THE MAGNETIC PROPERTIES OF SOME FOODS

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ABSTRACT

Preliminary magnetic measurements (low field magnetic susceptibility and isothermal remanent saturation magnetization) show a systematic magnetic signal in several plant samples (lentil seeds, etc.) or some processed foods especially black chocolate. The objective of this research project is to understand the origin of magnetic particles found in plants naturally rich in iron. A biogenic origin, like magnetite nanoparticles formed by bacteria, fungi or a kind of "green synthesis" is rejected. Scanning electron microscope data show evidence for an anthropogenic origin with pure iron through pollution during harvesting or processing is likely the main source of the magnetizations

Keywords: Plants, seeds, magnetic properties

RESUMEN

Mediciones magnéticas preliminares (susceptibilidad magnética de campo bajo y magnetización de saturación isotermal remanente) muestran una señal magnética sistemática en varias muestras de plantas (semillas de lentejas, etc.) o en algunos alimentos procesados, especialmente chocolate oscuro. El objetivo de este proyecto de investigación es comprender el origen de las partículas magnéticas que se encuentran en plantas naturalmente ricas en hierro. Se rechaza un origen biogénico, como podrían ser nanopartículas de magnetita formadas por bacterias, hongos o una especie de "síntesis verde". Los datos obtenidos de microscopía electrónica de barrido muestran evidencia de un origen antropogénico, con hierro puro probablemente como la fuente principal de las magnetizaciones por medio de la contaminación durante la cosecha o su procesamiento.

Palabras clave: Plantas, semillas, propiedades magnéticas.

1. Introduction

Biogenic magnetite has been found in organisms ranging from bacteria to unicellular protists, as well as in many living species of animals (Kirschvink, 1983; Kirschvink *et al*., 2010). To date, there is very little evidence for biogenic magnetite in plants. However, magneto-ferritin with magnetite nuclei has been described (Gajdardziska-Josifovska *et al*., 2001). A magnetic study, conducted by Kirschvink *et al* (2010) on a range of common foods, including avocados, bananas, garlic and apples, shows very low concentrations between 0.1 and 1 ng / g for samples at room temperature, and between 1 and 10 ng / g when frozen.

Out of curiosity, I tried to measure the magnetic properties of different plants in order to test the detection levels by the different techniques of the laboratory of paleomagnetism. This approach was also stimulated by my previous observations on a significant magnetic signal in a processed food (chocolate). The magnetic signal is quite strong and well above the detection limits of the techniques used in paleomagnetism.

For plants, magnetic susceptibility should be mainly diamagnetic due to the organic matter and the amount of water. Saturation Isothermal Remanent Magnetization (SIRM) is an artificial magnetization acquired in strong fields in the laboratory and carried only by "ferromagnetic" minerals (magnetite, hematite, or Iron). The laboratory's magnetometers can measure magnetic moments between 5 10^{-11} Am^2 and 10^{-2} Am^2. For a sample with a mass of about 1 g, magnetization can therefore be measured between 5 10^{-8} $Am^2\,kg^{-1}$ and 10 $Am^2\,kg^{-1}$. Knowing that magnetite has an SIRM between ~10 and 50 $Am^2\,kg^{-1}$, it is theoretically possible to measure a few ng of magnetite per g of sample. SIRM and Anhysteretic remanent magnetizations were measured with a 2G magnetometer. The bulk magnetic susceptibility was measured with the Agico KLY3 kappabridge.

Magnetic results.

Confirming previous observations, dark chocolate has high values of magnetic susceptibility as well as an easily measured SIRM whatever its geographical origins (Ecuador, Peru, Cuba, Tanzania) with various cocoa contents above 50% to 95% (Fig. 1). Chocolate is one of the iron-rich foods. So I tested several plants (especially seeds, with a high dry matter content) known to be rich in iron. The most significant magnetic results were obtained on various batches of green lentil seeds from different providers (Fig. 1).

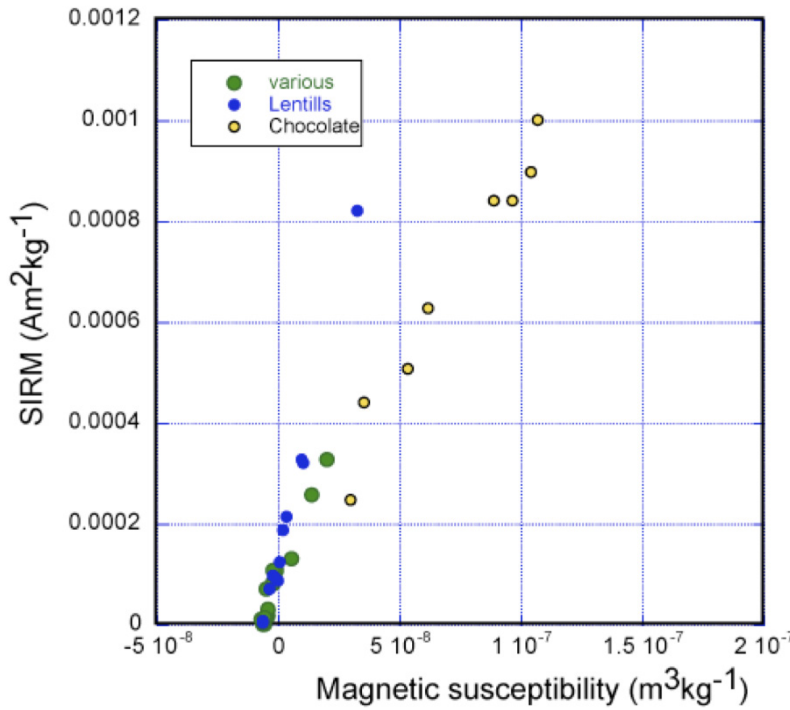

Figure 1. SIRM values versus bulk magnetic susceptibility for various samples of chocolate and plants. Note that a few samples have a remanent magnetic signal but a concentration too low and a still diamagnetic signal due to the organic matter.

The signal is generally very homogeneous per batch but varies according to the type and nature of the lenses. Green and Beluga lenses have SIRM between 1 and 3 $x10^{-4}$ Am^2 kg^{-1}. Coral and yellow lenses, which are peeled lenses, have a much weaker signal. The strong magnetic signal recorded in the lenses is mainly carried by the seed coat (Fig. 2).

Assuming magnetite as the magnetic carrier, there is approximately between 1 and 100 µg of magnetite per g of sample depending on the nature of the samples.

What is the source of the magnetic signal?

Alternating field (AF) demagnetization of SIRM and ARM provided magnetic properties expected for magnetite (Figure 3). Over the past two decades, many teams have used low-cost magnetic methods to estimate anthropogenic air pollution, which accumulates in mosses, lichens, leaves and bark (Fabian *et al*., 2011; Hofman *et al*., 2017; Mitchell and Maher, 2009). Indeed, air pollutants contain magnetite, associated with other heavy elements, and these elements spread in the environment and accumulate in the soil. Spectacularly, in an article published by PNAS (Maher *et al*., 2016), an English team has just proposed that these magnetites of anthropogenic origin can pass through the respiratory system barriers and accumulate in the brain.

Lentils, beans grow in pods, which make it possible to reject the hypothesis of air pollution during plant growth. Dusts of geological origin are unlikely because significant quantities would be required from soil already enriched with magnetite on volcanic rock (Fig. 2).

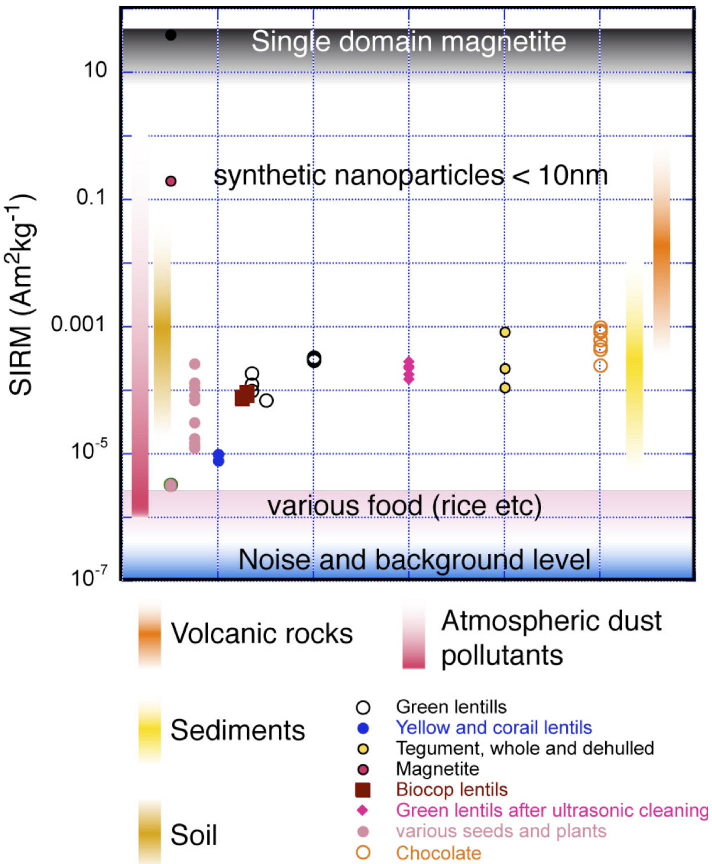

Figure 2. Comparison of the SIRM magnetic signal with the expected range of various rocks, soils and pollutants. Note that magnetite and pure iron have the same range of SIRM

It should also be noted that the peeled lenses have very low values. Magnetic particles are located in the integument and it is necessary to remove the integument to eliminate the magnetic signal.

For chocolate, the cocoa beans are formed in a pod, thus protected from air pollutants. Magnetic particles should be considered when extracting cocoa.

To test this hypothesis, 200 g of chocolate were dissolved in water for magnetic extraction with a hand magnet. The magnetic extracts were then observed on a scanning electron microscope. Iron flakes were clearly imaged (Fig. 4). Micron size particles of iron and brass were also detected on the surface of a grain of lentil.

In conclusion, the project started like a joke (Chocolate is magnetic and that's why we love it so much!) but the results show that contamination by equipment during harvest, by crushing and grinding equipment may be systematic whatever the origin and such pollutants are also found in "organic" food.

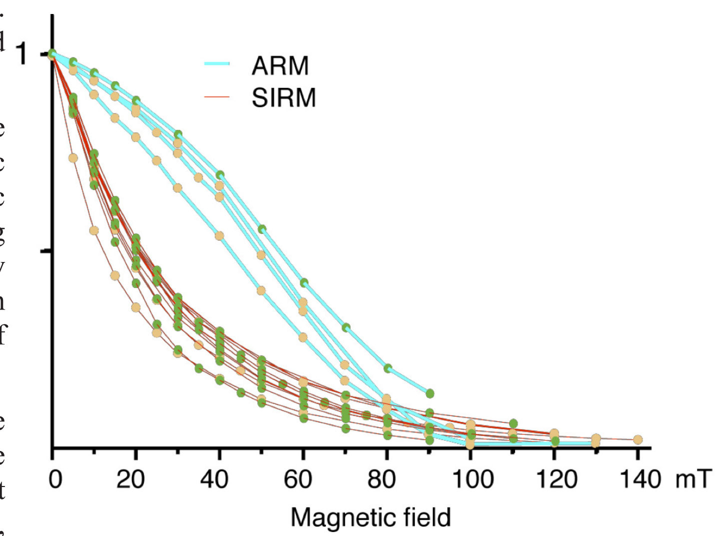

Figure 3. Comparison of AF demagnetization of SIRM (red curves) and ARM (blue curve) in green lentil seeds (green circles) and chocolate (brown circles).

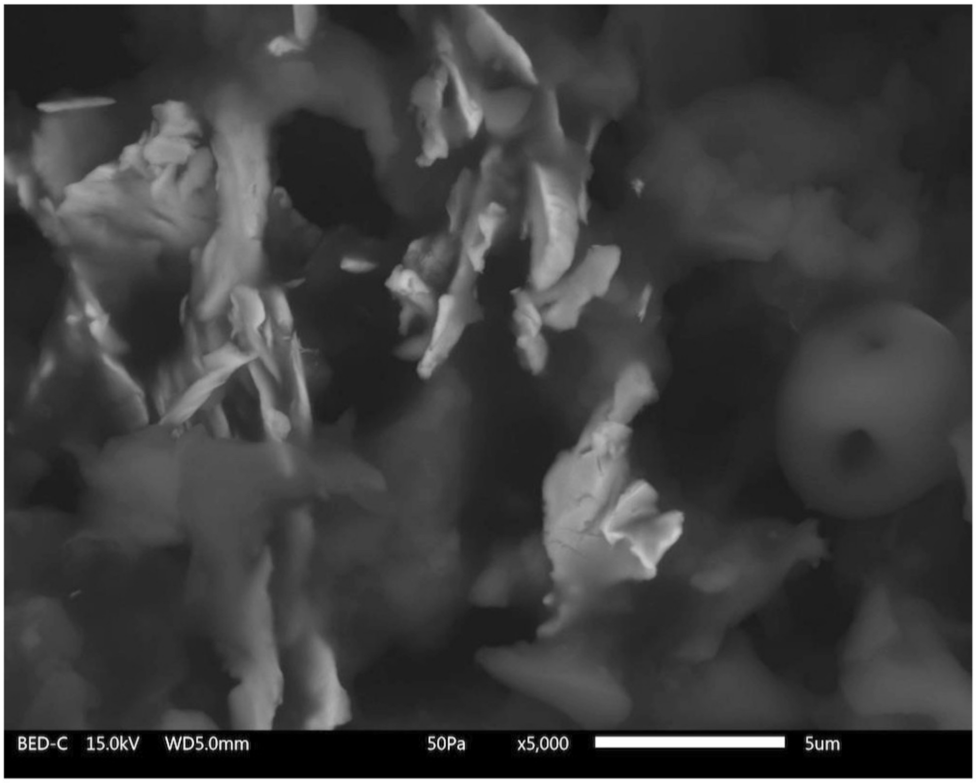

Figure 4. SEM images on magnetic extracts from chocolate. These particles are pure iron flakes, likely incorporated in the chocolate during grinding of cocoa beans.

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