INFLUENCE OF DIETARY FAT AND α-TOCOPHEROL SUPPLEMENTATION ON THE FATTY ACID COMPOSITION OF PORK AND ITS SUSCEPTIBILITY TO LIPID OXIDATION

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SUMMARY:

Dietary fat had a marked influence on the fatty acid composition of porcine muscle. The ratio of C18:2/C18:1 was significantly higher in muscle from pigs fed soya oil when compared to muscle from pigs fed tallow. Muscle tissue from pigs fed soya oil diets was significantly more susceptible to lipid peroxidation than muscle from pigs fed tallow diets. α-Tocopherol supplementation significantly reduced the susceptibility to lipid peroxidation of muscle from pigs fed both tallow and soya oil diets. It may be concluded that altering the fatty acid composition of porcine muscle by dietary means can lead to increased susceptibility to oxidation and hence a reduction in shelf life of pork. Dietary α-tocopherol supplementation may offer an effective means of minimizing the adverse effect of increased unsaturated fatty acid intake on the oxidative stability of meat and meat products.

INTRODUCTION:

Lipid oxidation in meats leads to loss of flavour, development of off-flavours, loss of colour and nutrient value (Pearson et al., 1983) and is a major problem in the development of new convenience meat products and processes. The susceptibility of muscle tissue to lipid peroxidation depends on a number of factors, the most important being the level of polyunsaturated fatty acids present in the particular muscle system (Allen & Foegeding, 1981). Modification of the fatty acid composition of lifestock by dietary means is receiving increasing attention because of the probable relationship between saturated fatty acid intake, plasma cholesterol and heart disease (Grundy, 1989).

The fatty acid composition of porcine muscle and adipose tissue is influenced by both the quality and quantity of fat fed to pigs (Marchello et al., 1983; Rhee et al., 1988).

Unfortunately, changes in fatty acid composition may be accompanied by changes in the susceptibility of tissue lipids to oxidative attack (Rhee et al., 1988). However, α-

tocopherol supplementation of pig diets has been shown to result in increased α-tocopherol concentration in porcine tissues with a concomitant increase in the stability of the muscle (Monahan et al., 1990).

The objectives of the present study were to investigate the effects of dietary fat on: (a) the fatty acid profile of porcine muscle lipids and (b) the susceptibility of muscle tissue to lipid oxidation and to assess the effect of dietary α-tocopherol supplementation on oxidative stability of muscle.

MATERIALS AND METHODS:

Sixty-four Landrace x Large White pigs, weighing approximately 7 kg each at weaning, were randomly divided into four groups of sixteen (8 male, 8 female). Each group was fed, for four months prior to slaughter, a diet containing 3% beef tallow or 3% soya oil with either a basal level of α-tocopherol acetate (50 mg/kg diet) or a supplemented level (200 mg/kg diet). The pigs were given water and feed ad libitum. The average weight of the pigs at slaughter was 84 kg. Blood samples were taken from the pigs at the point of slaughter. The Longissimus dorsi muscle was removed from carcasses at 24h post-slaughter. Blood plasma and muscle samples were stored under vacuum at -20°C until required.

Lipids were extracted from feed and muscle samples using the methods of Burton et al. (1985) and Marmer and Maxwell (1981), respectively. Fatty acid methyl esters of dietary lipids were prepared by the method of Slover and Lanza (1981). Fatty acid methyl esters of the neutral and polar lipid fractions isolated from muscle tissue were prepared by the methods of Slover and Lanza (1981) and Maxwell and Marmer (1983), respectively.

The methyl esters of the fatty acids were analysed on a glass column, 2 m x 3 mm i.d containing 10% Silar-10C on 100/120 mesh Gas-Chrom Q. The analysis was performed on a Shimadzu GC-14A gas chromatograph equipped with a flame ionization detector. A Shimadzu C-R6A Chromatopac integrator was used for the calculation of peak areas.

α-Tocopherol in plasma and muscle was determined by the HPLC methods of Bieri et al. (1979) and Buttriss and Diplock (1984), respectively.

The lability of muscle tissue homogenates to iron-induced lipid peroxidation was determined by a modification of the method of Kornbrust and Mavis (1980). 2-Thiobarbituric acid reactive substances (TBARS) were determined by the method of Buege and Aust (1978) and reportd as nmoles malonaldehyde per mg of protein.

Cooked pork patties were prepared as previously described

(Monahan et al., 1990) and lipid oxidation was assessed by the 2-thiobarbituric method of Ke et al. (1977). TBARS values were expressed as mg malonaldehyde per kg of tissue.

RESULTS AND DISCUSSION:

Muscle tissue fatty acids: The neutral lipid fractions isolated from the L. dorsi muscle of pigs receiving the 3% soya oil diet had a significantly lower proportion of C16:0 ($p < 0.05$) and C18:1 ($p < 0.05$) and a higher proportion of C18:2 ($p < 0.05$) than fractions isolated from pigs receiving the 3% tallow diet (Table 1). Polar lipid fractions from pigs receiving the 3% soya oil diet had significantly lower levels of C18:1 ($p < 0.01$) and significantly higher levels of C18:2 ($P < 0.05$) and C20:5 ($p < 0.05$) than pigs fed 3% tallow (Table 2). In muscle from pigs receiving the soya oil diet the ratio of unsaturated/saturated fatty acids was significantly higher ($p < 0.05$) in the neutral lipid fraction, but not in the polar lipid fraction, when compared with the pigs receiving the tallow diet (Tables 1 and 2). In both neutral and polar lipid fractions, the ratio of C18:2/C18:1 was significantly higher ($p < 0.05$) in muscle from pigs fed soya oil than in tissue from pigs fed tallow.

α-Tocopherol levels: The mean α-tocopherol levels in plasma and muscle of pigs fed the basal diet and the diet supplemented with α-tocopherol are presented in Table 3. Plasma α-tocopherol levels were significantly ($p < 0.01$) influenced by dietary levels and increased approximately 3.3-fold at the higher dietary level (200 mg/kg diet). The mean α-tocopherol level in muscle increased approximately 2.8-fold at the higher dietary level. The α-tocopherol levels were lower in plasma and muscle from pigs fed the soya oil diet compared to the tallow diet. However, the differences were only significant in the case of muscle tissue from pigs fed the basal level of α-tocopherol in their diets (Table 3). It has been shown that increasing the linoleic acid intake of rats can result in decreased absorption of α-tocopherol (Gallo-Torres, 1980). The increased linoleic acid intake of pigs receiving the soya oil diet probably accounted for the lower plasma and muscle α-tocopherol levels in these pigs compared to pigs fed the tallow-based diet.

Lipid oxidation in muscle: Homogenates of muscle tissue from pigs fed the 3% soya oil diet with basal α-tocopherol levels were significantly ($p < 0.01$) more susceptible to iron-induced lipid peroxidation after 120 min incubation than muscle homogenates from pigs fed the 3% tallow diet with basal levels of α-tocopherol (Fig. 1). The increased susceptibility to lipid peroxidation by the soya oil group is undoubtedly due to the increase in the percentage of C18:2 in the muscle, since the rate of oxidation is dependent on the number of allyl groups present (Arakawa & Sagai, 1986). In addition, the lower levels of α-tocopherol in muscle samples from pigs fed the soya soil diet may contribute to the increased susceptibility to lipid peroxidation. Dietary α-

tocopherol supplementation significantly increased the stability to lipid peroxidation of muscle from pigs fed tallow ($p < 0.05$) or soya oil ($p < 0.01$) diets.

Cooked muscle systems are particularly susceptible to oxidation due to the release of haem iron as non-haem iron (Gray and Pearson, 1983; Morrissey and Tichivangana, 1985). The lipid composition of the diet also has a marked influence on oxidative stability. The data (Fig. 2) showed that cooked muscle from the group fed the tallow diet had consistently lower TBARS numbers than cooked muscle from the group fed soya oil. Significant differences ($p < 0.01$) were observed after 48 h at 4°C. However, in cooked muscle from pigs fed both tallow and soya oil diets, α-tocopherol supplementation led to a significant ($p < 0.01$) reduction in TBARS after 48 h of storage at 4°C.

CONCLUSIONS:

Modification of the fatty acid composition of porcine muscle by dietary means resulted in increased susceptibility to lipid oxidation and loss of shelf-life. However, dietary supplementation with α-tocopherol may be an effective means of incorporating α-tocopherol into subcellular membranes and stabilising muscle tissue containing elevated levels of polyunsaturated fatty acids.

Table 1.-Fatty acid profiles of the neutral lipid fraction of muscle from pigs fed tallow and soya oil diets

Fatty acid	Tallow diet[1,2] (%)	Soya oil diet (%)
C14:0	0.59[a]	0.91[a]
C16:0	27.10[a]	24.14[b]
C16:1	4.29[a]	3.51[a]
C18:0	13.55[a]	13.18[a]
C18:1	45.11[a]	40.48[b]
C18:2	5.89[b]	13.29[a]
C18:3	2.33[a]	2.93[a]
C20:0	0.20[a]	0.38[a]
C20:4	0.37[a]	0.03[a]
C20:5	0.25[a]	0.03[a]
C22:6	0.06[a]	0.31[a]
Total saturates	41.33[a]	38.41[b]
Total unsaturates	58.24[b]	61.21[a]
Ratio:		
Unsaturates/saturates	1.41[b]	1.60[a]
C18:2/C18:1	0.13[b]	0.33[a]

[1]Percent of total peak area of fatty acids listed
[2]Means in the same row followed by different superscripts are significantly different ($p < 0.05$)

Table 2.-Fatty acid profiles of the polar lipid fraction of muscle from pigs fed tallow and soya oil diets

Fatty acid	Tallow diet[1,2] (%)	Soya oil diet (%)
C14:0	0.36[a]	0.99[a]
C16:0	19.68[a]	18.80[a]
C16:1	2.79[a]	0.94[a]
C18:0	11.83[a]	13.54[a]
C18:1	23.57[a]	15.54[b]
C18:2	28.85[b]	37.78[a]
C18:3	2.15[a]	2.10[a]
C20:4	6.72[a]	8.47[a]
C20:5	1.92[a]	0.90[b]
C22:0	0.78[a]	trace[a]
C22:6	1.30[a]	0.86[a]
Total saturates	32.75[a]	33.25[a]
Total unsaturates	67.16[a]	66.61[a]
Ratio:		
Unsaturates/saturates	2.05[a]	2.01[a]
C18:2/C18:1	1.22[b]	2.47[a]

[1]Percent of total peak area of fatty acids listed
[2]Means in the same row followed by different superscripts are significantly different ($p < 0.05$).

Table 3.-Mean α-tocopherol content of plasma and muscle of pigs fed tallow and soya oil diets with basal and supplemented levels of α-tocopherol acetate

Dietary treatment	α-Tocopherol[a]	
	Plasma (µg/ml)	Muscle (µg/g)
Tallow:		
basal α-tocopherol	2.23 ± 0.27[b]	3.22 ± 0.14[b]
supplemented α-tocopherol	7.27 ± 0.54[c]	8.00 ± 0.38[c]
Soya oil:		
basal α-tocopherol	2.07 ± 0.25[b]	2.22 ± 0.16[d]
supplemented α-tocopherol	6.85 ± 0.35[c]	6.96 ± 0.53[c]

[a]Mean values and standard error of the mean of six analyses performed in duplicate.
[b,c,d]Means in the same column bearing different superscripts differ significantly ($p < 0.01$)

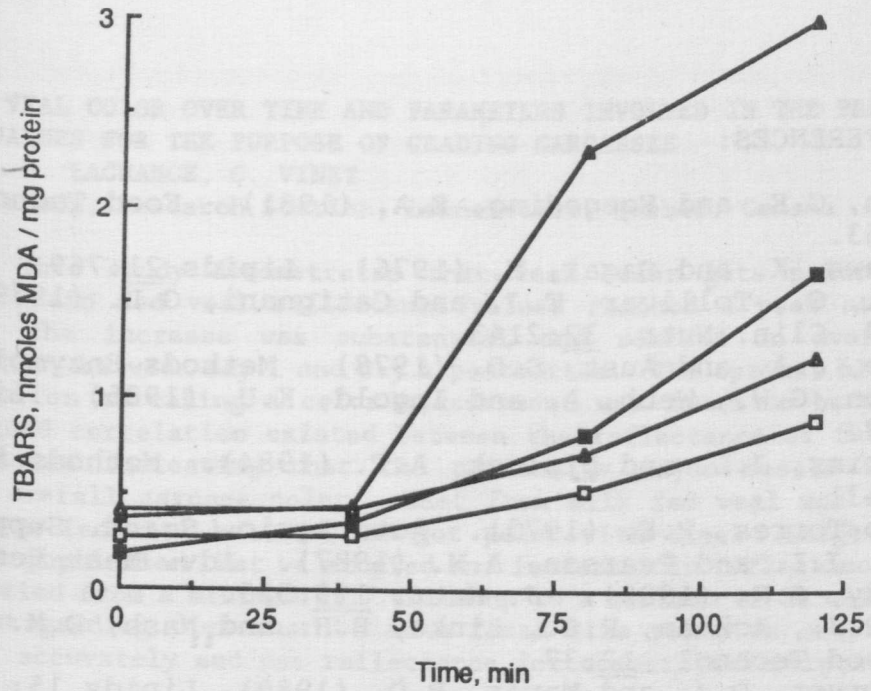

Fig.1. Effect of dietary fat and α-tocopherol supplementation on iron-induced lipid peroxidation in porcine muscle. ■,tallow with basal α-tocopherol acetate; □,tallow with supplemented α-tocopherol acetate; ▲,soya oil with basal α-tocopherol acetate; △,soya oil with supplemented α-tocopherol acetate.

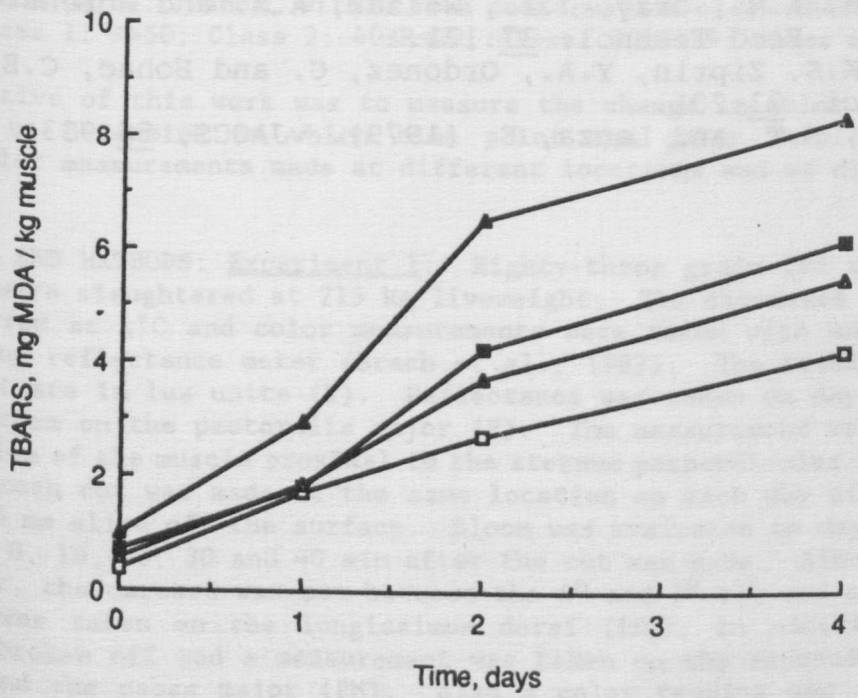

Fig.2. Effect of dietary fat and α-tocopherol supplementation on the TBARS numbers of pork patties stored at 4°C for up to 4 days. ■,tallow with basal α-tocopherol acetate; □,tallow with supplemented α-tocopherol acetate; ▲,soya oil with basal α-tocopherol acetate; △,soya oil with supplemented α-tocopherol acetate.

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