Relationship between dietary fat and fatty acid composition of subcutaneous and intramuscular fat in heavy pigs.(*)

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SUMMARY: A traditional feed (C) and two experimental diets with 20% (T1) and 40% (T2) sweet potatoes (SP) replacing maize meal, with 1, 1.5 and 2% lard added respectively, were fed to three groups of 25 Large White castrated males each (156 kg slaughter weight). Fatty acid composition of backfat and intramuscular fat in Parma-type hams (12 months ageing) and iodine value of ham subcutaneous fat are discussed. The backfat of pigs fed T1 and T2 diets showed significant increases in saturated fatty acids and a marked decrease in linoleic acid, whereas only linoleic and gondoic acid decreased significantly in intramuscular fat. Iodine value decreased too, but not significantly; no defects of odour, flavour, colour and firmness were found upon ham sensory evaluation in either fat or lean. Even with lard added, SP could therefore be used in heavy pig feeding for improving the fat keeping qualities in the ageing process.

INTRODUCTION: The reduction of feeding costs is of utmost interest to pig farmers in Northern Italy especially, where the production of aged meat products, such as Parma ham, requires high slaughter weights (approx. 160 kg). Thus much research has been directed at the evaluation of alternative feeds or by-products that are more economical with respect to traditional cereals. A suitable alternative feed must ensure the same performances, with equally satisfactory dressing percentages and carcass characteristics as traditional feeds. Furthermore, the quality of the lean and fat, which is of paramount importance for the final products, must be in no way negatively affected. The research into the possible use of sweet potatoes *(Ipomoea batatas)* as a replacement for maize meal in the diets of fattening pigs up to a slaughter weight of approx. 156 kg was carried out bearing in mind these factors. A first set of results has been published previously (MANFREDINI *et al.*, 1990).The aim of this trial was to assess if and how the fatty acid composition of the diets affects that of the backfat, as well as that of the intramuscular fat extracted from 12-month aged hams. In addition, an evaluation was made of the effects of the diets on the eating qualities of the hams.

MATERIALS and METHODS: A total of 75 Large White castrated male pigs with an initial weight of 42 kg were divided into three groups. The control group (C) was given a traditional maize-based (40%) diet; the two treated groups received 20% (T1) and 40% (T2) sweet potatoes (SP) in place of the same quantity of maize. Lard was added at levels of 1, 1.5, and 2% to diets C, T1 and T2 respectively to make them isocaloric. The different protein requirements of the animals as they grew were met by slightly changing the experimental diets when a live weight of 110 kg was reached.

Table 1 shows the percent composition and the lipid content of the diets given from 110 kg to slaughter, while Table 2 reports the fatty acid composition of the lard and of the diets. With the exception of myristic acid (C14:0), in the second table the fatty acids (f.a.) which are present in quantities below 1% of the total, i.e. lauric (C12:0), arachidic (C20:0) and gondoic (C20:1) acids, have been omitted. However, these were taken into consideration for the calculation of the various f.a. ratios. It may be observed that the replacement of maize with SP and the addition of lard changed the lipid f.a. composition of the diets. Whereas the myristic, palmitic (C16:0), palmitoleic (C16:1), stearic (C18:0), oleic (C18:1) and linolenic (C18:3) acids increase with the increase in the SP content of the diets, the opposite is true for linoleic acid (C18:2). Consequently, there is an increase in the saturated f.a./unsaturated f.a. and C18:0/C18:2 ratios, while the polyunsaturated f.a./monounsaturated f.a. ratio decreases.

The animals were slaughtered at an average live weight of 156 kg. A sample of backfat (both layers) was taken from each carcass in the rump region, to determine the f.a. composition. One leg from each carcass was processed as normal for the production of Parma-type ham (12 months ageing). The following determinations were made on 10 aged hams from each group: a) iodine value of the depot fat (inner layer); b) fat content of the *biceps femoris (b.f.)* and *semitendinosus (s.t.)* muscles; c) f.a. composition of the intramuscular fat extracted from the above mentioned muscles. The intramuscular fat content of the *b.f.* and *s.t.* muscles was determined by means of extraction with ethylic ether in a Soxhlet apparatus (AOAC, 1984). In order to determine the f.a. composition, lipids were extracted from the same muscles with a

Table 1 - Percent composition and ether extract of experimental diets

Ingredients	C	T1	T2
Sweet potatoes meal	0.0	20.0	40.0
Maize meal	40.0	20.0	0.0
Barley meal	30.0	28.0	27.0
Wheat bran	12.0	12.0	10.0
Soybean meal, solv. (44% prot.)	14.0	15.5	18.0
Lard	1.0	1.5	2.0
Phosphorus supplement	1.3	1.3	1.3
Calcium carbonate	1.1	1.1	1.1
Premix	0.5	0.5	0.5
L-Lisine chlorhydrate	0.1	0.1	0.1
Ether extract (% d.m.)	*4.50*	*4.13*	*4.01*

Table 2 - Fatty acid composition of lard and experimental diets (1)

Fatty acids and f.a. ratios	Lard	C	T1	T2
C14:0	1.47	0.68	0.81	0.93
C16:0	24.35	19.10	21.20	23.33
C16:1	2.94	1.22	1.47	1.76
C18:0	15.12	5.36	7.24	9.39
C18:1	42.50	27.79	29.44	31.12
C18:2	11.39	42.70	35.72	29.24
C18:3	1.80	3.16	3.32	3.39
satur./unsat.	0.69	0.34	0.42	0.52
polyun./monoun.	0.29	1.58	1.26	0.98
C18:0/C18:2	1.33	0.13	0.20	0.32

(1) f.a. as % by weight of total f.a.

chloroform-methanol 2:1 (v/v) mixture according to the method of FOLCH *et al.* (1957). The fatty acids were methylated with a 0.5 N solution of NaOH in methanol (MADARENA *et al.*, 1988-1989) and analysed by gaschromatography using a Carlo Erba Fractovap 2350 chromatograph with a flame ionisation detector. Both backfat layers were minced finely and methylated directly following the method already described for the intramuscular fat analysis. The iodine value was determined according to the method of WIJS (NGD, 1976). The hams underwent sensory evaluation by a panel of experts which assessed odour, flavour, colour and firmness of the depot fat and the lean.

RESULTS and DISCUSSION: Table 3 shows the f.a. composition of the backfat. Arachidonic acid (C20:4) and C20:1, with a content of less than 1% of the total, have been omitted. The table also reports some ratios between the fatty acids, in particular C18:0/C18:2 and (C16:1+C18:1)/(C16:0+C18:0),the so-called "index of softness". It may be seen that the content of C16:0, C16:1, C18:0, C18:1 and the ratios C18:0/C18:2, as well as saturated f.a./unsaturated f.a., are significantly higher in groups T1 and T2 than in C. On the other hand, C18:2 and polyunsaturated f.a./monounsaturated f.a. decrease significantly from C to T1 to T2. As expected, the f.a. composition of the backfat reflected that of the dietary fat in all three groups.The replacement of maize, which is relatively rich in lipids, with the almost lipid-free sweet potatoes, led to a significant decrease in C18:2. However, in groups T1 and T2 the C18:2 content decreased less than expected, perhaps due to the addition of lard. It is of interest that linoleic acid falls from slightly more than 15% (C) to slightly less than 12% (T2). These values were considered by ELLIS and ISBELL (1926) and by PRABUCKI (1978), respectively, as the limits beyond which fat shows reduced firmness and high susceptibility to oxidation. Nevertheless, the 12% limit is judged as excessively low by HOUBEN and KROL (1984). For the aged hams (Table 4), it may be observed that intramuscular fat content of the *b.f.* and *s.t.* muscles is not significantly different between the groups. As regards the f.a. composition, significant differences were found only for C18:2, C20:1, polyunsaturated f.a./monounsaturated f.a. and C18:0/C18:2. The diets thus affected the f.a. composition of intramuscular fat less noticeably than that of subcutaneous fat, as found by GIRARD *et al.* (1983). The treated groups showed a lower C18:2 content and thus a lower polyunsaturated f.a./monounsaturated f.a. ratio and a higher C18:0/C18:2 value. It would thus seem that this fat keeps better. This fact is of considerable importance if we consider the effect of intramuscular lipids on the eating qualities of the meat, as well as on its technological and nutritional properties. The iodine value of the ham depot fat (inner layer) is also reported in Table 4. The values are not significantly different in the three groups, although there is a slight decrease as the dietary SP increase.They vary between 65 and 70; the former value according to MORTENSEN *et al.* (1983), the latter one according to BARTON-GADE (1984) are to be considered the limits above which adipose tissue softness would be unacceptable. A limit value of 70 has been widely used in Italy, as it has been observed that over 70 oxidative rancidity is

Table 3 - Fatty acid composition of backfat (f.a. % by weight of total f.a.)

Fatty acids and f.a. ratios	C		T1		T2		Significance ([1])
	mean	s.d.	mean	s.d.	mean	s.d.	
C14:0	1.33	0.14	1.39	0.14	1.37	0.14	n.s.
C16:0 ([2])	22.40^{b}	0.93	23.11^{a}	1.03	23.04^{a}	1.04	*
C16:1	2.57^{B}	0.35	2.84^{A}	0.24	2.94^{A}	0.28	***
C18:0	13.70^{b}	1.69	14.09^{ab}	1.09	14.74^{a}	1.36	*
C18:1	40.85^{B}	1.73	41.61^{AB}	2.34	42.79^{A}	2.38	**
C18:2	15.55^{A}	1.55	13.93^{B}	1.86	11.99^{C}	1.30	***
C18:3	2.22	0.14	2.18	0.13	2.20	0.11	n.s.
saturated f.a./unsaturated f.a.	0.60^{bB}	0.05	0.63^{a}	0.04	0.64^{aA}	0.05	**
polyunsat. f.a./monounsat. f.a.	0.42^{A}	0.04	0.37^{B}	0.06	0.32^{C}	0.04	***
(C16:1 + C18:1)/(C16:0 + C18:0)	1.21	0.10	1.20	0.10	1.22	0.12	n.s.
C18:0/C18:2	0.88^{C}	0.15	1.03^{B}	0.13	1.24^{A}	0.15	***

([1]) n.s. : not significant; * P< 0.05; ** P<0.01; *** P<0.001.
([2]) Numbers within lines with different superscript letters differ significantly, P<0.05 if small letters, P<0.01 if capital ones are used.

Table 4 - Intramuscular fat content of aged hams with its fatty acid composition (% total f.a.) and iodine value of ham subcutaneous fat

Items	C		T1		T2		Significance
	mean	s.d.	mean	s.d.	mean	s.d.	
Ether extract (% w.b.)	3.46	1.27	3.75	0.93	3.23	0.81	n.s.
C14:0	1.10	0.12	1.19	0.13	1.16	0.13	n.s.
C14:1	0.39	0.15	0.32	0.05	0.40	0.17	n.s.
C16:0	22.09	0.99	22.73	0.92	22.52	1.29	n.s.
C16:1	3.50	0.37	3.68	0.48	3.67	0.44	n.s.
C18:0	13.34	1.04	13.28	1.24	13.62	1.09	n.s.
C18:1	44.90	2.13	46.46	1.97	46.90	1.77	n.s.
C18:2	10.92^{aA}	1.47	9.22^{b}	1.49	8.63^{bB}	0.74	**
C18:3	1.38	0.13	1.38	0.08	1.39	0.13	n.s.
C20:1	0.38^{A}	0.05	0.30^{B}	0.03	0.27^{B}	0.03	***
C20:4	1.93	0.56	1.55	0.54	1.58	0.40	n.s.
saturated f.a./unsaturated f.a.	0.57	0.03	0.59	0.04	0.60	0.05	n.s.
polyunsat. f.a./monounsat. f.a.	0.29^{a}	0.05	0.25^{b}	0.05	0.23^{b}	0.03	*
C18:0/C18:2	1.21^{bB}	0.15	1.44^{a}	0.27	1.59^{aA}	0.15	**
Iodine value	67.70	2.69	66.92	1.93	66.62	2.36	n.s.

Same footnotes as in Table 3.

more likely to develop in fat during ageing. In the present trial, a panel of experts noticed no significant differences between the hams of the three groups as regards eating qualities affected by ham fat. Furthermore the hams showed no difference as regards marbling, salty taste, the amount of fat placed between *b.f.* and *semimembranosus* muscles or presence of tyrosine. No unusual flavour was found either for lean or fat.

CONCLUSIONS: The replacement of maize with sweet potatoes brought about changes both in backfat and intramuscular fatty acid composition. A lower degree of f.a. unsaturation, a lower C18:2 content and a higher C18:0/C18:2 value were found in the treated groups, especially in the backfat and with the higher level of SP. These characteristics inprove fat keeping qualities and enhance the final quality of Parma-type hams. As changes in the f.a. composition of the diets were due to both the SP and the lard, it is not possible to establish to what extent each of them affected the composition of adipose tissues in pigs. The addition of lard was necessary, however, to ensure that the diets were isocaloric and therefore to operate as close as possible to reality. The use of sweet potatoes in the fattening of heavy pigs may be uneconomical due to a decrease in feed efficiency and in dressing percentage at slaughter (MANFREDINI *et al.*, 1990). It does not, however, affect eating qualities of Parma-type ham and indeed improves both depot and intramuscular fat quality.

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