Composition of Fatty Acids in Adipose Tissue by *In Vivo* ^{13}C MRS at 7T

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INTRODUCTION

Epidemiological evidence suggests that the amount (1) and composition (2) of dietary fats and body adipose tissue influences the risk for cancer. The ratio of ω-6/ω-3 fats may be particularly important (3). Since the composition and amount of fats in the diet can be controlled, there is strong public and medical interest in understanding the interactions among diet, body fat composition, and cancer risk. Proton MRS at 7T has been used for fat composition determination (4). Here we show that ^{13}C MRS at 7T carries additional information compared to proton MRS, namely the ω-6/ω-3 ratio.

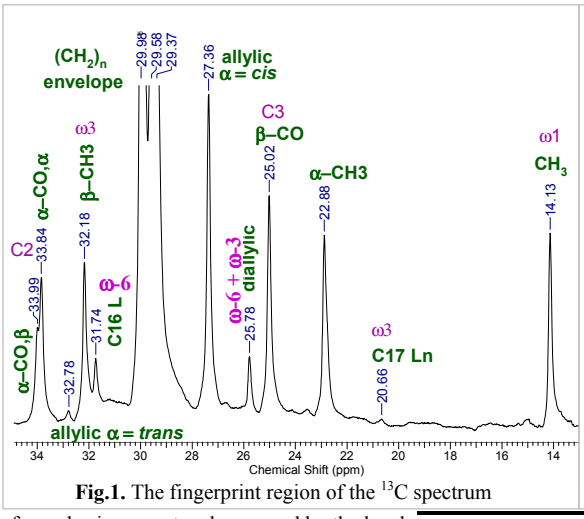

Fig.1. The fingerprint region of the ^{13}C spectrum

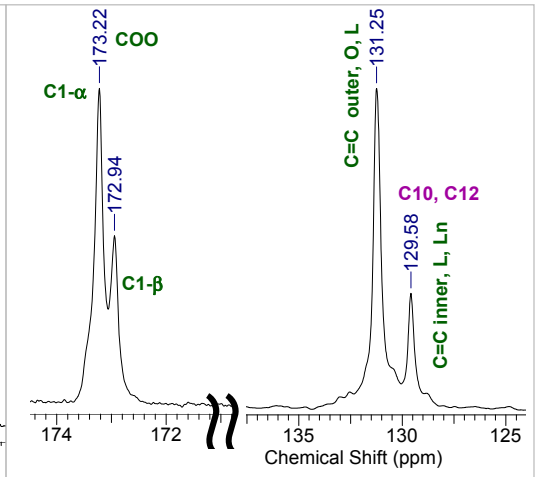

Fig.2. The double-bond and carbonyl regions of the spectra

METHODS

All human experiments (n = 5) were performed using a protocol approved by the local IRB. Spectra were acquired on a whole-body 7T scanner (Achieva, Philips Medical Systems, Cleveland, OH, USA) using a partial volume human calf coil operating in quadrature for both ^{1}H and ^{13}C. ^{13}C spectra were acquired by averaging 32 non-selective FIDs with TR 8 s for a total scan time of 5 min per offset. Two offsets were used, one centered on the CH_2 envelope of the fingerprint region (~ 29 ppm) and a second acquisition centered at 152 ppm (halfway between COO and C=C signals). For determination of NOE correction coefficients, every offset was run twice, once with NOE and once without. WALTZ-16 decoupling with a 18 μT proton pulse centered at 1.3 ppm (for the fingerprint region) or at 5.32 ppm (for the C=C region), and NOE (10 μT at 5% duty cycle and a mixing time of 1.5 s) were used to simplify the spectra and enhance SNR. To avoid power limitations while preserving spectral resolution, the decoupling was performed only during the first 20% of the 630 ms acquisition time. Scans were acquired with BW 13 kHz and 8k points. Four sets of T_1 measurements with 10 logarithmically spaced inversion times were done on two volunteers. One set was centered at 29 ppm with TR 10 s (to characterize spins with T_1 < 1 s), a second set centered at 29 ppm with TR 20 s (for spins with T_1 > 1 s), a third set centered at 172.33 ppm with TR 30 s (for the COO), and a fourth set at 130 ppm with TR 10 s (for C=C). Total scan time was 90 minutes. All subjects tolerated the scan well. To characterize the flatness of the block excitation pulse, a series of excitations with varying offsets was performed on a phantom of olive oil.

Name	*Structure*	*ppm*	*T_1, ms*	*NOE coeff*
CH_3	-CH_2-**C**H_3	14.13	2833	1.85 ± 0.05
C17, Ln	=CH-**C**H_2-CH_3	20.64		1.71
α-CH_3	-CH_2-**C**H_2-CH_3	22.88	1359 ± 71	2.09 ± 0.06
β-CO	COO-CH_2-**C**H_2	25.01	363 ± 19	2.31 ± 0.12
diallylic	=CH-**C**H_2-CH=	25.77	857 ± 135	2.37 ± 0.24
αC= *cis*	=CH-**C**H_2-	27.36	498 ± 4	2.33 ± 0.07
CH_2 envR	-CH_2-**C**H_2-CH_2-	29.58	511 ± 5	2.23 ± 0.12
CH_2 envL	-CH_2-**C**H_2-CH_2-	29.98	482 ± 7	2.25 ± 0.13
C16, L	-CH_2-**C**H_2-CH_2-CH_3	31.73	1164 ± 120	2.33 ± 0.30
β-CH_3	-CH-**C**H_2-CH_3	32.16	1007 ± 104	2.26 ± 0.14
αC= *trans*	=CH-**C**H_2-	32.80		2.04 ± 0.47
αCO, α	COO-**C**H_2-CH_2-R	33.84	289 ± 9	2.11 ± 0.03
αCO, β	COO-**C**H_2-CH_2-R`	33.91	234	2.22
C=C inner	-CH=**C**H-CH_2-**C**H=CH-	129.61	968 ± 67	2.24 ± 0.14
C=C outer	-**C**H=CH-CH_2-CH=**C**H- -**C**H=**C**H- (MUFA)	131.26	751 ± 35	2.19 ± 0.18
COO, β	**C**OO-CH_2-R`	172.94	1644 ± 208	1.11 ± 0.08
COO, α	**C**OO-CH_2-R	173.22	2098 ± 18	1.27 ± 0.08

Table 1: Ln = Linolenic, L = Linoleic, envR, L = CH_2 envelope Right, Left

RESULTS AND DISCUSSION

Broadband proton decoupled ^{13}C NMR spectra from the left calf of a normal volunteer are shown in Figures 1 and 2. Assignments of 17 peaks are given in Table 1, together with the T_1 values of most peaks, and the NOE correction values. These correction values are used when quantifying lipid composition. The importance of considering the RF excitation profile is illustrated in Figure 3. Using C=C inner/COO, and C=C outer/COO ratios, after correction for T_1 and NOE, we obtained 19 % poly-unsaturated, 49 % mono-unsaturated, and 32 % saturated fat composition. This is in close agreement with values obtained in subcutaneous fat by ^{1}H MRS (4). In addition to this information, ω-6/ω-3 ratios can be obtained from the ratio of peak C16,L (31.73ppm) / diallylic (25.77 ppm); nominal values from 2.9 – 7.2 were obtained for this ratio.

In conclusion, ^{13}C MRS at 7T provides rich information on lipid composition, which may be used to investigate relations among obesity, cancer, and diet.

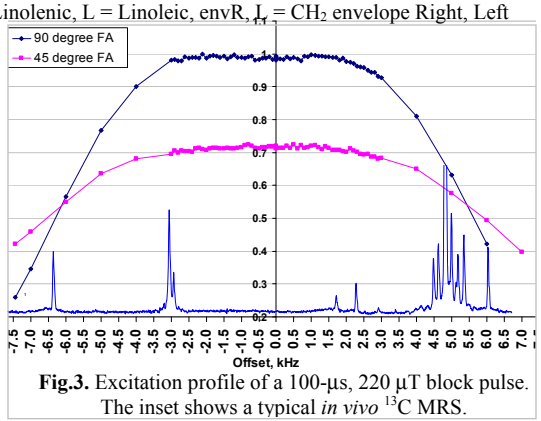

Fig.3. Excitation profile of a 100-μs, 220 μT block pulse. The inset shows a typical *in vivo* ^{13}C MRS.

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