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POINT OF VIEW

The Role of Analytical Chemistry in Agrofood

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The State of Food Security and Nutrition in the World program for sustainable development presents a transformative vision, recognizing that our planet is changing, bringing with it new challenges that must be overcome if we want to live in a world without hunger, food insecurity, and malnutrition, in any of its forms [1]. At the same time, there is a direct relationship between the quality of food and health. The production of high-quality food in high quantities is an emerging concern. However, the challenges are enormous, as demonstrated by the following: i) there is a demand for food production, occurring amid a declining rural labor force; ii) there is an increasing amount of raw material production (*e.g.*, biomass generated) for a market that has been only mildly explored; iii) there is a lack of simpler and cheaper analytical alternatives to apply in undeveloped countries, whose developments is highly dependent of agriculture; and iv) there is the necessity to adopt more efficient and sustainable production methods that are adapted to climate change [2]. On almost all these fronts, the field of analytical chemistry has a lot to contribute.

Small-scale and affordable agricultural production, close to the consumed markets, can be a way to expand food production at more modest costs. For this, the development of sustainable, low-cost, and easy to use analytical devices that can meet technological demands and monitor the quality of irrigation water, soil nutrients or hydroponic solutions, and substance levels from pesticides could help to overcome some of these challenges [3]. On the other hand, the environmental impacts caused by the intense use of nitrogen and phosphate fertilizers can already be seen, especially in countries where agriculture is produced intensively and extensively. The consequences can be seen in the short term, with the irreversible impairment of cultivated soils [4]. One way to remedy these impacts is to use technology to produce food in a more sustainably way. The internet of things is a trend that aims to establish a technical and integrated evolution, with the objective of making processes and products more efficient. For this, integrated machines and sensors can use decision-making routines to work towards a common product or solution. The expansion of this technical revolution in the value chain of complex areas, such as agriculture, food production, and health, requires the implementation and connection of sophisticated methods [5]. In this way, the integrated control of parameters, such as humidity, pH and soil composition, dosage of nutrients or pesticides, leaf composition, and physical–chemical characteristics of the harvested agricultural product, can be monitored in situ using optical (*e.g.*, LIBS) or electrochemical sensors (*e.g.*, electrodes and microelectrodes), which can be monitored remotely to minimize costs, reduce environmental impacts, and increase production efficiency.

From the point of view of the most fundamental studies, there are still many unanswered questions in the food production sector that cannot do without analytical chemistry support, such as in the evaluation of the synergistic effects between the elements during translocation to plants (*e.g.*, the role of rare earth elements [6] and selenium [7] in protecting against abiotic stress, especially stress associated with metals), in the control of residues and organic contaminants [8], and in the use of proteomic and metabolomic strategies for identification of target and non-target species in plants and food [9] to compare, for example, transgenic

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and non-transgenic soybean strains [10]. In addition, analytical chemistry can support studies related to the production of food fortified with inorganic nutrients, evaluating the translocation efficiency, generating information about the concentration of elements and species that can help to understand physiological effects on plants and monitor safe and quality of the food produced. The deficiency of micronutrients (*e.g.*, Fe, Se, and Zn) in the diet of the populations is increasingly prevalent. The concern to decrease this deficiency is related to the current concept of biomedical agriculture [11], requiring interdisciplinary actions between different experts to ensure that the food production cycle, aligned with this concept, is respected [12]. In the field of fortification and biomedical agriculture, chemical speciation is particularly one of the specialties of analytical chemistry that could be very useful.

Finally, in addition to the development of easy, cheap, robust and environmentally friendly methods, in this field, analytical chemistry has to work in a more integrated, inter and multidisciplinary way in order to help solve the great challenges of the agrofood sector, producing high-quality and safe food, while respecting life and the planet.

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