The effect of different dietary fat sources, withdrawal times, and castration on the fatty acid composition of backfat in baconer pigs

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Seventy-eight pigs (40 boars and 38 castrates) were used in a growth trial to study the effect of high oil class FH sunflower seed on the long chain fatty acid composition of backfat in baconer pigs. Three diets were formulated to contain 18% protein, 1,0% lysine and 13,5 MJ/kg digestible energy. Diet A, the control, was a normal pig growth diet. Diet T1 contained 16% class FH sunflower seed (sunflower oil cake + sunflower oil). Diet B was similar to diet T1, but for the sunflower oil being substituted with tallow. Seven experimental treatments were used. In treatments A, B, and T1 the respective diets were fed from eight weeks of age until slaughter at 85 kg live mass. In treatments T2, T3, T4, and T5 diet T1 was fed *ad lib.* until the pigs were 45 kg, 55 kg, 65 kg, or 75 kg in live mass, respectively, from which point diet B was fed until the animals were slaughtered at 85 kg live mass. The linoleic acid content in the backfat of the pigs that received treatment T1 was 197% higher than that of pigs on treatment B, indicating an enormous effect of dietary fat source on backfat fatty acid composition. The substitution of diet T1 with diet B resulted in increased unsaturated backfat in the pigs as the point of substitution approached 85 kg live mass. The significant differences ($P \leq 0,01$) in linoleic acid content between the experimental treatments suggest the possibility of manipulating the fatty acid composition of backfat by strategically feeding diets containing fats with different levels of saturation. No significant differences were found in growth performance or efficiency between pigs receiving T1 and B and for treatments T2, T3, T4, and T5. Boars had a 12,5% higher ($P \leq 0,01$) backfat linoleic acid content than castrates, probably resulting in a softer backfat.

Agt-en-sewentig varke (40 bere en 38 burge) is in 'n groeistudie gebruik om die effek van hoë-olie klas FH-sonneblomsaad op die langketting vetsuursamestelling van spekvarke se rugvet te bestudeer. Drie diëte is saamgestel om 18% proteïen, 1,0% lisien, en 13,5 MJ/kg verteerbare energie te hê. Dieet A, (kontrole dieet) was 'n normale groeidieet. Dieet T1 het 16% klas FH-sonneblomsaad (sonneblomoliekoekmeel + sonneblomolie) bevat. Dieet B was soortgelyk aan dieet T1 behalwe dat sonneblomolie met beesvet vervang is. Daar is van sewe eksperimentele behandelings gebruik gemaak. In behandelings A, B, en T1 is die onderskeie diëte vanaf agt weke ouderdom tot by slag op 85 kg lewende massa gevoer. In behandelings T2, T3, T4, en T5 is dieet T1 *ad lib.* vanaf agt weke ouderdom tot 45 kg, 55 kg, 65 kg, of 75 kg lewende massa, onderskeidelik, gevoer, waarna dieet B tot met slagting op 85 kg lewende massa gevoer is. Die rugvet-linoleïensuur-inhoud van die varke wat Behandeling T1 ontvang het was 197% hoër ($P \leq 0,01$) as dié van die varke wat Behandeling B ontvang het, wat op die groot effek van dieetvetbron op rugvetsamestelling wys. Die vervanging van dieet T1 met dieet B het tot 'n geleidelike verhoging in onversadigde vetsure met nadering van 85 kg lewende massa, gelei. Die betekenisvolle verskil ($P \leq 0,01$) in rugvet-linoleïensuur-inhoud tussen die eksperimentele behandelings was op die moontlikheid om rugvet-vetsure te manipuleer deur die strategiese aanwending van voerbronne met verskillende vetsuursamestellings. Geen betekenisvolle verskille in gemiddelde groeiprestasie of doeltreffendheid is by die varke wat behandelings T1, B, of met substitusie by verskillende massas, ontvang het, gevind nie. Bere het 12,5% hoër ($P \leq 0,01$) rugvet-linoleïensuur-inhoud as burge getoon, wat waarskynlik sagter rugspek tot gevolg gehad het.

Key words: Baconer, boar, castrate, fat source, fatty acids, pig

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Introduction

The consistency of pig fatty tissue is important in meat processing and consumer acceptability (Whittington *et al.*, 1986). The main cause of a deviation in consistency is too soft backfat as a result of high proportions of linoleic acid (C18:2) in the lipid. The constituents most closely related to firmness and cohesiveness are stearic acid (C18:0) (positively) and C18:2 (negatively) (Wood & Enser, 1989). Linoleic acid in the backfat of the pig is related to its concentration in the diet (Dahl & Persson, 1965; Wood, 1984; St John *et al.*, 1987). According to Wood (1984), the concentration of linoleic acid in fat tissue is normally about 10 – 15% of total fatty acid content. This can be raised to 30% and above by increasing the concentration of linoleic acid in the diet as shown by Marchello *et al.* (1983) who used different levels of sunflower seed in the diet.

Feedstuffs such as maize meal, fish meal, sunflower oil cake meal, and soya bean oil cake meal are commonly used in pig diets in South Africa. The fat component of these feedstuffs contains high proportions of unsaturated fatty acids which have the potential of producing soft fatty tissue in the baconer. The high proportion of unsaturated fatty acids in the oil contained in products such as full fat soya bean meal and class FH sunflower seeds (42% oil) restrict their potential use as feedstuffs for use in pig growth diets.

Not only dietary factors, but also sex, can have an effect on the backfat fatty acid composition of the pig. According

to Wood (1984), lipid extracted from boar fat tissue is slightly more unsaturated and thus softer than that from castrates, when comparisons are made at the same carcass mass. However this author stated that diet has a more marked effect on fat quality than breed or sex. A knowledge of the effects of sex and of diet on fatty acid composition will permit the efficient use of feedstuffs in producing a desirable carcass for a given requirement.

The aim in this study was to determine the extent to which the fatty acids in the backfat of baconers could be manipulated by inclusion of class FH sunflower seed and tallow as lipid source in the diets of growing pigs.

Materials and methods

Thirty-nine Large White and 39 Landrace pigs (40 boars and 38 castrates) were used in a growth trial to study the effect of high oil containing sunflower seed (Class FH) on the long chain fatty acid composition of backfat in baconer pigs. Backfat samples of 55 (28 boars and 27 castrates) of the 78 pigs were taken and analysed for the long chain fatty acids.

Three diets (Table 1) were formulated to contain 18% protein, 1,0% lysine, and 13,5 MJ/kg digestible energy. Diet A, the control, was a normal pig growth diet. Diet T1 contained 16% class FH sunflower seed (sunflower oil cake + sunflower oil). Diet B was similar to diet T1, but for the sunflower oil being substituted with tallow.

The experimental treatments and the number of pigs per treatment are given in Table 2. Two sexes × 7 dietary treatments were used. Treatments A, B, and T1 were fed from eight weeks of age until slaughter at 85 kg live mass. In treatments T2, T3, T4, and T5 diet T1 was fed *ad lib.* until the pigs were 45 kg, 55 kg, 65 kg, or 75 kg in live mass, respectively. From these respective masses diet B was fed until the animals were slaughtered at 85 kg live mass.

Feed intake and live mass were recorded every four days. The pigs were kept individually in cages of 1,0 m × 1,5 m equipped with a self feeder and a continuous supply of fresh water.

All pigs were slaughtered at approximately 86 ± 1,50 kg live mass and the carcasses chilled at 2°C for 24 h. Measurements of P_2 backfat were made and backfat samples of both the layers taken at the last rib (at the P_2 position). All the samples were vacuum packed and stored at –20°C until analysis was performed within 4 weeks after sampling. The fat samples were analysed for the long chain fatty acids (C14 to C18) as described by Christopherson & Glass (1969) and Marchello *et al.* (1983).

The fat samples were blended with chloroform ($CHCl_3$) for 4 to 6 h. The suspension was stored in a freezer until further analysis. The sample extract was mixed with a 2M sodium hydroxide in methanol solution mixed with chloroform. Analysis was performed on a glass column, 3 m × 3 mm i.d. packed with Silar 10C on Gas Chrom Q using a Carlo Erba gas chromatograph, equipped with a flame ionization detector. The carrier gas used was N_2 at a rate of 0,9 kg/cm^2. The temperature conditions were 150 – 210°C at 5°C/min. A standard was prepared containing methyl esters of the fatty acids to be determined, in approximately the same concentrations as those expected for the samples.

Statistical analysis

Data were analysed by analysis of variance using a mixed model least-squares and maximum likelihood computer program (Harvey, 1988). Growth data were calculated, between 30 and 90 kg live mass, by means of the Allometric Autoregressive model as described by Siebrits (1986).

Table 1 Experimental diets

Source		Experimental diets A (Control)	B	T1
Maize meal	%	67,7	42,9	42,9
Wheaten bran	%	12,0	25,0	25,0
Fish meal	%	11,4	10,6	10,6
Soya bean oil cake	%	7,1	–	–
Sunflower oil cake	%	–	9,9	9,9
Sunflower oil	%	–	–	6,1
Tallow	%	–	6,1	–
Lucerne meal	%	–	3,7	3,7
Fine salt	%	1,0	1,0	1,0
Feedlime	%	0,76	0,49	0,49
Synthetic lysine	%	–	0,15	0,15
Antioxidant	ppm	–	250	250
Minerals plus vitamins	+	+	+	+
Nutrient composition (calculated)*				
Protein	%	18,0	18,0	18,0
Lysine	%	1,0	1,0	1,0
DE	MJ/kg	13,5	13,5	13,5
Fat	%	4,0	10,3	10,3
Fibre	%	3,6	7,3	7,3
Linoleic acid	%	1,5	1,4	5,3

* On an air dry basis.

Table 2 Experimental treatments

Treatment	Number of pigs per treatment: Growth trial Boars	Growth trial Castrates	Fatty acid determinations Boars	Fatty acid determinations Castrates	Live mass of pigs at substitution of diet T1 with diet B (kg)
A (Control)	6	6	4	3	No substitution
B	6	6	4	4	No substitution
T1	5	5	5	3	No substitution
T2	5	5	4	4	45
T3	6	5	4	4	55
T4	6	5	5	5	65
T5	6	6	2	4	75
	40	38	28	27	
Total	78		55		

Results and discussion

The fatty acid composition of backfat of the pigs slaughtered at 85 kg live mass on the various treatments is given in Table 3.

The fatty acid composition of pigs on the tallow (treatment B) diet was significantly ($P \leq 0,01$) different for palmitic, stearic, oleic, and linoleic acid from that of pigs on the sunflower oil (treatment T1) diet. Significant differences between treatments A and B were found only in stearic and linolenic acid ($P \leq 0,01$). However, treatment A caused a slightly more saturated backfat at 85 kg live mass than treatment B.

It is evident that the greatest effect on linoleic acid content was exerted by the experimental treatment. The linoleic acid content of pigs on the sunflower oil based diet (treatment T1) was 197% higher than that of the pigs on the tallow based diet (treatment A). A substantial effect on stearic/linoleic acid composition is evident in the 271% difference found between treatments, indicating a swing to an unsaturated backfat in pigs that received an unsaturated fat source.

The substitution of the sunflower oil based diet with the tallow based diet at higher live masses resulted in an elevated content of unsaturated fatty acids in the backfat as the point of substitution approached 85 kg live mass. However, the significant differences ($P \leq 0,01$) in linoleic acid content between T2 and T3; T4 and T5; as well as between T5 and T1 show a possibility of manipulating fatty acid composition by strategically feeding diets that contain fats differing in saturation. The desirable fatty acid composition for baconers must however still be determined to provide an acceptable product. According to Wood (1984), problems with soft fat arises when the linoleic acid content of the backfat is higher than 15% of the fatty acids. This would mean that if substitution of diets high in unsaturated fat sources with diets high in saturated fat

Table 3 Mean percentages of fatty acids in backfat determined at the position of the last rib of pigs slaughtered at 85 kg live mass (expressed as a percentage of total long chain fatty acids)

		Experimental treatments						
		A	B	T1	T2	T3	T4	T5
				(Sunflower	T1 substituted with B at live mass:			
Fatty acid		(Control)	(Tallow)	oil)	45 kg	55 kg	65 kg	75 kg
Myristic	(C14:0)	$1,1^{a}$	$1,5^{a}$	$0,8^{a}$	$1,0^{a}$	$1,4^{a}$	$1,5^{a}$	$0,9^{a}$
Palmitic	(C16:0)	$22,5^{a}$	$21,3^{ac}$	$16,3^{d}$	$18,9^{cf}$	$19,9^{cg}$	$19,0^{bc}$	$18,1^{bdfg}$
Palmitoleic	(C16:1)	$1,0^{a}$	$1,5^{a}$	$0,9^{a}$	$1,2^{a}$	$1,5^{a}$	$1,3^{a}$	$1,2^{a}$
Stearic	(C18:0)	$16,6^{a}$	$13,8^{b}$	$10,1^{c}$	$13,3^{beg}$	$12,4^{bhf}$	$11,9^{cgh}$	$11,3^{cdef}$
Oleic	(C18:1)	$47,0^{a}$	$46,3^{a}$	$34,1^{b}$	$45,0^{a}$	$40,0^{efh}$	$40,0^{dgh}$	$38,7^{cfg}$
Linoleic	(C18:2)	$11,1^{a}$	$13,0^{a}$	$36,3^{b}$	$18,6^{d}$	$22,5^{e}$	$24,6^{e}$	$28,6^{e}$
Linolenic	(C18:3)	$0,8^{a}$	$2,6^{b}$	$1,4^{ab}$	$2,0^{ba}$	$2,3^{bc}$	$1,7^{ab}$	$1,1^{ca}$
Stearic/Linoleic ratio		$1,58^{a}$	$1,11^{b}$	$0,30^{hc}$	$0,72^{fd}$	$0,57^{cdeg}$	$0,49^{efh}$	$0,39^{gh}$

^{a,b,c,d,e,f,g,h} Least square means within a row bearing different superscripts differ ($P \leq 0,01$).

Table 4 Growth performance of the pigs between 30 and 90 kg live mass

	Experimental treatments						
	A	B	T1	T2	T3	T4	T5
			(Sunflower	T1 substituted with B at live mass:			
Performance parameter	(Control)	(Tallow)	oil)	45 kg	55 kg	65 kg	75 kg
Average daily gain (g/day)	861^{a}	846^{ab}	803^{ab}	798^{b}	801^{b}	820^{ab}	812^{ab}
Feed intake (g/day)	2340^{a}	2118^{b}	2101^{b}	2036^{b}	2136^{b}	2082^{b}	2035^{b}
Feed conversion (kg feed/kg gain)	$2,67^{a}$	$2,53^{b}$	$2,63^{ab}$	$2,57^{b}$	$2,68^{ab}$	$2,56^{b}$	$2,60^{b}$
Age at 90 kg live mass (days)	151^{a}	148^{a}	154^{a}	156^{a}	155^{a}	153^{a}	152^{a}
P_2 backfat (mm)	$19,2^{a}$	$16,8^{ac}$	$14,7^{be}$	$13,6^{b}$	$16,7^{ad}$	$14,2^{bcd}$	$16,5^{ace}$

^{a,b,c,d,e} Least square means within a row bearing different superscripts differ ($P \leq 0,05$).

sources is done, the dietary fat sources must be taken into account to assess at what stage of the growth phase substitution should take place.

Treatments T1 and B did not differ ($P \leq 0,05$) in their effects on average daily gain (g/day), feed intake (g/day), feed conversion (kg feed/kg gain), or age at 90 kg live mass. Similarly, the other treatments where diet T1 was substituted with diet B at various live masses, did not differ (Table 4).

The P_2 backfat measurement of the pigs receiving treatment T1 was 12,5% lower ($P \leq 0,05$) than that of the pigs receiving Diet B. In spite of significant differences ($P \leq 0,05$) in P_2 backfat measurements between some of the treatments, no clear pattern emerged.

Results on the effect of castration on the fatty acid composition of backfat in this study (Table 5) are in agreement with results found by Wood & Enser (1982); Wood *et al.* (1986) and Barton-Gade (1987). Boars had a 12,5% higher (23,4%) ($P \leq 0,01$) linoleic acid content than castrates (20,8%), indicating a softer backfat. According to Wood & Enser (1989) and Wood *et al.* (1989), part of the sex differences in fatty acid contents of backfat could be ascribed to differences in fat thickness. Wood *et al.* (1989) stated that there appears to be a constant difference in fatty acid composition between sexes so that boars have concentrations equivalent to those of gilts with a 15% lower fat thickness. The 31,8% higher ($P \leq 0,01$) P_2 backfat thickness of the castrates in this study could therefore have contributed to the significantly lower linoleic acid content.

No significant ($P > 0,5$) interaction was found between treatment and sex, treatment and breed, or breed and sex.

Table 5 The effect of castration on the mean percentages of fatty acids and P_2 backfat of pigs slaughtered at 85 kg live mass

Fatty acid		Sex		
		Boars	Castrates	
Myristic	(C14:0)	1,3	1,1	NS
Palmitic	(C16:0)	18,8	20,0	*
Palmitoleic	(C16:1)	1,3	1,1	NS
Stearic	(C18:0)	12,6	13,0	NS
Oleic	(C18:1)	40,8	42,4	*
Linoleic	(C18:2)	23,4	20,8	**
Linolenic	(C18:3)	1,8	1,6	NS
Stearic/Linoleic ratio		0,67	0,81	*
P_2 backfat (mm)		13,8	18,2	**

NS Non significant $P > 0,05$

* $P \leq 0,05$

** $P \leq 0,01$

It can be concluded that the fatty acid composition of the diet is directly reflected in the fatty acid composition of backfat. It should therefore be possible to change the fatty acid composition of the backfat in the pig by manipulating dietary fatty acid content. The sex of the pig is however also an important consideration to be taken into account. Further work needs to be done to determine the maximum linoleic acid level in backfat that will yield an end product acceptable to both the consumer and the processor. Finally it is important that direct relationships between dietary fatty acids and fatty acids in the backfat be established for use in the prediction of effect of diet on product quality (i.e. backfat firmness).

References

BARTON-GADE, P.A., 1987. Meat and fat quality in boars, castrates and gilts. *Livest. Prod. Sci.* 16, 187–196.

CHRISTOPHERSON, S.W. & GLASS, R.L., 1969. Preparation of milk fat methyl esters by alcolysis in an essentially nonalcoholic solution. *J. Dairy Sci.* 52, 1289.

DAHL, O. & PERSSON, K., 1965. Properties of animal fat in relation to dietary fat. *J. Sci. Food Agric.* 16, 452–455.

HARVEY, W.R., 1988. User's guide for LSMLMW PC-1 version mixed model least-squares and maximum likelihood computer program.

MARCHELLO, M.J., COOK, N.K., SLANGER, W.D., JOHNSON, V.K., FISHER, A.G. & DINUSSON, W.E., 1983. Fatty acid composition of lean and fat tissue of swine fed various dietary levels of sunflower seed. *J. Food Sci.* 48, 1331–1334.

SIEBRITS, F.K., 1986. Application of the allometric autoregressive growth description in studies of growth and body composition. *Pig News & Information* 7, 413–145.

St JOHN, L.C., YOUNG, C.R., KNABE, D.A., THOMPSON, L.D., SCHELLING, G.T., GRUNDY, S.M. & SMITH, S.B., 1987. Fatty acid profiles and sensory and carcass traits of tissues from steers and swine fed an elevated monounsaturated fat diet. *J. Anim. Sci.* 64, 1441–1447.

WHITTINGTON, F.M., PRESCOTT, N.J., WOOD, J.D. & ENSER, M., 1986. The effect of dietary linoleic acid on the firmness of backfat in pigs of 85 kg live weight. *J. Sci. Food Agric.* 37, 753–761.

WOOD, J.D., 1984. Fat deposition and the quality of fat tissue in meat animals. In : J. Wiseman, Ed., *Fats in Animal Nutrition*. Butterworths, London, 407–453.

WOOD, J.D., BUXTON, F.M., WHITTINGTON, F.M. & ENSER, M., 1986. The chemical composition of fat tissues in the pig: Effects of castration and feeding treatment. *Livest. Prod. Sci.* 15, 73–82.

WOOD, J.D. & ENSER, M., 1982. Comparison of boars and castrates for bacon production. 2. Composition of muscle and subcutaneous fat, and changes in side weight during curing. *Anim. Prod.* 35, 65–74.

WOOD, J.D. & ENSER, M., 1989. Fat quality in pigs with special emphasis on genetics. 40th Annual Meeting of the Study Commissions EAAP, Dublin, 17–31 August 1989. Commissions on Animal Genetics and Pig Production.

WOOD, J.D., ENSER, M., WHITTINGTON, F.M., MONCRIEFF, C.B. & KEMPSTER, A.J., 1989. Backfat composition in pigs: Differences between fat thickness groups and sexes. *Livest. Prod. Sci.* 22, 351–362.