level	diet
Feed intake level		ad libitum	pair fed	ad libitum	ad libitum			
Week								
5	$\bar{x}$	2.61	3.33	3.64	3.39	*	-	-
	s	0.31	0.51	0.24	1.75			
10	$\bar{x}$	2.16	2.71	2.84	3.08	*	-	-
	s	0.22	0.26	0.15	0.39			
13	$\bar{x}$	2.89	3.83	3.86	3.17	*	-	-
	s	0.41	0.58	0.84	0.42			

Trial 2

Compared to trial 1, the performance depression and the iodine deficiency symptoms appeared later and were not so distinct (Table 6).

The serum T_4 level was only slightly above the detection limit of 10 nmol/l, the T_3 content was even increased, but the thyroid glands were as enlarged as in trial 1. Since there were no differences with regard to the investigated criteria, the iodine dosages (from 0.125 to 1 mg/kg of the RSM-containing diet and from 0.0625 to 0.5 mg/kg of the RSM Cu^{2+}-containing diet) were summarized for both diets.

In comparison with the control group (SBM diet), the RSM treatment with copper sulphate solution normalized the performance completely. In pigs, however, which were fed the RSM Cu^{2+} diet without iodine supplementation the thyroid mass was increased by factor 7, with little T_4 found in the serum. The livers of these animals were by 40 % larger than those of pigs fed the RSM Cu^{2+} ration with iodine supplementation ($P < 0.05$). With regard to the H antigen of S. dublin, the serum antibody content was not influenced by vaccination (Table 7) or feeding: RSM and RSM Cu^{2+} without iodine supplementation 3.8 and 5.0; RSM and RSM Cu^{2+} with iodine supplementation 4.1 and 4.2; SBM 4.0 titer stages (-log 2). On the other hand, serum antibody titers were significantly increased due to the vaccination with the LPS of S. dublin and HGG, resp. (Table 7).

Table 6

Feed intake, growth, thyroid hormone status and thyroid and liver mass of the fattening pigs at the end of trial 2 (15 weeks, initial body mass 20 kg)

Iodine supplementation		Rapeseed meal -	Rapeseed meal +	Cu^{2+} treated rapeseed meal[x] -	Cu^{2+} treated rapeseed meal[x] +	Soybean meal +	Significance P< 0.05 Iodine	Significance P< 0.05 Cu^{2+}
No. of animals		4	17	3	18	6		
Feed intake,	x̄	1.79	2.31	2.38	2.51	2.46	*	*
kg/d	s	0.21	0.10	0.10	0.13	0.10		
Body mass	x̄	438	641	705	728	709	*	*
gain, g/d	s	132	58	28	49	41		
Final body mass	x̄	65	87	94	96	94	*	*
kg	s	15	6	4	5	6		
Thyroid mass	x̄	805	273	648	112	89	*	*
mg/kg body mass	s	353	113	355	45	29		
Liver mass	x̄	24.7	18.8	16.0	14.3	13.4	*	*
g/kg body mass	s	2.4	1.0	2.4	1.6	1.0		
Serum-T_4-level	x̄	16	56	13	61	54	*	*
nmol/l	s	4	10	0	16	10		
Serum-T_3-level	x̄	1.36	1.17	0.78	1.08	0.98	-	-
nmol/l	s	0.48	0.25	0.15	0.19	0.26		

[x] Rapeseed meal treated with copper ions

Table 7

Influence of the vaccination on serum antibody titers after 15 weeks, 15 d after administration of antigens

		Vaccination yes	Vaccination no	Significance P< 0.05
No. of animals		6	35[1)]	
H antigen from S. dublin	x̄	3.3	4.1	-
	s	1.2	1.2	
Lipopolysaccharid from S. dublin	x̄	4.3	6.1	*
	s	1.6	1.6	
Human Gamma Globulin	x̄	2.5	6.6	*
	s	0.8	1.4	

1) Without 7 animals without additional iodine supply

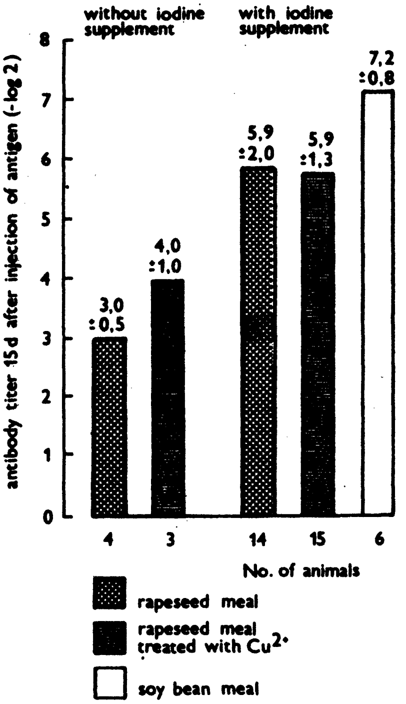

Fig. 1. Serum antibody titer to lipopolysaccharid from Salmonella dublin of growing pigs fed rapeseed meal diets varying in the content of iodine and antinutritive substances.

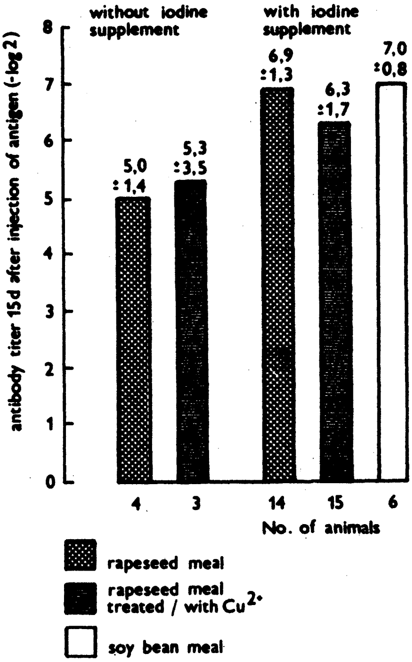

Fig. 2. Serum antibody titer to human gamma globulin of growing pigs fed rapeseed meal diets varying in the content of iodine and antinutritive substances.

The insufficient I supply impaired the serum concentration of antibodies to these two antigens significantly (Fig. 1, Fig. 2). The quantity of goitrogenic compounds reduced by the Cu treatment only took slight effect on antibody titers ($P > 0.05$). The stronger immune response of animals fed the RSM diet (compared to the SBM ration), which was observed in trial 1, failed to occur.

Depending on the offer of iodine and goitrogenic compounds in the diet, the serum concentration of protein, albumin and globulins was not influenced (Table 8). The insufficient iodine supply in the RSM ration, however, increased the urea level of the serum significantly after 4 and 10 weeks (Table 9) and decreased the serum P level significantly after 10 and 15 weeks (Table 10). It is remarkable that in a lack of iodine supplementation the serum P level is still reduced even if, due to the Cu^{2+} treatment of RSM, goitrogenic compounds decreased (Table 10). In accordance with the findings in trial 1, the serum urea level of pigs fed the SBM diet

Table 8

Serum concentration of protein, albumin and globulins (g/l) at the end of trial 2

Iodine supplementation		Rapeseed meal		Cu^{2+} treated rapeseed meal		Soybean meal	Significance $P < 0.05$	
		-	+	-	+	+	Iodine	Cu^{2+}
n		4	17	3	18	6		
Protein	$\bar{x}$	76	69	71	73	74	-	-
	s	8	4	3	12	5		
Albumin	$\bar{x}$	34	32	34	35	31	-	-
	s	3	3	2	3	4		
α Globulin	$\bar{x}$	16	14	13	13	16	-	-
	s	2	2	0	2	3		
β Globulin	$\bar{x}$	12	9	12	11	11	-	-
	s	2	2	1	1	2		
γ Globulin	$\bar{x}$	14	13	12	13	16	-	-
	s	4	3	3	3	4		

was higher than in the RSM groups with iodine supplementation (after 15 weeks $P < 0.05$).

Discussion

In the present investigations, growing pigs received a diet containing 8 % RSM. The iodine intake as well as goitrogenic compounds and the feed intake level were varied. If the HGRSM content of the diet exceeds 15 % (Münchmeyer et al. 1974; Pearson et al. 1983; Anke et al. 1984) or if, even in the case of less than 3 % RSM, there is a lack of iodine in the feed, the performance reductions are unreasonably high. Results from such experiments with a high goitrogenic or toxic exposure do not permit definite statements on the feeding value of RSM and are suited for the comparison with present findings only up to a point. The effect of the iodine supply, food goitrogens, energy and protein intake and of other factors on the thyroid gland and the serum thyroid hormone level were comprehensively discussed recently (Schöne et al. 1986c). There is no doubt about the causative participation of thyroid hormone deficiency in feed intake and growth depression. On the other hand, a very low T_4 level in the pigs fed the Cu^{2+}-created RSM without iodine supplementation was sufficient in trial 2 (Table 6) to maintain normal growth. There are similar findings in sheep following the ingestion of iodine deficient feed with goitrogenic compounds (kale). The T_4 level was very low, but it maintained the T_3 level necessary for normal growth. The wool production of hypothyroid animals, however, was lowered (Barry et al. 1983). Though growth was not affected in our investigations, the strong goitre development and the significant decrease of the serum P level as well as of antibody titers indicated an impaired metabolism following iodine deficiency and possible residual goitrogenic compounds in the RSM diet treated with Cu^{2+}.

The impaired immune response after feeding RSM without iodine supplementation was proved in our investigations for the first

Table 9

Serum urea level in trial 2 (mmol/l)

Iodine supplementation		Rapeseed meal -	Rapeseed meal +	Cu^{2+} treated rapeseed meal -	Cu^{2+} treated rapeseed meal +	Soybean meal +	Significance P< 0.05 Iodine	Significance P< 0.05 Cu^{2+}
Week								
4	x̄	7.6	4.9	5.8	5.7	5.5	*	-
	s	1.1	1.3	1.2	1.1	0.3		
10	x̄	6.6	5.0	5.6	4.8	5.3	*	*
	s	1.0	0.6	0.8	0.6	0.8		
15	x̄	5.3	5.4	4.6	5.5	6.3	-	-
	s	1.2	1.1	0.5	0.7	0.8		

time. There are no references as to the effect on the immune system in the case of endemic goitre or hypothyroidism in the literature (Gershwin et al. 1985; Sheffy and Williams 1982). Under the conditions of iodine deficiency, LPS antibody titers were significantly decreased by 3 titer stages both in trial 1 and 2. The antibodies to the protein antigen (HGG) only reacted in the second trial ($P<0.05$) and not as strongly as those of LPS on nutrition.

In previous investigations (Schöne 1981; Lüdke et al. 1985b), a vitamin A deficit also resulted in the greatest reduction of LPS serum antibody titers. The titer increase (only demonstrated in 2 of 5 investigations) which followed vaccination underlines the hypothesis that nutrient deficiency primarily affects the synthesis of antibodies against weak immunogenes (Miller 1979). This hypothesis, however, could not be confirmed for the H antigen in our investigations.

As for the clinical relevance of reduced antibody titers to two of three antigens administered, no definite answer can be given. In spite of the methodical separation, the components of humoral immunity should not be regarded isolated from the cellular one (Gershwin et al. 1985; Chandra and Dayton 1982). The uninfluenced antibody concentrations (Table 3) of the pigs restrictively fed at the nutrition level of iodine deficient animals (pair fed) show clearly that the deficiency of certain micronutrients cannot be simply explained by reduced energy and protein intake.

In agreement with the higher serum urea content, significantly

Table 10

Serum level of inorganic P in trial 2 (mmol/l)

I suppementation Iodine supplementation		Rapeseed meal -	Rapeseed meal +	Cu^{2+} treated rapeseed meal -	Cu^{2+} treated rapeseed meal +	Soybean meal +	Significance P< 0.05 Iodine	Significance P< 0.05 Cu^{2+}
Week								
4	$\bar{x}$	3.07	3.55	3.13	3.54	3.52	-	-
	s	0.67	0.44	0.23	0.47	0.62		
10	$\bar{x}$	2.88	3.46	2.86	3.46	3.35	*	-
	s	0.28	0.60	0.23	0.42	0.40		
15	$\bar{x}$	2.76	3.13	2.77	3.10	2.91	*	-
	s	0.19	0.35	0.29	0.38	0.25		

less protein than in the pair-fed littermates with iodine supplementation could be detected in the homogenized empty bodies of iodine deficient animals after slaughter (Schöne et al. 1986b). There is a negative correlation between the blood urea level and the utilization of protein when a fasting period of more than 4 hours is observed (Berschauer 1977).

In the present investigations, the content of protein and especially of albumin in the serum of hypothyroid animals was not changed in spite of the enormously enlarged liver (Table 8).

This does not point to a remarkable impairment of the liver function. The serum creatinine level was never influenced by hypothyroidism (Kirchner, unpublished data), the renal function seemed normal. Therefore, the increase of the serum urea level together with the reduced intake of the RSM diet without iodine supplementation can be explained by the impaired protein synthesis or the unfavourable relation "synthesis - catabolism".

At the beginning of the deficient protein-energy supply, the restrictively fed animals of the pair-fed group (trial 1) reacted with an increased serum urea level (Table 9). In the case of food withdrawal, the mobile body protein reserve first meets the energy requirement (Jungermann and Möhler 1980). It is only after longer starvation periods that protein saving mechanisms are activated. The serum urea content of the restrictively fed animals which was lowered at the end of the trial underlines the correctness of this opinion. The fact that, even in the case of similar feed intake, pigs fed SBM had higher serum urea values than those fed RSM has also been observed by other authors (Bowland 1975; Orok and Bowland 1975). That would point to a lower quality of soy protein. According to later experiments. however, the digestibility of the amino acids of soy protein up to the ileum was better than that of rapeseed protein (Sauer et al. 1982). Further investigations are necessary to answer the open questions with regard to the digestibility and utilization of rapeseed protein.

The inorganic P concentration of the serum of pigs fed the RSM diet without iodine supplementation was significantly lowered, but did not drop below the range of reference values (Moser et al. 1982). The changes in the body proportions of animals towards cretinism point to disturbances in bone metabolism as described after goitrogenic exposure or due to hypothyroidism (Bijlsma et al. 1983). The analysis of the P content of the rib did not result in differences between feeding groups (in preparation). Therefore, the drop of the serum P level could also be explained by an adaptation to the diminished energy status or requirement of the hypothyroid organism (Siegenthaler 1984). The energy released in metabolism is stored in the organism with the participation of P:

$$ADP \xrightarrow[O_2,\ energy]{PO_4} ATP$$

The assumption of an adaptation to the lowered energy or O_2 requirement caused by hypothyroidism is also supported by the reduced red blood cell count and hemoglobin caused by feeding the RSM diet without iodine supplementation (Schöne et al. 1988). The T_4 deficit observed in our investigations after feeding a iodine-deficient RSM diet was accompanied by the reduction of feed intake, growth and immune response. The increased serum urea content ($P < 0.05$) and the lowered serum P content ($P < 0.05$) of hypothyroid animals were still within the range of reference values and might hardly be of any diagnostic use in practice.

Vliv diet s extrahovaným pokrutinovým šrotem obsahujícím různá množství strumigenních sloučenin jodu na zdravotní imunologickou odpověď a některé ukazatele krevního séra rostoucích prasat

Ve dvou krmných pokusech na 74 rostoucích prasatech od 20 do 100 kg živé hmotnosti byly srovnávány diety s 8 % neošetřených řepkových pokrutin extrahovaných (R) s dietami, jejichž obsah strumigenních substancí byl redukován pomocí iontů mědi (Cu^{2+}). Diety R byly zkrmovány bez přídavku jódu anebo s přídavkem 0.0625 až 1 mg $J.kg^{-1}$. Kontrolním zvířatům byla zkrmována dieta s extrahovaným sojovým šrotem (S) s 0,125 mg $J.kg^{-1}$ krmiva. Podávání diety R bez přídavku jódu snížilo koncentraci T_4 v krevním séru, příjem potravy a zpomalilo růst. Deficience thyroidního hormonu se objevila i při zkrmování diety R ošetřené Cu^{2+}, nebyla však doprovázena zpomalením růstu. V obou dietách snížil nedostatek jódu titry sérových protilátek proti dvěma ze tří podaných antigenů. Hypothyreóza neovlivnila koncentraci sérových bílkovin, albuminu a globulinu, zvýšila koncentraci močoviny v séru ($P < 0,05$), snížila obsah anorganického fosforu ($P < 0,05$). Deprese imunní odpovědi a růstu hypothyroidních zvířat byla zřejmě vyvolána narušením proteosyntézy anebo nepříznivým poměrem anabolických a katabolických dějů. Při párovém krmení (zvířata ze stejného vrhu byla krmena stejným množstvím krmiva jako zvířata s deficiencí jódu) byl konzum krmiva nižší a neměl vliv na imunní odpověď a některé biochemické ukazatele krevního séra. Proto nelze patofyziologii hypothyreózy jednoduše vysvětlit narušením příjmu potravy.

Влияние диетических рационов с экстрагированным дпобленными жмыхами, содержающими разное количество струмигенных соединений йода, на состояние здоровья, иммунологический ответ и некоторые показатели кровяной сыворотки растущих свиней

В ходе двух экспериментов с кормами на 74 растущих свинях от 20 до 100 кг живого веса проводилиць сравнения диеты с 8% необработанных рапсовых жмыхов экстрагированных (R) с диетами, содержание струмигенных вещест которых было редуцировано с помощю ионов между (Cu^{2+}). Рацион R скармливали без добавки йода или с добавкой 0,0625 - 1 мг Дж. кг.$^{-1}$. Контрольным животным давали диету с экстрагированным соевым шротом (S) с 0,125 мг Дж. кг$^{-1}$ корма. Потребление диеты R без добавления йода вылилось в понижение концентрации T_4 в кровяной сыворотке, в понижении приема пищи и замедлении роста. Недостаточность тиреоидного гормона проявилась даже при скармливании диеты R, обработанной Cu^{2+}, однако без сопровождения замедления процесса роста. В обеих диетах нехватка йода выразилась в понижении титров сывороточных антител против двух из трех подаваемых антигенов.Гипотиреоз не оказал влияния на концентрацию сывороточных белков, альбумина и глобулина, повлиял на повышение концентрации мочевины в сыворотке ($P < 0,05$), понизилось цодержание неорганического фосфора ($P < 0,05$). Депрессия иммунологического ответа и роста гипотиреоидных животных была, по всей вероятности, вызвана нарушением протеосинтеза или неблагоприятным соотношением анаболических и катаболических процессов. При кормлении парами (животных одинакового племенного гнезда кормили одинаковым количеством как животных с нехваткой йода) потребление кормов было ниже и не оказало влияния на иммунологический ответ и некоторые биохимические показатели кровяной сыворотки. Поэтому патофизиологию р-гипотиреоза нельзя просто объяснить нарушением приема пищи.

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