

# Laser-induced plasma for detecting trace elements in biological materials

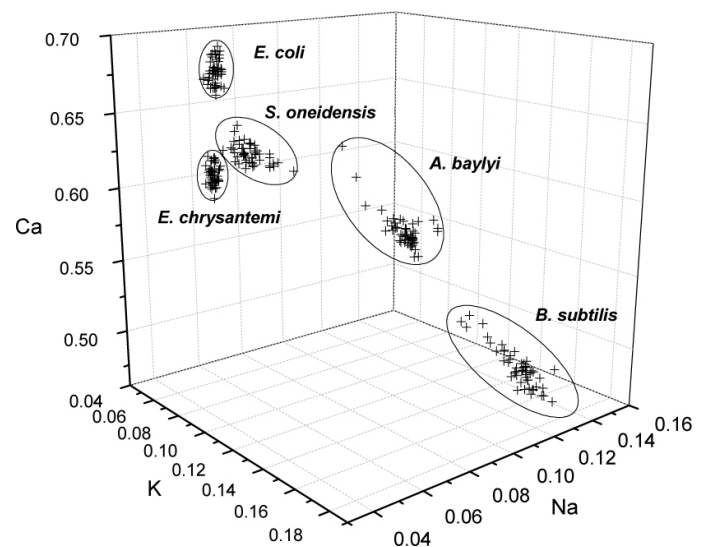
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*Ablating a biological sample leads to atomization of a small amount of material in a hot, light-emitting plasma that can then be effectively analyzed.*

Trace mineral elements play an important role in biological materials. Even minute portions of them can powerfully affect living processes. Indeed, it is possible to characterize such materials and processes by the concentration of trace elements they contain. Humans, too, rely on intake of these substances from foods for health. But the balance is a delicate one: excessive amounts of heavy metals in food—for example, those caused by pollution—are dangerous. Consequently, the ability to detect and analyze trace elements is essential.

Several current techniques have attempted to address this problem, such as inductively coupled plasma mass spectrometry. But these methods often require laboratory-scale equipment and sophisticated sample preparation. Our group has taken a different approach that consists of applying laser-induced breakdown spectroscopy (LIBS) to biological materials. Briefly, in LIBS a laser pulse is focused on the surface of a sample. A small amount of material is ablated from the sample in a hot, light-emitting plasma. The spectral analysis of the emitted light reveals the elemental composition and especially the trace element concentration of the sample. The advantages of the technique include direct analysis without sample preparation, a compact system that operates under atmospheric pressure, and high spatial resolution.

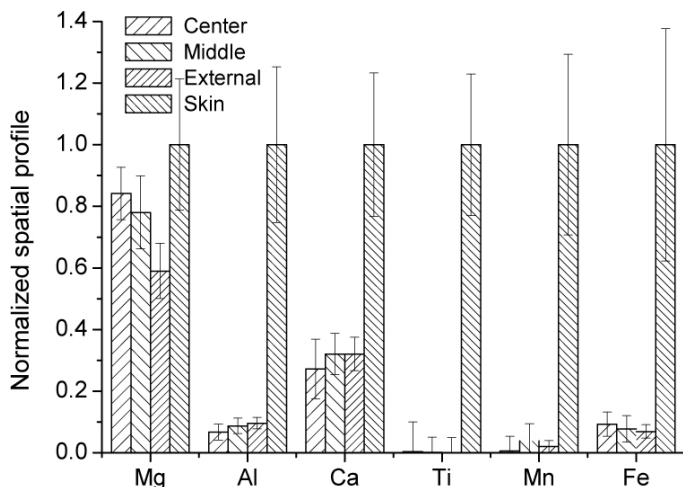
Our work has proceeded in two stages. First, we managed to discriminate a variety of bacteria by detecting the trace mineral elements contained in them.<sup>1</sup> Five different types of bacteria were grown in the same nutrient liquid, among them four so-called Gram-negative species (*Acinetobacter baylyi*,



**Figure 1.** Discrimination of bacteria in a three-dimensional trace element space. (Reproduced with permission.<sup>1</sup>)

*Erwinia chrysanthemi*, *Escherichia coli*, and *Shewanella oneidensis*) and one Gram-positive bacterium (*Bacillus subtilis*). Lyophilized (i.e., freeze-dried) bacteria were prepared in pellets. Plasmas were induced on the surface of the pellets. We detected emitted light using a spectrometer coupled to an intensified CCD camera, and recorded many spectra for each type of bacterium for statistical analysis. We used a hyperspace based on six elements—Na, Mg, P, K, Ca, and Fe—to represent the light intensities from trace mineral elements detected in the organisms. Each spectrum of a given bacterium generates a point in the hyperspace. The cluster patterns of the points correspond to different bacteria. To illustrate this process, Figure 1 presents a three-dimensional projection of the hyperspace based on the elements Na, K, and Ca. The five bacteria studied are clearly distin-

*Continued on next page*



**Figure 2.** Relative concentration profiles of trace elements in a fresh potato. (Reproduced with permission.<sup>2</sup>)

guished, as is the grouping of the four Gram-negative bacteria with respect to the Gram-positive one.

In the second stage of this work, we evaluated the performance of LIBS for both sensitive detection of mineral trace elements in fresh vegetables and highly spatially resolved measurements of the amounts.<sup>2</sup> In potatoes, a typical root vegetable, 27 elements were identified in the LIBS spectrum. In addition to organic elements (H, C, N, O), we also observed many inorganic elements, including metals (Li, Be, Na, Mg, Al, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Rb, Sr, Mo, and Ba) and nonmetals (F, Si, S, and Cl). According to a study of foods by the French National Institute for Agricultural Research (INRA),<sup>3</sup> some of the detected elements—e.g., Co, Ni, and Cr—generally have very low concentrations in potatoes at the level of fractions of milligrams per kilogram of fresh matter. Spatially resolved measurements revealed the distribution of several trace elements in a vegetable. Figure 2 shows relative concentrations of inorganic elements in different parts of a potato. One can see the quite uniform distribution of Mg as well as the accumulation of Al, Ca, Ti, Mn, and Fe on the skin.

In conclusion, we have shown the suitability of LIBS for sensitive detection and analysis of trace mineral elements in biological materials, especially in bacteria and fresh vegetables.<sup>4</sup> Further work will concentrate on quantitative measurements using different methods, such as calibration-free LIBS,<sup>5</sup> and the addition of reference samples.

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