

Mapping the Double Bonds in Triglyceride

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Introduction

Magnetic resonance techniques exploit differences in the precession frequencies to differentiate and quantify the fat-water ratio in tissues. The chemical shifts of the 6 or so fat peaks are known but their amplitudes vary depending on the type of triglyceride, in particular the degree of saturation. The degree of saturation may indicate the risk of disorders, including cancer [Griffits 2009], type 2 diabetes [Risérus 2009], heart disease [Hu 2002] and steatohepatitis [Araya 2004]. Therefore it is of potential clinical interest to develop and improve sensitivity to this property of triglycerides.

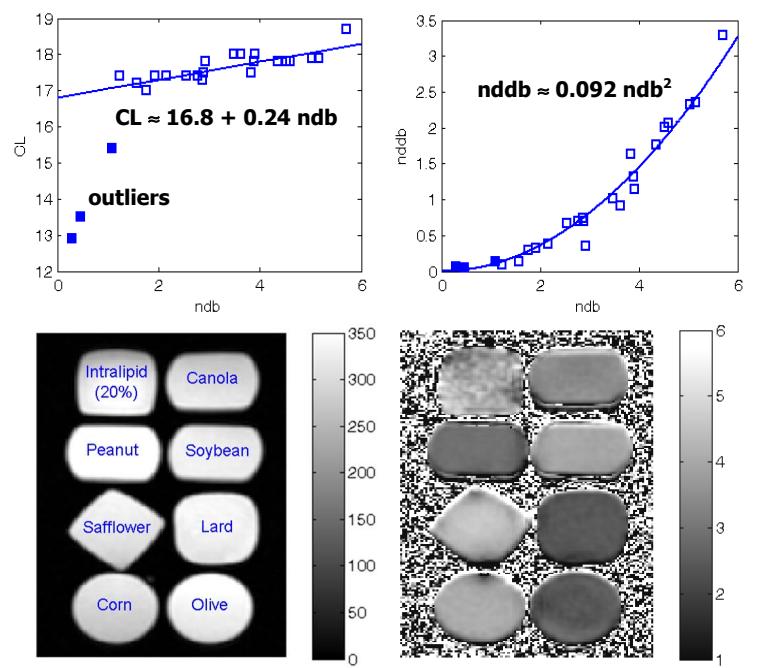
It has been shown previously from spectroscopic data that the degree of saturation can be obtained from the ratio of CH₃ (0.9 ppm) to diallylic CH₂ (2.75 ppm) protons [Lunati 2001]. High resolution spectroscopy is required to isolate the minor peaks and long acquisitions are needed for spatial coverage. A complementary approach to spectroscopy is chemical shift imaging, which allows much faster acquisitions but with low spectral resolution. The spectral resolution (i.e. number of echos) is generally too low to allow reliable detection of the minor peaks.

However a recent study has suggested a way to characterize fat with 3 variables rather than the 6 peak areas [Hamilton 2010]: chain length (CL), number of double bonds (ndb) and number of double-double bonds (nddb). Furthermore, Figure 1 shows empirical data that indicate CL and nddb can be estimated from ndb, hence the number of variables to characterize triglyceride is just 1. The relevance for water/fat modeling is that the degree of saturation can be estimated by fitting 1 variable to the data rather than 6 individual fat peak areas.

The feasibility of measuring triglyceride saturation was tested in phantoms on a GE Healthcare 3.0T scanner using 3D SPGR and 15 echos (3 interleaves \times 5 echos), flyback gradients, TE=1.2 ms, $\Delta TE=0.6$ ms, TR=13 ms, $\alpha=2^\circ$, matrix 192, slice 8 mm, bandwidth ± 62.5 kHz. In the proposed model, 6 variables need to be estimated: field inhomogeneity (ΔB_0), transverse decay ($R2^*$), initial phase (ϕ), water peak amplitude, total fat peak amplitude and ndb. Nonlinear least squares curve-fitting was performed in each pixel to obtain values for these variables.

Figure 1 Chain length and number of double-double bonds as a function of the number of double bonds in various oils and fats from [USDA 2010]. In the case of CL, a linear trend is observed over most of the range while for nddb the trend is quadratic. Palm kernel oil, coconut oil and butter have much shorter CL than predicted and are considered outliers. Thus the valid range is limited to $1 < \text{ndb} < 6$.

Figure 2 Image of the oil phantoms and ndb estimated in every pixel. Maps of ΔB_0 , $R2^*$, ϕ and fat fraction were also obtained (not shown). Differences in ndb in the oils are detected robustly and are clearly outside the noise level. Comparison with reference values from [USDA 2010] gives a correlation coefficient $r = 0.95$, $p < 0.0002$ with regression slope 0.95 ± 0.12 and intercept 0.008 ± 0.467 .



Conclusion

The minor peaks in the fat spectrum are indicative of the degree of saturation. With suitable modeling, the number of double bonds (ndb) per triglyceride molecule can be estimated using chemical shift imaging.

References Araya *Clin Sci* 2004; 106: 635 | Griffits *J Lipid Res* 2009; 50: 611 | Hamilton *NMR Biomed* (2010, In Press) | Hu *J Am Med Assoc* 2002; 288: 2569 | Lunati *Magn Reson Med* 2001; 46: 879 | Risérus *Prog Lipid Res* 2009; 48: 44 | USDA National Nutrient Database for Standard Reference, Release 23 (2010). Nutrient Data Laboratory Home Page, <http://www.ars.usda.gov/ba/bhnrc/ndl>