MEMBRANAL LIPID PEROXIDATION IN RELATION TO MEAT STABILITY

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SUMMARY

Studies were designed to evaluate the effect of dietary oils and/or α-tocopherol supplementation on the oxidative stability of membranal lipids in broiler and pig muscles, and on the oxidative stability of broiler and pork products during storage. Results of these investigations indicated that: (a) the consumption of the polar lipids of the membranes were influenced by dietary oil and that changes in the fatty acid composition of the membranal lipids of broilers were reflected in their susceptibility to metmyoglobin/hydrogen peroxide initiated peroxidation, and (b) membrane-bound α-tocopherol stabilizes the membranal lipids of both broiler and pork muscles, and this reduced the extent of lipid oxidation occurring in broiler meat and pork during refrigerated and frozen storage. These observations support the hypothesis that lipid peroxidation in raw meat is initiated in the membrane-bound lipids and that stabilization of the membranal lipids, either through alteration of the fatty acid composition or by incorporation of -tocopherol into them, has positive influence on the oxidative stability of muscle foods during storage.

INTRODUCTION

Lipid peroxidation is one of the major causes of deterioration in the quality of meat and meat products, particularly during frozen storage. Oxidative deterioration can directly affect many quality characteristics such as colour, flavour, texture, nutritive value and safety (Pearson et al. 1983). Membrane-bound lipids associated wit the muscle cell wall, the mitochondria and the sarcoplasmic reticulum are especially susceptible to oxidation because of their high contents of polyunsaturated fatty acids (Pearson et al. 1977). This study is based on the hypothesis that membrane-bound lipids in muscle foods are the central point in the development of oxidative rancidity in fresh meat products during storage. Thus, stabilization of the membrane lipids should influence the stability of meat products. The major objectives of this study were: (1) to determine the effects of dietary oils and -tocopherol supplementation on the oxidative stability of membranal lipids in dark and white meat of broilers, and (2) to study the influence od dietary α-tocopherol and oxidized oil supplements on the stability of pig membranal lipids toward metmyoglobin/ hydrogen peroxide-initiated peroxidation and on the oxidative stability of pork products during storage.

EXPERIMENTAL METHODS

Broiler study: One hundred and seventy five one-day old White Mountain chicks were randomly divided into five groups. Each group was given standard broiler feed supplemented (5.5%) with vegetable oils of varying degrees of unsaturation: coconut oil, olive oil, linseed oil and partially hydrogenated soybean oil (HSBO). A fifth diet containing HSBO and α-tocopherol (100mg/kg feed) was used. The broilers were raised for seven weeks and then slaughtered. Lipids (neutral and polar) were extracted from the muscle samples using the dry column method of Marmer and Maxwell (1981), while fatty acid composition was established by GC analysis of the fatty acid methyl esters. The TBA method of Tarladgis et al. (1964) was used to monitor lipid oxidation in the meat samples during storage.

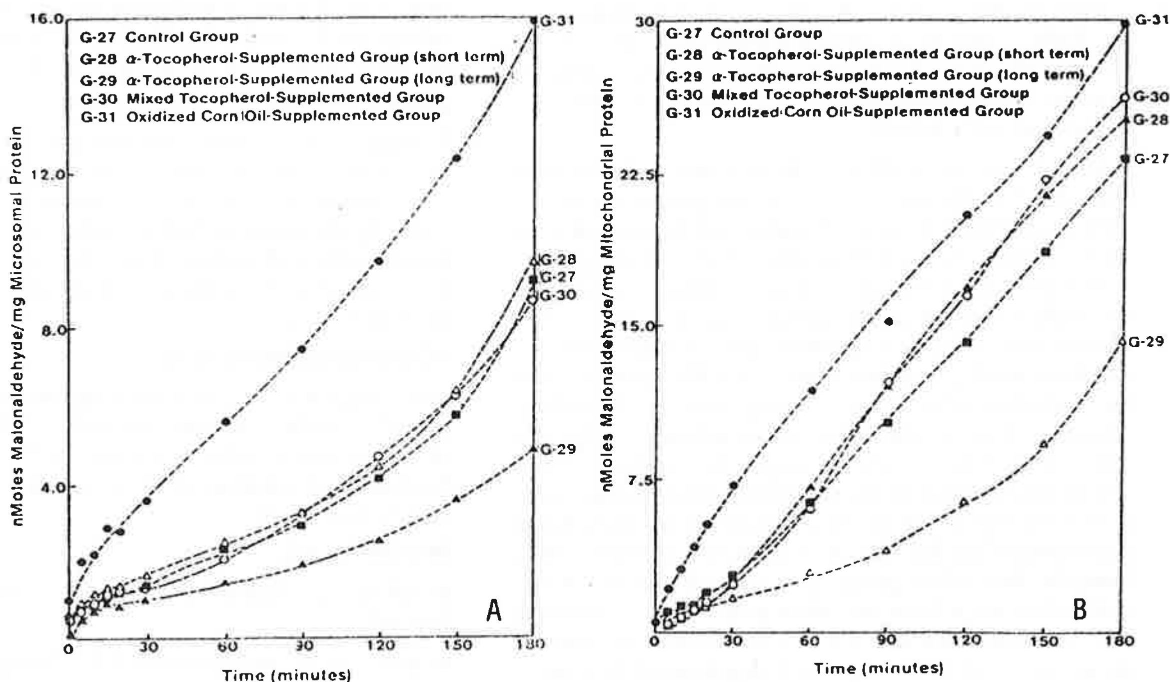

Figure 1. Metmyoglobin/hydrogen peroxide-initiated peroxidation in microsmal (A) and mitochondrial (B) lipids from pigs fed various diets

Isolation of microsomal and mitochondrial subcellular fractions of the white and dark muscles was achieved by differential centrifugation (Schenkman and Cinti 1978). The lability of the isolated fractions to peroxidation was determined using the metmyoglobin-hydrogen peroxide assay of Harel and Kanner (1985).

Pig study: Thirty cross-bred pigs (approximately three months old, equal numbers of barrows and gilts) were alloted at random into five groups of six pigs and fed the following diets: (1) control diet; (2) control diet + added α-tocopherol (200 mg/kg feed) for the last four weeks of the feeding trial; (3) control diet + added α-tocopherol (200 mg/kg feed) for the duration of the feeding trial (10 weeks), (4) control diet + natural mixed tocopherols (200 mg/kg feed) for ten weeks and (5) a diet containing oxidized corn oil to produce a meal having a peroxide value of 9 meq/kg feed. The semitendinosus muscles from the pigs were used to study the extent of peroxidation of membrane-bound lipids (microsomes and mitochondria) when subjected to the non-enzymic (metmyoglobin/ hydrogen peroxide) lipid peroxidation assay of Harel and Kaner (1985). The oxidative stability of various pork products (pork chops, restructured pork roasts) from the pigs fed the various diets was evaluated using the TBA procedure described previously.

RESULTS AND DISCUSSION

Results of the broiler experiments indicated that the composition of the polar lipids of subcellular membranes was influenced by dietary oil and that the changes in the fatty acid composition of the microsomal and mitochondrial lipids were reflected in their susceptibility to metmyoglobin/hydrogen peroxide initiated peroxidation. The polar lipids of the microsomes isolated fr the broilers fed linseed oil contained much higher levels of pentane ($C_{20:5}$) and hexane ($C_{22:6}$) fatty acids compared to the other broiler groups (Table 1). This indicates that the high amounts of linolenate in the diet led to the biosynthesis and deposition of these fatty acids in the microsomes. Another noticeable feature was the higher content of saturated fatty acids ($C_{12:0}$) and $C_{14:0}$) in the polar lipids of the broilers fed coconut oil. Similar fatty acid trends were observed for the mitochondrial fractions.

When the metmyoglobin/ hydrogen peroxide initiator was added to the isolated microsome preparations, the microsomal lipids from the broilers fed linseed oil were more rapidly oxidized than those fr the other groups. This rapid rate of oxidation can be explained, in part, by the higher content of the polyunsaturated fatty acids. Microsomes isolated from the α-tocopherol - supplemented group had lower TBARS numbers than the respective HSBO control group, which reflected the presence of α-tocopherol in the membranes. This was substantiated by gas chromatographic analysis. Dark muscle microsomal lipids peroxidized fasted than lipids from white muscle microsomes, an observation similar to that reported earlier by Harel and Kanner (1985). Meat from the linseed oil group, as expected, was much less stable than meat from the other groups, when stored at 4°C for 9 days and at -20°C for 6 months. In contrast, meat from the α-tocopherol-supplemented broilers exhibited the highest oxidative stability among the five treatments. Trends in meat stability generally followed those established for the subcellular membranes, as reported above.

The rates of metmyoglobin/ hydrogen peroxide-initiated peroxidation of microsomes and mitochondria isolated from the semitendinosus red muscles of pigs receiving diets supplemented with tocopherols (groups 28, 29 and 30) are shown in Figure 1. These data suggest that membranal lipids from the pigs receiving the α-tocopherol supplement for ten weeks (group 29) were much more stable to oxidation than those from the control pigs (group 27), whereas short term α-tocopherol supplementation was less effective. In contrast, long term supplementation with mixed tocopherols (group 30) made little difference to the stability of the microsomes and mitochondria in semitendinosus red muscle. The rates of metmyoglobin/ hydrogen peroxide-initiated lipid peroxidation in the subcellular fractions isolated from the pigs fed the oxidized oil (group 31) were much higher than those from the control pigs (group 27). This suggests that oxidized fat in the diet becomes a source of free radicals which can destabilize the lipids in subcellular membranes. Several trends were established for the mitochondrial fractions.

When pork chops were stored at 4°C in the dark and under fluorescent light, products from pigs fed -tocopherol-enriched diets were more stable than those from the control pigs (Table 2). These data support the hypothesis that incorporation of antioxidants into the membrane lipids well influence the stability of meat products, particularly during refrigerated and frozen storage of uncooked meat products. Similar trends for restructured pork roasts were observed (Table 3). However, TBHQ, when added to the control pork samples, was more effective in reducing lipid peroxidation than the membrane-bound antioxidants. Similarly, nitrite, when added during the processing of restructured pork roasts from pigs fed the oxidized oil diet, was effective in reducing lipid peroxidation during refrigerated storage. Similar trends were observed when the pork roasts were stored at -20°C for six months.

CONCLUSIONS

Results of this study support the theory that lipid peroxidation in raw meat is initiated in the membrane-bound lipids. Stabilization of these lipids, either by alteration of the fatty acid composition or by the incorporation of α-tocopherol into them through diet, has a very positive influence on the oxidative stability of meat during storage.

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Table 1. Effect of dietary oils on the fatty acid composition of the polar lipids of microsome fractions isolated from dark muscles of broilers

Fatty[a] Acid	Dietary Treatment				
	Coconut Oil	Olive Oil	Linseed Oil	HSBO +α-Tocopherol	HSBO
Saturated	36.7	23.6	24.9	25.2	24.5
Monoene	25.5	28.1	22.8	19.8	22.6
Diene	18.8	14.8	22.6	21.6	21.2
Triene	3.7	5.0	4.8	4.4	3.4
Tetraene	11.3	12.6	5.2	16.3	12.0
Pentaene	1.3	2.3	3.9	2.8	1.9
Hexaene	0.1	1.2	5.5	1.5	1.1

[a] Fatty acid data represent the mean of three analysis of a composite meat sample from 35 broilers.

Table 2. Effect of tocopherol-supplementation and oxidized oil in pig diets on the stability of pork chops during refrigerated storage as measured by the TBA procedure

Treatment	Days of storage at 4°C							
	Fluorescent light				Dark			
	0	3	6	9	0	3	6	9
Control	0.09[a,b]	0.48	0.82	2.76	0.09	0.54	0.77	0.47
Short-term α-tocopherol	0.08	0.18	0.70	0.96	0.08	0.35	0.28	0.33
Long-term α-tocopherol	0.09	0.15	0.51	0.84	0.09	0.36	0.27	0.24
Mixed tocopherols	0.09	0.26	0.60	0.88	0.09	0.37	0.62	0.39
Oxidized oil	0.09	1.4	4.34	5.46	0.09	1.22	3.66	4.15

[a] TBARS number, expressed mg malonaldehyde/kg of meat product
[b] TBARS numbers are based on triplicate analyses of two composite samples obtained on grinding three pork chops per treatment

Table 3. Effect of tocopherol-supplementation and oxidized oil in pig diets on the stability of restructured pork roasts during refrigerated storage, as measured by the TBA procedure

Treatment	TBARS number[a,b]			
Day	0	3	8	15
Control	0.17	0.59	1.42	2.20
Control + TBHQ[c]	0.18	0.18	0.25	0.40
Short-term -tocopherol	0.16	0.25	0.38	1.00
Long-term -tocopherol	0.10	0.22	0.28	0.87
Long-term mixed tocopherols	0.21	0.31	0.88	1.55
Oxidized oil diet	0.32	1.37	2.55	3.23
Oxidized oil + nitrite during processing[d]	0.12	0.27	0.36	0.60

[a] TBARS number, expressed as mg malonaldehyde/kg of meat product
[b] TBARS numbers are based on triplicate analyses of two restructured pork roasts per treatment
[c] TBHQ, 0.02% based on fat content
[d] Nitrite, 156 mg/kg