Abundance Distribution of Compounds: Fatty Acids

Patterns in carboxylic acids, or fatty acids, can be useful in determining the origin (biotic or abiotic) of organic material. Carboxylic acids consist of a hydrocarbon chain with a carboxylic acid functional group on one end. Fatty acids are universal components of bacterial and eukaryotic membranes, but they can also be synthesized abiotically. Fatty acids in living organisms are commonly found esterified to other molecules, however they can also be found as “free” fatty acids in the environment. Fatty acids are major components of phospholipids which are a major component of the lipid bilayers which form the membranes delineating and protecting a cell from its environment. Fatty acids are also used for energy storage. Organisms have evolved pathways for the biosynthesis of fatty acids and also for oxidation for energy. The biosynthetic pathways result in fatty acid patterns with specific carbon number features and stable carbon isotopic composition that allow them to be distinguishable from their abiotic counterparts. These patterns are easily distinguishable using analytical methods that are capable of chemically separating and characterizing the molecular structures of the fatty acids (such as gas-chromatography and mass spectrometry, etc.). Abiotic Fischer-Tropsch syntheses produce fatty acids with a Poisson-like distribution in their carbon chain length number, with a maximum of “short fatty acids” at a length of 7 to 10 carbon atoms and decreasing abundance of fatty acid chains above 15 carbon atoms. Conversely, bacterial systems produce certain fatty acids in excess, typically resulting in a bimodal distribution with two maxima. This signal can be preserved over geological timescales. The molecular dimensions of these two maxima correspond to the biotic systems specific fatty acid requirements for functional cell membranes. Fatty acid biosynthesis is remarkably similar in microorganisms, plants and animals. Acetyl-coenzyme A is used as a primer with sequential addition of C2 units provided by malonyl-CoA.The result is that even numbered carbon fatty acids, palmitic and stearic acid with 16 and 18 carbon atoms, respectively, are the dominant fatty acid in most bacteria generally in a range from 16 to 20 carbon atoms. Biosynthesis of odd numbered carbon chains is initiated with an odd carbon primer, e.g. propionyl-CoA. Some bacteria also biosynthesize terminally branched fatty acids (iso- and anteiso-) by elongating a branched short chain acyl-CoA primer. Most bacteria exhibit an even carbon chain length preference, yet for many bacteria have with branched fatty acids, an odd carbon chain length predominance can result. This preference for either even or odd numbers of carbons in their chains is absent from the fatty acids produced by the abiotic Fischer-Tropsch syntheses, as carbon atoms are added one at a time. Chain-length preference is found to be preserved in ancient sediments but is often lost over time as the biogenic material undergoes thermal maturation processes. This so-called carbon preference index (CPI) is used to assess the maturity of oil and source rocks. The CPI of Fischer-Tropsch type syntheses of fatty acids around one.