

EFFECT OF GAMMA IRRADIATION AT VARIOUS TEMPERATURES ON AIR AND VACUUM PACKED CHICKEN TISSUES II. FATTY ACID PROFILES OF NEUTRAL AND POLAR LIPIDS SEPARATED FROM MUSCLE AND SKIN IRRADIATED AT 2-5°C

Abstract—Chicken muscle and skin were separately irradiated in air and under vacuum packaging at 0, 1, 3, 6 and 10 kGy using ^{137}Cs (dose rate = 0.1 kGy/min). Lipids were isolated as neutral and polar subclasses from muscle samples and as total lipid extracts from skin. Lipids were converted to fatty acid methyl esters, analyzed by capillary gas chromatography and the data compiled as fatty acid profiles by statistical computer analysis. Normalized reports were assembled from this data for the three lipid extract types. Only negligible changes in fatty acid profiles were observed for the neutral lipids of muscle and for the fatty acyl residues of skin lipids. Minor changes of interest, however, were observed for the polyunsaturated fatty acyl residues in the polar lipid fractions of muscle tissue, especially at higher irradiation doses (6 and 10 kGy). Comparisons were made between these results and those of an earlier study where similar tissues were irradiated at -20°C . No new fatty acyl residues or other artifacts due to γ -irradiation were found in detectable amounts by gas chromatography in any of the lipid fractions isolated.

INTRODUCTION

There is considerable interest today in the use of low to medium doses (1–10 kGy) of ionizing radiation to delay spoilage in meat, poultry and fish. In poultry, for instance, levels of 3–7 kGy are allowed in some countries to eliminate harmful bacteria such as salmonella and other food-borne pathogens (Jones, 1986). In spite of the fact that limited approval has been granted in some countries for the irradiation of poultry, questions continue to be raised regarding the possibility of radiolytic products being formed at permitted dose levels. Lipid constituents of food such as triglycerides and phospholipids may be one source of free radical radiolytic products (Merritt *et al.*, 1983). The volatile products from irradiated lipid precursors have been investigated in detail (Merritt *et al.*, 1985), however little work has been done on the fatty acids from intact glycerides and phospholipids to determine whether structural changes from the irradiation process have occurred. The present study was therefore undertaken to provide a systematic analysis of lipid fatty acid patterns from irradiated and nonirradiated chickens. Chicken skin and muscle packaged in air and under vacuum were irradiated at 2–5°C at doses from 0–10 kGy. The lipids were extracted and simultaneously separated into neutral and polar fractions (Marmer and Maxwell, 1981), derivatized to methyl esters and then examined individually in detail by gas chromatography to provide

separate profiles of the minor but nutritionally significant unsaturated fatty acids associated with polar lipids of muscle. Dose related differences found in these profiles are reported and comparisons are made with results obtained in another study where chicken muscle tissue was irradiated at -20°C (Rady *et al.*, 1988).

MATERIALS AND METHODS

Twelve fresh frying chickens (1.5–2.0 kg ea) were purchased locally (24 h post-slaughter) and hand deboned. The skin was separated from the muscle tissue and each were frozen, then ground in a bowl cutter. Samples (25 g) were wrapped in Saran film and packed in Kenfield All-Vac No. 13 pouches. Half of the pouches were sealed under vacuum using a Swiss Vac machine (Transvac Machine Nag, Lucerne, Switzerland) and the others were left unsealed. Both vacuum and air packaging pouches were γ -irradiated (on the same day that the chickens were purchased) in duplicate at 0, 1, 3, 6 and 10 kGy using ^{137}Cs (dose rate 100 Gy/min) at 2–5°C.

Extraction of lipids

Duplicate chicken muscle samples (5.0 g \pm 0.1 mg) were each extracted sequentially by a dry column method (Marmer and Maxwell, 1981). The lipids were isolated and simultaneously separated into neutral and polar fractions by sequential elution as

described. Neutral lipids free of polar lipids were eluted first with dichloromethane, followed by elution of polar lipids with a mixture of dichloromethane/methanol (90:10, v/v). Eluates from the individual neutral and polar fractions were collected in 200 ml round bottom flasks. Solvent was removed on a rotary evaporator at room temperature, and the contents of the flask were transferred with hexane to 100 ml volumetric flasks and brought to volume with hexane. Aliquots were taken for weight determination and for derivatization to fatty acid methyl esters (FAMES) for subsequent gas chromatographic analysis.

Duplicate chicken skin samples (5.0 ± 0.1 mg) were extracted for total lipid by a dry column method (Marmer and Maxwell, 1981). Lipids were eluted from the column with a mixture of dichloromethane/methanol (90:10 v/v). Eluates were then handled by the procedure described for chicken muscle (*vide supra*).

Derivatization of glycerides to methyl esters

(a) Neutral lipid fraction: the lipids were converted to their methyl esters by treatment with NaOH/methanol followed by BF_3 /methanol (Slover and Lanza, 1979). (b) Polar lipid fraction: an aliquot of the polar lipid fraction containing *ca* 20 mg lipid first was reduced to 5 ml on a rotary evaporator at room temperature. The contents of the flask were quantitatively transferred to a 15 ml centrifuge tube with hexane and the remaining solvent was removed under nitrogen. The residue was dissolved in 1.0 ml of isooctane containing 2 mg of the internal standard methyl hencosanoate (21:0). The lipids then were converted to their methyl esters by treatment with KOH/methanol followed by saturated ammonium acetate solution as described by Maxwell and Marmer (1983).

Equipment

GC analyses were carried out on a Hewlett-Packard 5880A level 4 capillary gas chromatograph (Hewlett-Packard, Palo Alto, CA), equipped with a flame ionization detector, magnetic tape storage capability and a Model 7672A automatic sampler. The column was a 50 m \times 0.25 mm I.D. fused silica SP2340 column (Quadrex, New Haven, CT). Carrier gas was helium at a flow of 1 ml/min and make-up gas was nitrogen at a flow of 30 ml/min. The temperature program was: 150–170°C at 0.4°C/min, then 1°C/min to 200°C, at which temperature the oven was held for a maximum of 40 min until all FAMES had been eluted.

Determination of FAMES identity and reference standards

Initial identification of FAMES was made by injecting the unknown samples into a Hewlett-Packard 5992B GC–Mass spectrometer to identify the major components in the mixture. Verification of other

constituents was made by peak enhancement of unknown components using authentic compounds and by retention time analysis of unsaturated FAMES before and after hydrogenation.

A specially prepared reference standard containing 18 FAMES common to chicken lipids was obtained (Nu Chek Prep, Inc., Elysian, MN). This standard was chromatographed after the automated analysis of each group of 8 samples to ascertain whether changes had occurred in retention times and peak shape due to instrumental variations and to provide data needed to determine individual correction factors (Slover and Lanza, 1979).

STATISTICAL ANALYSIS

After analysis by capillary gas chromatography of the fatty acid methyl esters, the normalized data (weight percent of total FAME) from the individual gas chromatograms were consolidated (Marmer *et al.*, 1983). The data were subjected to an analysis of variance and Bonferroni mean separation techniques (Miller, 1981), to discern statistically significant differences in profiles as a function of air and vacuum packaging.

RESULTS AND DISCUSSION

Irradiation of chicken muscle and skin tissue samples packaged in air and vacuum was carried out at various dose levels. Simultaneous isolation and separation of lipids from muscle tissue into neutral and polar subfractions allowed for their individual acyl group analysis (Marmer and Maxwell, 1981). However, because of the negligible phospholipid content of chicken adipose tissue, the control and irradiated skin samples were analyzed as total lipid.

The fatty acyl profiles for the control and irradiated chicken tissues are assembled in Tables 1–3. The results for the neutral and polar chicken muscle and the skin lipids are compiled as normalized reports (% of total fatty acids).

The data in these tables are not listed according to increasing chain length, instead, individual fatty acids are grouped as saturated, unidentified saturated, *trans*-monoene, *cis*-monoene, diene, nondienoic polyene and unidentified unsaturated. Statistically significant deviations ($P < 0.05$) from nonirradiated controls are indicated by superscript b in the tables. Although the entries under the superscript b headings are statistically significant, no real trends were apparent in most cases. Under the heading for each dose level (1, 3, 6 and 10 kGy) two columns of values are given. These columns show the results obtained for samples irradiated under either air and vacuum packaging conditions. For purposes of comparison, gc chromatograms of nonirradiated (control-0 kGy) and irradiated (10 kGy) samples are shown in Fig. 1a,b. Examination of these chromatograms shows that the patterns are quite similar regardless of dose levels (0

Table 1. Fatty acid composition^a of nonirradiated and irradiated (2–5°C) neutral muscle lipid fractions

| Fatty acid | Radiation dose (Normalized %) | | | | | | | | | |
|---|-------------------------------|-------------------|-------------------|-------------------|-------------------|-------|-------------------|--------|-------------------|--|
| | 0 kGy | 1 kGy | | 3 kGy | | 6 kGy | | 10 kGy | | |
| | | A | V | A | V | A | V | A | V | |
| Saturated | | | | | | | | | | |
| 14:0 | 0.85 | 0.85 | 0.83 ^b | 0.83 ^b | 0.85 | 0.86 | 0.85 | 0.85 | 0.85 | |
| 15:0 | | | | | | | | | | |
| 16:0 | 23.01 | 23.30 | 23.12 | 23.02 | 22.90 | 23.41 | 23.10 | 23.04 | 23.27 | |
| 17:0 | 0.12 | 0.11 ^b | 0.11 ^b | 0.11 ^b | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | |
| 18:0 | 5.23 | 5.32 | 5.43 ^b | 5.39 ^b | 5.21 | 5.30 | 5.34 ^b | 5.27 | 5.27 | |
| ai19:0 | 0.05 | 0.04 | 0.02 | | 0.08 | 0.09 | 0.06 | 0.06 | 0.08 | |
| 19:0 | | | | | | | | | | |
| 20:0 | 0.06 | 0.06 | 0.06 | 0.02 ^b | 0.08 | 0.08 | 0.11 ^b | 0.09 | 0.09 | |
| 24:0 | | 0.05 | | | | | | | | |
| Unidentified sum | 0.10 | 0.09 | 0.09 | 0.09 | 0.10 | 0.10 | 0.10 | 0.10 | 0.10 | |
| Total saturated | 29.42 | 29.82 | 29.66 | 29.46 | 29.34 | 29.96 | 29.68 | 29.53 | 29.78 | |
| Unsaturated <i>Trans</i> monoene | | | | | | | | | | |
| 16:1 ω 7t | 0.50 | 0.48 ^b | 0.48 ^b | 0.47 ^b | 0.49 | 0.50 | 0.50 | 0.51 | 0.50 | |
| 18:1 ω 9t | 0.62 | 0.62 | 0.65 | 0.70 | 0.63 | 0.60 | 0.68 | 0.70 | 0.74 ^b | |
| Sum | 1.12 | 1.10 | 1.13 | 1.17 | 1.12 | 1.10 | 1.18 | 1.21 | 1.24 | |
| <i>Cis</i> monoene | | | | | | | | | | |
| 16:1 ω 7c | 7.98 | 7.89 | 7.72 | 7.81 | 8.07 | 7.99 | 7.81 | 7.87 | 7.87 | |
| 18:1 ω 9c | 40.50 | 40.56 | 40.86 | 40.85 | 40.14 | 40.24 | 40.43 | 40.37 | 40.40 | |
| 18:1 ω 7c | 2.45 | 2.44 | 2.45 | 2.46 | 2.39 | 2.40 | 2.42 | 2.44 | 2.46 | |
| 20:1 ω 9c | 0.32 | 0.33 ^b | 0.34 ^b | 0.33 ^b | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | |
| Sum | 51.25 | 51.22 | 51.37 | 51.45 | 50.92 | 50.95 | 50.98 | 51.00 | 51.05 | |
| Diene | | | | | | | | | | |
| 18:2 ω 6c | 15.42 | 15.23 | 15.34 | 15.43 | 15.65 | 15.04 | 15.29 | 15.28 | 14.99 | |
| 20:2 ω 6c | 0.14 | 0.14 | 0.13 | 0.13 | 0.14 | 0.13 | 0.14 | 0.14 | 0.13 | |
| Sum | 15.56 | 15.37 | 15.47 | 15.56 | 15.79 | 15.17 | 15.43 | 15.42 | 15.12 | |
| Nondienoic polyene | | | | | | | | | | |
| 18:3 ω 3c | 0.67 | 0.65 | 0.67 | 0.67 | 0.70 ^b | 0.67 | 0.67 | 0.67 | 0.66 | |
| 20:3 ω 6c | 0.21 | 0.20 | 0.19 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | |
| 20:4 ω 6c | 0.37 | 0.35 | 0.35 | 0.37 | 0.39 | 0.34 | 0.35 | 0.35 | 0.33 | |
| 20:5 ω 3c | | | | | | | | | | |
| 22:4 ω 6c | 0.12 | 0.10 | 0.10 | 0.11 | 0.12 | 0.11 | 0.11 | 0.11 | 0.11 | |
| 22:5 ω 3c | 0.02 | | | | 0.02 | | | | | |
| 22:5 ω 6c | | | | | | | | | | |
| 22:6 ω 3c | | | | | | | | | | |
| Sum | 1.39 | 1.30 | 1.31 | 1.35 | 1.43 | 1.32 | 1.33 | 1.33 | 1.30 | |
| Unidentified sum | 0.88 | 0.75 | 0.66 | 0.61 | 0.85 | 0.96 | 0.86 | 1.01 | 1.01 | |
| Total monoene | 52.25 | 52.32 | 52.50 | 52.62 | 52.04 | 52.05 | 52.16 | 52.21 | 52.29 | |
| Total ω 3 polyene | 0.69 | 0.65 | 0.67 | 0.67 | 0.72 | 0.67 | 0.67 | 0.67 | 0.66 | |
| Total ω 6 polyene | 0.70 | 0.65 | 0.64 | 0.68 | 0.71 | 0.65 | 0.66 | 0.66 | 0.64 | |
| Total unsaturated | 70.08 | 69.74 | 69.94 | 70.11 | 70.11 | 69.50 | 69.78 | 69.97 | 69.72 | |

^aTabulated values are averaged over 4 samples. ^bTabulated values were significantly different from 0 kGy dose means by Bonferroni LSD (Miller, 1981). Fatty acid structures are indicated by (chain length: number of methylene-interrupted double bonds); ω 3: double bonds progress toward carboxylate functionality from the third carbon from terminal methyl group (ω 3 carbon). ai = anteiso (CH₃ on ω 3 carbon).

or 10 kGy). There are no peaks in the chromatogram for the 10 kGy sample (Fig. 1b) that do not appear in the control sample chromatogram (Fig. 1a). The normally present unidentified saturated and unsaturated fatty acids detected in the mixtures (\geq 1.0% in neutral muscle fractions or skin and < 2.0% of polar muscle fractions) changed little when the variations in treatments employed in these studies (Tables 1–3). These unidentified compounds appear to be identical, from comparisons of chromatograms (Fig. 1), in both control and irradiated samples regardless of radiation dosage.

Saturated fatty acids

Approximately 30% of the fatty acids from the neutral and polar muscle and from the skin are saturated (Tables 1 and 2). The neutral fraction and the total skin lipids (Tables 1 and 3) showed only a few random changes for the irradiated samples when compared to the nonirradiated controls. No important differences could be detected between air and

vacuum packaged samples. However, a somewhat different result was obtained for the saturated fatty acids of the polar muscle fractions. In this case some slight variations occurred, but mostly at 10 kGy for both air and vacuum packaging. When a similar study was carried out with muscle tissue at -20°C (5) the saturated fatty acids for neutral and polar chicken muscle were unchanged at all radiation levels.

Trans-monoenoic fatty acids

These fatty acids were virtually unchanged in the neutral muscle and skin at all dose levels (Tables 1 and 3). In contrast, both 16:1 ω 7t and 18:1 ω 9t displayed a steady increase as percentages of the total composition with dose level for the polar lipids (Table 2). This sub-class and the *cis*-monoenoic fatty acids were the only classes of fatty acids that displayed such a trend. Total monoene increased from 24.44–27.17% (Table 2). Similar changes were not observed in this class when chicken muscle tissues were irradiated at -20°C (Rady *et al.*, 1988).

Table 2. Fatty acid composition^a of nonirradiated and irradiated (2–5°C) polar muscle lipid fractions

| Fatty acid | Radiation dose (Normalized %) | | | | | | | | |
|---|-------------------------------|-------------------|-------------------|-------------------|-------------------|--------------------|--------------------|--------------------|--------------------|
| | 0 kGy | 1 kGy | | 3 kGy | | 6 kGy | | 10 kGy | |
| | | A | V | A | V | A | V | A | V |
| Saturated | | | | | | | | | |
| 14:0 | 0.25 | 0.30 | 0.33 | 0.28 | 0.26 | 0.26 | 0.36 ^b | 0.29 | 0.33 |
| 15:0 | | | | | | | | | |
| 16:0 | 19.57 | 20.04 | 19.75 | 20.05 | 19.88 | 19.89 | 21.06 ^b | 20.05 | 20.27 ^b |
| 17:0 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.13 | 0.14 ^b | 0.14 ^b | 0.13 |
| 18:0 | 13.93 | 14.10 | 14.02 | 13.86 | 14.22 | 13.77 | 13.72 | 13.42 | 12.92 ^b |
| ai19:0 | 0.10 | 0.09 | 0.09 | 0.09 | 0.09 | 0.10 | 0.11 | 0.11 | 0.12 ^b |
| 19:0 | | | | | | | | 0.06 ^b | 0.03 |
| 20:0 | | | | 0.08 ^b | 0.06 ^b | 0.08 ^b | 0.10 ^b | 0.09 ^b | 0.08 ^b |
| 24:0 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| Unidentified sum ^c | | | | | | | | | |
| Total saturated | 33.98 | 34.70 | 34.35 | 34.45 | 34.71 | 34.25 | 35.53 | 34.20 | 33.92 |
| Unsaturated <i>Trans</i> monoene | | | | | | | | | |
| 16:1 ω 7t | 0.23 | 0.21 ^b | 0.22 ^b | 0.25 ^b | 0.22 ^b | 0.22 ^b | 0.22 ^b | 0.24 ^b | 0.30 ^b |
| 18:1 ω 9t | 0.22 | 0.40 ^b | 0.29 | 0.45 ^b | 0.48 ^b | 0.50 ^b | 0.49 ^b | 0.60 ^b | 0.70 ^b |
| Sum | 0.43 | 0.61 | 0.51 | 0.70 | 0.72 | 0.72 | 0.71 | 0.84 | 1.00 |
| <i>Cis</i> monoene | | | | | | | | | |
| 16:1 ω 7c | 1.59 | 1.62 | 1.70 | 1.64 | 1.61 | 1.69 | 1.93 ^b | 1.91 ^b | 2.08 ^b |
| 18:1 ω 9c | 18.63 | 18.82 | 19.30 | 19.09 | 18.86 | 19.29 | 19.74 | 19.99 ^b | 20.38 ^b |
| 18:1 ω 7c | 3.53 | 3.43 | 3.41 | 3.55 | 3.44 | 3.53 | 3.25 ^b | 3.60 | 3.44 |
| 20:1 ω 9c | 0.26 | 0.27 | 0.28 | 0.27 | 0.26 | 0.27 | 0.27 | 0.29 ^b | 0.27 |
| Sum | 24.01 | 24.14 | 24.69 | 24.55 | 24.17 | 24.78 | 25.19 | 25.79 | 26.17 |
| Diene | | | | | | | | | |
| 18:2 ω 6c | 17.65 | 17.57 | 17.55 | 17.66 | 17.73 | 17.72 | 17.15 ^b | 17.38 | 17.45 |
| 20:2 ω 6c | 0.53 | 0.52 | 0.51 | 0.45 ^b | 0.52 | 0.53 | 0.48 ^b | 0.50 | 0.51 |
| Sum | 18.18 | 18.09 | 18.06 | 18.11 | 18.25 | 18.25 | 17.63 | 17.88 | 17.96 |
| Nondienoic polyene | | | | | | | | | |
| 18:3 ω 3c | 0.12 | 0.12 | 0.13 | 0.12 | 0.13 | 0.14 | 0.17 | 0.16 | 0.17 |
| 20:3 ω 6c | 1.64 | 1.64 | 1.65 | 1.62 | 1.57 | 1.59 | 1.47 ^b | 1.48 ^b | 1.41 ^b |
| 20:4 ω 6c | 12.01 | 11.55 | 11.51 | 11.34 | 11.48 | 11.13 ^b | 10.47 ^b | 10.48 ^b | 10.26 ^b |
| 20:5 ω 3c | 0.66 | 0.62 | 0.64 | 0.68 | 0.53 | 0.62 | 0.58 | 0.54 | 0.71 |
| 22:4 ω 6c | 2.79 | 2.63 | 2.60 | 2.63 | 2.66 | 2.57 ^b | 2.35 ^b | 2.45 ^b | 2.38 ^b |
| 22:5 ω 3c | 1.78 | 1.72 | 1.73 | 1.69 | 1.64 ^b | 1.66 ^b | 1.54 | 1.48 ^b | 1.49 ^b |
| 22:5 ω 6c | 0.77 | 0.71 | 0.70 | 0.71 | 0.71 | 0.68 ^b | 0.64 ^b | 0.67 ^b | 0.65 ^b |
| 22:6 ω 3c | 2.13 | 2.07 | 2.09 | 2.01 | 1.94 | 1.95 ^b | 1.87 ^b | 1.72 ^b | 1.74 ^b |
| Sum | 21.90 | 21.06 | 21.05 | 20.80 | 20.66 | 20.34 | 19.09 | 18.98 | 18.81 |
| Unidentified sum | 1.31 | 1.32 | 1.29 | 1.30 | 1.37 | 1.56 | 1.73 | 2.20 | 2.04 |
| Total monoene | 24.44 | 24.14 | 25.20 | 25.25 | 24.87 | 25.50 | 25.90 | 26.63 | 27.17 |
| Total ω 3 polyene | 4.69 | 4.53 | 4.59 | 4.50 | 4.24 | 4.37 | 4.16 | 3.90 | 4.11 |
| Total ω 6 polyene | 17.21 | 16.53 | 16.46 | 16.30 | 16.42 | 15.97 | 14.93 | 15.08 | 14.70 |
| Total unsaturated | 65.83 | 64.61 | 65.60 | 65.46 | 65.15 | 65.65 | 64.35 | 65.69 | 65.98 |

^aSee footnote a, Table 1. ^bSee footnote b, Table 1. ^cNo unidentified saturated fatty acids were found in the polar lipid fractions.

Cis-monoenoic fatty acids

This sub-class comprises the largest class of acids (>50%) in chicken muscle and skin with the principle member of the group being 18:1 ω 9c (oleic acid). The neutral muscle and skin lipids showed only negligible changes with dosage (Tables 1 and 3). The same results were noted in the earlier (–20°C) study (Rady *et al.*, 1988). In contrast, some differences of interest were found in the polar muscle fractions (Table 2). Two fatty acids in this subclass, 16:1 ω 7c and 18:1 ω 9c steadily increased with increasing dose levels (from 1.59 to 2.08% and from 18.63 to 20.38% respectively at 0–10 kGy Table 3). A similar trend was detected for these two fatty acids from polar muscle lipids when irradiation was carried out by Rady *et al.* (1988), at –20°C (from 1.66 to 1.94% and from 18.98 to 20.06% respectively at 0–10 kGy).

Dienoic fatty acids

Two acids are found in this class; 18:2 ω 6c and 20:2 ω 6c. Of the two, only 18:2 ω 6c decreased slightly with increasing dose levels in the polar

muscle lipids (Table 2) while the neutral and skin dienoic acids were virtually unaffected by treatment (Tables 1 and 3).

Nondienoic polyenoic fatty acids

This class of fatty acids is of recent nutritional and health related significance because it contains all of the ω 3 acids. These compounds are principally associated with membrane lipids and would be expected to occur mainly in the polar muscle lipid fraction (Table 2). However, small amounts of these polyenes were detected in both the neutral muscle and skin lipids (Tables 1 and 3); while the acids in both of these fractions were virtually unaffected by treatment (irradiated vs nonirradiated and air vs vacuum). Although the nondienoic polyenes from the neutral fractions and from skin tissue were unchanged by γ -irradiation, the patterns of these same fatty acids in the polar fractions were slightly altered by radiolytic treatment. For instance, with the exception of 18:3 ω 3c, all of the fatty acids in this group decreased with increasing dosage while the total monoenes

Table 3. Fatty acid composition^a of nonirradiated and irradiated (2–5°C) total skin lipids

| Fatty acid | Radiation dose (Normalized %) | | | | | | | | |
|---|-------------------------------|-------|-------------------|-------------------|-------------------|-------------------|-------------------|--------------------|-------------------|
| | 0 kGy | 1 kGy | | 3 kGy | | 6 kGy | | 10 kGy | |
| | | A | V | A | V | A | V | A | V |
| Saturated | | | | | | | | | |
| 14:0 | 0.86 | 0.85 | 0.87 | 0.87 | 0.85 | 0.86 | 0.86 | 0.85 | 0.86 |
| 15:0 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 ^b | 0.01 | 0.01 | 0.02 |
| 16:0 | 23.62 | 23.55 | 23.49 | 23.67 | 23.94 | 23.70 | 23.46 | 22.85 ^b | 23.59 |
| 17:0 | 0.14 | 0.14 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.15 ^b | 0.14 |
| 18:0 | 5.68 | 5.66 | 5.17 | 5.61 ^b | 5.68 | 5.64 | 5.67 | 5.77 ^b | 5.67 |
| ai19:0 | 0.08 | 0.07 | 0.07 | 0.08 | 0.08 | 0.05 | 0.07 | 0.05 | 0.08 |
| 19:0 | 0.01 | | | | | | | | |
| 20:0 | 0.11 | 0.11 | 0.11 | 0.09 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 |
| 24:0 | | | | | | | | | |
| Unidentified sum | 0.10 | 0.09 | 0.10 | 0.10 | 0.10 | 0.09 | 0.10 | 0.10 | 0.10 |
| Total saturated | 30.61 | 30.48 | 30.51 | 30.57 | 30.89 | 30.59 | 30.42 | 29.89 | 30.57 |
| Unsaturated <i>Trans</i> monoene | | | | | | | | | |
| 16:1 ω 7t | 0.45 | 0.45 | 0.46 | 0.44 | 0.44 ^b | 0.43 ^b | 0.49 | 0.46 | 0.44 |
| 18:1 ω 9t | 0.60 | 0.61 | 0.61 | 0.58 | 0.58 | 0.66 | 0.62 | 0.67 ^b | 0.62 |
| Sum | 1.05 | 1.06 | 1.07 | 1.02 | 1.02 | 1.09 | 1.07 | 1.13 | 1.06 |
| <i>Cis</i> monoene | | | | | | | | | |
| 16:1 ω 7c | 7.38 | 7.35 | 7.21 | 7.58 | 7.52 | 7.60 | 7.41 | 7.01 ^b | 7.45 |
| 18:1 ω 9c | 40.65 | 40.64 | 40.79 | 40.30 | 40.61 | 40.54 | 40.68 | 40.94 | 40.56 |
| 18:1 ω 7c | 2.40 | 2.42 | 2.44 ^b | 2.47 ^b | 2.35 ^b | 2.36 ^b | 2.34 ^b | 2.31 ^b | 2.33 ^b |
| 20:1 ω 9c | 0.32 | 0.32 | 0.32 | 0.31 | 0.32 | 0.32 | 0.32 | 0.32 ^b | 0.32 |
| Sum | 50.75 | 50.74 | 50.76 | 50.66 | 50.80 | 50.82 | 50.75 | 50.89 | 50.66 |
| Diene | | | | | | | | | |
| 18:2 ω 6c | 15.00 | 15.07 | 15.16 | 15.07 | 14.75 | 15.04 | 15.16 | 15.75 | 15.08 |
| 20:2 ω 6c | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.08 |
| Sum | 15.11 | 15.18 | 15.27 | 15.18 | 14.86 | 15.15 | 15.27 | 15.86 | 15.16 |
| Nondieneoic polyene | | | | | | | | | |
| 18:3 ω 3c | 0.66 | 0.69 | 0.67 | 0.67 | 0.67 | 0.68 | 0.69 | 0.69 | 0.67 |
| 20:3 ω 6c | 0.14 | 0.14 | 0.13 | 0.14 | 0.13 | 0.14 ^b | 0.14 | 0.14 ^b | 0.14 |
| 20:4 ω 6c | 0.24 | 0.25 | 0.24 | 0.24 | 0.23 | 0.25 | 0.25 | 0.27 ^b | 0.25 |
| 20:5 ω 3c | | | | | | | | | |
| 22:4 ω 6c | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 |
| 22:5 ω 3c | | | | | | | | | |
| 22:5 ω 6c | | | | | | | | | |
| 22:6 ω 3c | | | | | | | | | |
| Sum | 1.10 | 1.14 | 1.10 | 1.11 | 1.09 | 1.13 | 1.14 | 1.17 | 1.12 |
| Unidentified sum | 0.95 | 1.00 | 0.88 | 0.99 | 0.70 | 0.76 | 0.73 | 0.81 | 0.84 |
| Total monoene | 51.80 | 51.80 | 51.83 | 51.68 | 51.82 | 51.91 | 51.82 | 51.72 | 51.72 |
| Total ω 3 polyene | 0.66 | 0.69 | 0.67 | 0.67 | 0.67 | 0.68 | 0.69 | 0.69 | 0.67 |
| Total ω 6 polyene | 0.44 | 0.45 | 0.43 | 0.44 | 0.42 | 0.45 | 0.45 | 0.48 | 0.45 |
| Total unsaturated | 68.96 | 69.12 | 69.08 | 68.96 | 68.47 | 68.95 | 68.96 | 69.56 | 68.84 |

^aSee footnote a, Table 1. ^bSee footnote b, Table 1.

displayed corresponding increases (Table 2). These changes in concentration ranged from 15–19% as the dosage was increased from 0–10 kGy. One possible pathway to account for the decomposition of the polar polyenoic fatty acids in the presence of ionizing radiation would be the loss of some double bonds character in these compounds and the subsequent formation of monoenoic fatty acids due in part to presence of water in the cellular membranes, which would not be a significant factor in adipose tissue. These results are in marked contrast to those obtained in the earlier study by Rady *et al.* when the same tissues were irradiated at –20°C (Rady *et al.*, 1988). That investigation found that the profiles of the nondieneoic polyenes were unchanged at dose levels up to 6 kGy and that only slight but significant decreases in some members of this group occurred in vacuum packaging at 10 kGy.

CONCLUSION

On the tissues studied, only the skin lipids showed no significant changes in composition due to irradiation

levels in either air or vacuum packaging. In fact, the skin fatty acid profiles at 10 kGy are nearly identical with those of the control samples (Table 3). Some slight changes were however, found in the neutral muscle lipid fractions (Table 1) and were in line with those observed when similar tissues were irradiated at –20°C (Rady *et al.*, 1988). As a class, the polar muscle lipid fractions (Table 2) showed the most changes due to γ -irradiation. Although these changes were slight, they were statistically significant. Fewer alterations to this lipid class occurred when samples were irradiated at –20°C (Rady *et al.*, 1988) than at 2–5°C, which would indicate that it would be preferable to irradiate chicken muscle at the lower temperature. This observation has also been noted by other investigators for the radurization of meats and poultry (Urbain, 1983). Irradiation levels and packaging type, air or vacuum, had little effect on the fatty acid profiles. Comparisons of chromatograms of control and irradiated samples showed different levels of unidentified compounds; however no new unidentified peaks were detected in the chromatograms of irradiated samples up to 10 kGy. Therefore, no

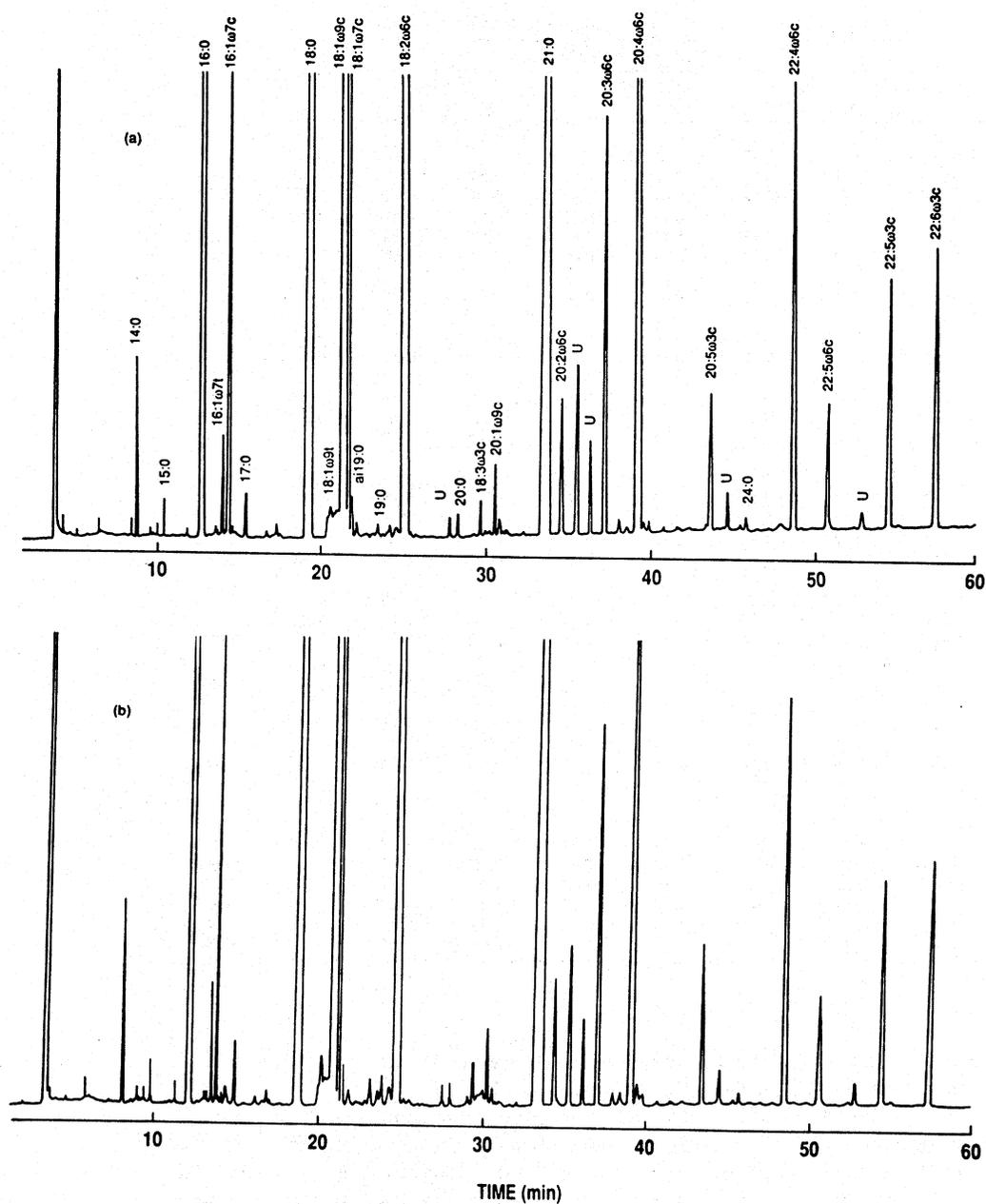


Fig. 1. Capillary GC chromatograms of polar muscle fatty acid methyl esters. Trace a: control sample (0 kGy) showing peak identities; trace b: vacuum packed irradiated sample (10 kGy).

unique radiolytic products were apparent by gas chromatography at the low dose levels employed for either chicken muscle or skin lipids

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