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Energy metabolism in growing-finishing pigs fed rapeseed meal

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ABSTRACT

Thirty six Landrace pigs from 60 to 110 kg liveweight were given diets of similar available lysine and metabolizable energy contents. The feed mixtures contained an average of 16% soya bean meal (SBM) or 21% rapeseed meal (RSM) of a double-low variety (8.7 moles glucosinolates per g fat-free dry matter). Energy retention in the body was measured by the comparative slaughter technique. The weight of the internal organs and thyroid gland and T_3 and T_4 hormone concentrations in blood samples taken at slaughter were also determined.

The weight of the thyroid and liver were 55% ($P \leqslant 0.001$) and 16% ($P \leqslant 0.001$) higher, respectively, in the animals fed RSM. The RSM diet caused no significant difference in the chemical composition of the body gain, blood T_3 and T_4 levels as in the weight of the kidneys. The maintenance requirement and energy cost of protein deposition in the body of pigs did not differ between the groups (511 kJ/kg$^{0.75}$/d and 68 kJ/g, respectively).

KEY WORDS: pigs, rapeseed meal, energy metabolism, glucosinolate, thyroid hormones, internal organs

INTRODUCTION

A study of the use of rapeseed meal (RSM) in the feeding of pigs (Fandrejewski et al., 1994) showed that animals fed a diet containing RSM had a tendency to increased heat production.

The objective of this study was to determine the energy costs of deposition of protein in the body and maintenance requirements of pigs fed RSM.

MATERIAL AND METHODS

The experiment was carried out using 60 Landrace pigs (30 gilts and 30 barrows) from 30 to 110 kg liveweight. Pigs were kept in individual pens with no bedding.

The experiment was divided into two periods: preliminary (from 30 to 60 kg) and experimental (from 60 to 110 kg). During the preliminary phase all the animals were fed a standard diet containing 12.2% digestible protein and 12.6 MJ metabolizable energy (ME) per kg. A rationed feeding regimen was used as recommended in the Nutrient Requirements of Pigs (1993). The preliminary phase was to equalize the chemical composition of the pigs' bodies. At 60 kg liveweight the backfat thickness was measured by ultrasonic apparatus (with an accuracy of 1 mm) in seven points along the entire body. Twelve randomly selected gilts and 12 barrows were slaughtered and the chemical composition of their bodies determined. The remaining animals (18 gilts and 18 barrows) were divided into 12 experimental groups based on their rates of daily gain during the preliminary period, backfat thickness measurements, sex and relation.

A factorial model in a 2 x 3 x 2 design was used in the experiment, taking the following factors into account: two sources of protein feed in the mixture - SBM and RSM; three levels of daily ME intake: 31.4 (group L), 33.9 (group M) and 36.0 MJ (group H), and sex (gilt or barrow).

The main components of the 6 different types of mixtures used were barley, soya bean (SBM) or RSM meals (Table 1). The energy concentration in feeds L, M and H were differentiated by adding a fat concentrate and wheat starch. All the mixes were supplemented with synthetic lysine to a level of 5.2-5.5% in crude protein.

The feeds were given in such a way that the pigs consumed equal average daily amounts of crude protein (390 g) and available lysine (17 g), but different amounts of ME (from 31 to 36 MJ). The size of the daily ration was therefore dependent on its ME content (Table 4). The rations were increased weekly depending on the animal's weight.

The apparent digestibility of protein and energy were determined in all animals at 80-85 kg liveweight using an indicator method (Cr_2O_3) over a three-day faeces collection period.

The animals were slaughtered at the end of the second stage of the experiment at 100 kg liveweight and the fat content, weight of the thyroid, liver and kidneys were determined.

The chemical composition of the feeds and pigs bodies were determined using conventional methods. The gross energy content of a feed was measured by combustion of samples in a bomb calorimeter, while ME was calculated from digestible energy and percent of crude protein in the feed (Noblet et al., 1989).

The glucosinolate content in the meal expressed as the total of its fractions was detrmined according to Youngs-Wetter, as modified by Byczyńska (1971). The amino acid composition of the feeds was assayed according to method described by Buraczewska et al. (1987), using a Beckman Unichrom analyzer. Available lysine was determined using the method of Carpenter as modified by Booth (1971).

T_3 and T_4 levels in blood samples taken at slaughter were determined using RIA-T_3 and RIA-T_4 kits from POLATAM, Świerk, Poland.

Mean values obtained for groups of animals were compared by variance analysis. The calculations were made using 12 arithmetic means from subgroups containing animals of the same sex in the same feed groups. Data relating to sex were omitted because the differences between barrows and gilts were insignificant ($P \geqslant 0.05$) and typical for this type of comparison.

On the basis of the chemical composition of the body and ultrasonic backfat thickness (b. th. mm) of 60 kg pigs, regression equations were developed for estimating the initial protein ($Prot_{60}$, kg) and fat (Fat_{60}, kg) contents in the bodies of the experimental animals:

$$Prot_{60} = 9.06 - 0.05 \times b.th. \quad s.e. = 0.13 \text{ kg}, \quad n = 24 \quad (1)$$
$$Fat_{60} = 5.00 + 0.39 \times b.th. \quad s.e. = 1.16 \text{ kg}, \quad n = 24 \quad (2)$$

Energy retention was estimated on the basis of increased protein and fat contents in the bodies using the coefficients for protein (23.86 kJ/g) and fat (39.76 kJ/g) given by Brouwer (1965).

The calculations of energy metabolism were done using multiple regression equation (Kielanowski, 1965). The amount of ME taken up ($MJ/kg^{0.75}/d$) expresses the sum of maintenance energy and energy needed to deposit 1 kg protein (PROT, MJ) and fat (FAT, MJ). It was assumed that the cost of depositing fat is the same in both groups (57 kJ/g).

RESULTS AND DISCUSSION

Rapeseed meal contained 99 g less protein in 1 kg dry matter and 61 g more crude fibre than SBM (Table 1). This did not, however, affect the gross energy concentration, which was the same in both feeds. The RSM protein contained 0.72 g less lysine and over 1.5 g/16 g N more methionine and cystine than SBM protein. The amount of available lysine per kilogram SBM and RSM was 20.7 and 14.5 g respectively. The coefficient determining the availability of lysine was similar for both meals (80 and 79% respectively). This is lower than published (data for SBM and relatively high for RSM). These values do, however, fit into

TABLE 1

Composition of the barley, soybean meal (SBM) and rapeseed meal (RSM)

Item	Barley	SBM	RSM
Dry matter, g/kg	879	878	893
In DM:			
ash, g	35	83	79
crude protein, g	124	455	356
crude fibre, g	58	68	129
ether extract, g	21	26	42
N-free extractives, g	760	368	395
gross energy, MJ/kg	17.99	19.95	20.05
Glucosinolates, μmoles/g ffdm[1]	—	—	8.7
Amino acids, g/16 g N			
Lys	3.83	6.50	5.78
Met	1.68	1.55	2.12
Cys	2.12	1.50	2.49
Thr	3.47	4.19	4.72
Trp	1.17	1.22	1.27
Ile	3.68	4.82	4.18
Arg	5.29	7.46	6.40
His	2.31	2.80	2.84
Leu	7.10	8.19	7.43
Phe	4.88	5.42	4.10
Val	5.22	5.23	5.57
Ala	4.19	4.70	4.78
Asp	6.97	12.25	8.16
Glu	24.05	19.71	18.02
Gly	4.16	4.62	5.42
Pro	10.96	5.38	6.67
Ser	4.22	5.31	4.49
Tyr	3.31	3.74	3.31
Chemical availability of lysine	0.86	0.80	0.79

1 Composition: glukonapin-2.6, glucobrassicanapin-0.4, progoitryn-5.7 μmoles/g fat-free dry matter

the variability range for analytical parameters obtained for these types of feeds (Buraczewska, personal communication).

It is assumed that the ileal digestibility of SBM lysine is at least 10% greater than that in RSM (Sauer and Ozimek, 1986; van Leeuwen et al., 1993) and equals 86 vs. 75%. However, the ileal digestibility of lysine is not always in agreement with the chemically determined availability as this amino acid (with a blocked epsilon-NH_2 group) may be digested in the small intestine (Buraczewska et al., 1973; Moughan, 1993).

TABLE 2

Formulation and chemical composition of experimental diets

Item	Protein source					
	Soybean meal			Rapeseed meal		
	Energy level					
	L	M	H	L	M	H
Ingredients, g/kg						
Soya bean oil meal	165	157	150	—	—	—
Rapeseed oil meal	—	—	—	216	207	198
Barleyh	808	770	735	732	698	666
Wheat starch	7	6	6	32	30	29
Tallow	—	47	91	—	46	88
Vitamins and minerals	19.5	19.5	17.5	19.2	18.3	18.3
L-lysine. HCl	0.5	0.5	0.5	0.8	0.7	0.7
Chemical composition						
Gross energy, MJ/kg	15.58	16.29	17.17	15.83	16.49	17.18
Crude protein, %	14.81	14.21	14.27	14.36	13.94	13.58
Ash, %	7.38	6.64	6.66	7.07	7.05	6.63
Crude fibre, %	5.04	4.31	4.20	6.55	5.93	5.89
Ether extract, %	1.92	4.01	4.10	3.22	3.53	4.46
Lysine, %	0.81	0.77	0.74	0.77	0.73	0.70
Methionine and cystine, %	0.54	0.51	0.49	0.62	0.59	0.57
Threonine, %	0.58	0.56	0.53	0.60	0.58	0.55
Tryptophan, %	0.54	0.51	0.49	0.49	0.47	0.45
Available lysine, %	0.67	0.64	0.61	0.65	0.62	0.59

TABLE 3

Digestibility coefficients of crude protein and gross energy

Digestibility, %	Soya bean meal (SMB)			Rapeseed meal (RSM)			SE pooled	Significance	
	L	M	H	L	M	H		source of protein	energy level
Energy	79.4	77.5	75.3	75.9	75.7	74.8	0,316	x	NS
Protein	74.6	74.2	76.2	71.0	72.4	74.4	0.351	xx	x

six pigs in each group
calculated from formula: ME/DE=99.8-0.02 x CP (Noblet et al., 1989)
x – P<0.05; xx – P<0.01

The digestibility of crude protein (Table 3) increased as the percentage of ash and fibre decreased, which is in agreement with published data (e.g. Just, 1980; 1982). In feed H it was on average 2.5% higher (P≤0.05) than in feed L.

Protein and energy digestibility in RSM feeds were 2.4% (P≤0.01) and 1.9% (P≤0.05) lower than in SBM feeds. The differences in apparent protein and energy digestibilities between the meals were from 12 to 15%, i.e. similar to values found in the literature (NCR, 1988).

During the preliminary phase of the experiment (30-60 kg liveweight), the animals gained an average of 770 g daily. The magnitude of the daily gains in the experimental period (60-110 kg liveweight) was a simple function of energy consumed (Table 4). The gains of animals in group H who received 36 MJ ME/d were an average 736 g/d and were in agreement with expected values according to the Nutrient Requirements of Pigs (1993). In groups M and L, these values were 62 g (P≤0.05) and 146 g (P≤0.01) lower. Replacing SBM with RSM and appropriately supplementing the diet in respect to lysine and energy did not affect daily gains, which is in agreement with the results of such studies as those by Rowan and Lawrence (1986). When SBM was replaced by RSM without supplementing lysine, the weight gains in this group were smaller than when the pigs were fed SBM (Raj et al., 1990).

The type of protein feed (SBM or RSM) in the diet did not affect the chemical composition of the body or its energy content (Table 5). This is in agreement with the study by Thomke (1984) on the quality of pig carcasses fed diets containing RSM. The weight of the animals in groups L, M and H differed in respect to the amount of deposited protein and fat depending on the rate of gain. Increasing ME intake from 31.4 to 36.0 MJ/d significantly (P≤0.01) increased protein, fat and energy deposition by 22 and 53 g and 2.63 MJ/d, respectively.

No statistically significant interaction between protein source and energy level on any of the studied traits was found in the experiments reported here.

TABLE 4

Effect of soya bean meal (SBM) and rapeseed meal (RSM) and energy levels (L, M, H) on growth performance of pigs

Item	SBM			RSM			SE	Significance	
	L	M	H	L	M	H	pooled	source of protein	energy level
Daily intake									
Feed, kg	2.65	2.74	2.85	2.73	2.84	2.93	0.006	NS	NS
Metabolizable energy, MJ	31.2	33.5	35.6	31.6	34.5	36.5	0.151	NS	NS
Crude lysine, g	21.40	21.10	21.00	20.90	20.70	20.50	0.538	NS	NS
Chemical available lysine, g	17.9	17.6	17.5	17.6	17.5	17.3	0.365	NS	NS
Performance data									
No. of pigs	6	6	6	6	6	6	—	—	—
Ultrasonic backfat thickness at 60 kg, mm	14.1	14.5	15.1	15.1	15.1	14.1	0.267	NS	NS
Live weight at 60 kg, kg	60.0	59.8	60.3	60.0	60.0	60.0	0.052	NS	NS
Final live weight, kg	110.2	111.3	110.6	110.2	110.6	110.8	0.182	NS	NS
Average daily gain 60-110 kg, g	588	678	723	594	671	749	7.601	NS	xx
ME per gain, MJ/kg	53.28	49.48	49.68	53.58	51.58	48.98	0.661	NS	NS

xx – $P < 0.01$

TABLE 5

Effect of soya bean meal (SBM), rapeseed meal (RSM) and energy levels (L, M, H) on chemical body composition and energy retention in pigs from 60 to 110 kg live weight

Item	SBM			RSM			SE	Significance	
	L	M	H	L	M	H	pooled	source of protein	energy level
Chemical composition									
No. of pigs	6	6	6	6	6	6	—	—	—
Empty body weight, kg	103.5	105.2	104.5	104.3	104.2	104.9	0.187	NS	NS
Protein, kg	15.24	15.54	15.32	15.16	15.16	15.51	0.102	NS	NS
Fat, kg	26.47	27.70	28.22	28.57	29.07	27.60	0.486	NS	NS
Energy, kJ/g EBW	13.7	14.0	14.2	14.4	14.6	14.0	0.173	NS	NS
Daily deposition 60-110 kg									
Protein, g	80.3	95.0	100.5	81.0	91.3	105.2	1.451	NS	xx
Fat, g	187.8	224.7	249.8	208.8	240.2	252.3	5.984	NS	xx
Energy, MJ	9.39	11.2	12.33	10.24	11.72	12.54	0.381	NS	xx
$\frac{\text{Energy retained}}{\text{Energy intake}}$, %	0.30	0.34	0.35	0.32	0.34	0.35	0.007	NS	NS

xx – P < 0.01

TABLE 6

Weight of internal organs and the thyroid hormones concentration in the blood of pigs fed soya bean meal (SBM) or rapeseed meal (RSM)

Item	SBM (n = 18)	RSM (n = 17)	Probability of difference
Glucosinolate intake moles/d	—	4.4	—
Liver, g	1540±35	1786±50	0.001
	(100)	(116)	
Kidneys, g	312±9	324±10	0.150
	(100)	(104)	
Thyroid gland, g	10.1±0.3	15.7±0.7	0.001
	(100)	(155)	
Triiodthyronine (T_3), ng/ml	1.15±0.08	1.04±0.05	0.210
	(100)	(91)	
Thyroxine (T_4), ng/ml	82.2±4.9	66.0±4.5	0.070
	(100)	(80)	

On average, 34% of metabolizable energy was retained in the body. This value did not differ among groups, which made it possible to develop a joint regression equation for estimating the cost of depositing protein in the body:

$$ME = (0.511 \pm 39)LW_m + (67.7 \pm 11.7)\ PROT + 57\ FAT \qquad (3)$$

s.e = 0.4 MJ/d (1.2% of ME), n = 12 arytm. means

where:

- ME – intake of metabolizable energy, MJ/d
- LW_m – metabolic body weight, $kg^{0.75}$
- Prot – protein deposition, kg/d
- Fat – fat deposition, kg/d

The partial regression coefficients which express maintenance requirements (511 kJ/$kg^{0.75}$) and cost of protein deposition (67.7 MJ/kg) are similar to the values obtained by Fandrejewski (1992) in studies on energy utilization by growing gilts. These values are relatively high but are comparable to the results of studies of energy metabolism in animals kept under standard conditions (in pens with no bedding, not in balance cages) and using the comparative slaughter technique to measure energy retention in their bodies (e.g. Ewan, 1983).

The weight of the liver and kidneys of pigs receiving RSM in their ration was greater by 16% ($P \leq 0.001$) and 4% (NS) than pigs fed SBM. We previously found similar changes in our own studies (Fandrejewski et al., 1994; Raj et al.,

1990) as have others (e.g. Thomke, 1984). These changes should be related to the presence of glucosinolates in RSM, which over the 76 day period of feeding this meal gave an average consumption of 4.4 moles/day/animal.

Feeding RSM increased the weight of the thyroid by 55% ($P \leqslant 0.001$) and caused an insignificant fall in both serum hormone levels, T_3 by 9% ($P=0.21$) and T_4 by 20% ($P=0.07$; Table 6). These results, as in the study by Christison and Laarveld (1981) can indicate that the hypertrophy of the thyroid did not compensate the negative effect of glucosinolates on iodine uptake, thus on hormone secretion. There was no negative effect, however, of decreased T_3 and T_4 levels on the metabolism on the studied pigs. This shows that it is possible for the organism to adapt to absorption of nutrients from feeds containing such antinutrients.

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STRESZCZENIE

Przemiana energii u świń żywionych poekstrakcyjną śrutą rzepakową

Doświadczenie przeprowadzono na 36 świniach rasy pbz (18 loszek i 18 wieprzków) o masie ciała od 60 do 110 kg. Zwierzęta utrzymywano indywidualnie. W doświadczeniu zastosowano model czynnikowy w układzie 2 x 3 x 2. Czynnikami były: 2 źródła paszy białkowej w mieszance - poekstrakcyjna śruta sojowa (SBM) i rzepakowa (RSM) odmiany "00" (8.7 moli glukozynolanów /g smb); 3 poziomy dobowego pobrania energii metabolicznej (31,4; 33,9 i 36,0 MJ EM/dzień) oraz 2 płci (loszki i wieprzki). Średnie dzienne pobranie białka ogólnego i lizyny we wszystkich grupach było podobne i wynosiło odpowiednio: 396 i 17,5 g. Przy masie ciała 110 kg wszystkie zwierzęta ubito. Oznaczono skład chemiczy ich ciała, określono masę tarczycy, wątroby i nerek, a we krwi oznaczono poziom hormonów tarczycy T_3 i T_4. Przemianę energii oszacowano metodą regresyjną.

Masa tarczycy, wątroby i nerek świń otrzymujących w dietach RSM była większa o 55, 16 ($P<0.001$) i o 4% ($P=0.15$), a koncentracja trójjodotyroniny i tyroksyny w osoczu krwi była mniejsza o 9 i 20% niż u świń żywionych mieszanką ze śrutą sojową. Zródło paszy białkowej (SBM lub RSM) nie miało istotnego wpływu na wielkość i chemiczny skład przyrostu masy ciała. Przy dobowym zapotrzebowaniu bytowym na energię metaboliczną w wysokości 0.511 $MJ/kg^{0.75}$ koszt odłożenia 1 g białka w ciele wynosił 68 kJ ME.