

Electrochemical methods as a helpful tool in managing postharvest losses of fresh fruit



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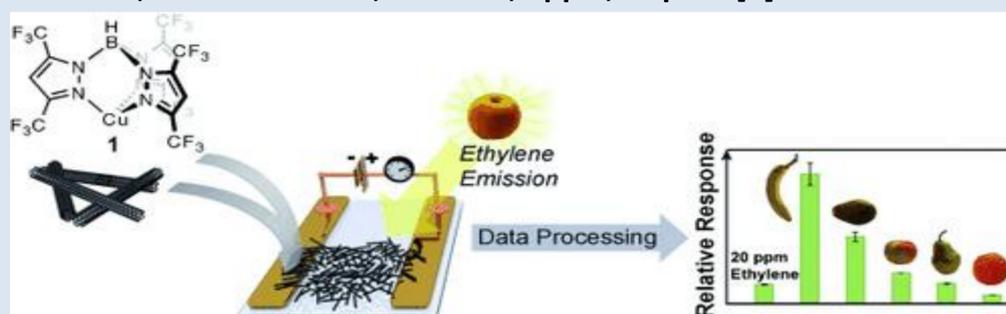
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Electrochemical methods are an effective tool for assessing fruit quality, offering objective and precise measurements of various parameters. Non-destructive electrochemical methods deserve special mention, as their advantages make them a useful tool in reducing losses during fruit harvesting by enabling the assessment of ripeness and early detection of fruit spoilage or disease.

Ethylene is crucial for the commercial ripening of citrus fruits, an artificial process in packing houses, where it is released to change the fruit's external color from green to orange (oranges, tangerines, grapefruits) or yellow (lemons). Ethylene concentrations must be monitored during these processes, as excessive ethylene can easily lead to over-ripening and even spoilage (rotting), resulting in losses. Therefore, numerous simple non-destructive chemical sensors specialized in determining ethylene released from fruit, which can also be used in the inspection of citrus fruits.

Chemoresistive sensors

These sensors change the electrical resistance in response to ethylene concentration. They consist of two electrodes with a sensing material filling the space between them. In this case, a mixture of single-walled carbon nanotubes and a copper complex is dropped between the gold electrodes, and the change in resistance in response to ethylene exposure is then measured. The copper complexes partially bind to ethylene molecules, causing a change in resistance. Ethylene concentrations detected by these sensors range from 0.5 to 50 ppm. This work confirmed that orange, as a climacteric citrus fruit, releases the least ethylene compared to other fruits tested, such as banana, avocado, apple, or pear [1].



Gas sensors

Gas sensors constitute a very large group of chemical sensors used to determine ethylene release. Among the gas sensors, sensors based on metal-oxide semiconductors are attracting considerable attention, characterized by low cost, miniaturization possibilities, high sensitivity, good long-term stability, and selectivity. For example highly sensitive ethylene gas sensor based on SnO₂ decorated with PtO₂ was proposed, with a detection limit of 60 ppb. It was used to monitor the ripening and spoilage of fruits. Test results revealed a correlation between their optimal shelf life/spoilage date and the amount of ethylene released [2].

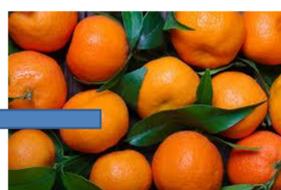
Electronic noses

Already in the 1980s, the first devices using arrays of several gaseous chemical sensors appeared. Due to their analogy to the sense of smell, i.e., the use of multiple chemical sensors (receptors), and the method of analyzing the information obtained using them (artificial intelligence methods), such devices were called "electronic noses". Currently, electronic noses have become the fastest-growing devices for odor analysis, which can be used to assess fruit quality. An electronic nose consists of an array of chemical sensors that respond to volatile organic compounds emitted by the fruit, and this data is then processed by algorithms (e.g., artificial neural networks), creating an "olfactory fingerprint" of the sample. By comparing the odor pattern with patterns for different degrees of ripeness or quality, the device can assess the condition of the fruit. This allows the electronic nose to help identify ripeness (it can help precisely determine when the fruit has reached optimal ripeness for consumption or processing), freshness (it can detect odor changes associated with fruit spoilage), and even potential fruit defects (it can help identify mold or other factors affecting quality).

The main advantages of electronic noses

- speed and objectivity (electronic nose assessment is quick and does not depend on subjective human judgment)
- detection of subtle changes (the device can detect odor changes that are imperceptible to the human nose)
- the possibility of automation (the electronic nose can be integrated into quality control systems in fruit production and processing)
- possibility of miniaturization, which enables the creation of portable equipment

An electronic nose, consisting of ten sensors sensitive to the following gases: toluene, NO₂, benzene, H₂, propane, CH₃, H₂S, and CO was designed to assess the quality of mandarins. The results showed that storage time and temperature affected the vitamin C content and the sugar-to-acid ratio [3].



An electronic nose consisting of three gas sensors was used to detect gaseous emissions produced by pomelo as a basis for classifying its sweetness. One sensor was designed to detect ethanol or ethanol with ethylene; a second sensor to detect propane or butane; and a third sensor to detect hydrogen present in ethylene gas. Based on the experiments, a classification was established in which a reading of approximately 45 ppm was considered slightly sweet, above 45 ppm was considered sweet, and below 45 ppm was classified as not sweet [4].

[1] Esser B., Schnorr J.M., Swager T.M. *Angew. Int. Ed.* 51 (2012) 572

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[3] Qiu S., Wang J. *Innov. Food Sci. Emerg. Technol.* 31 (2015) 139.

[4] Quinola C.V., Lapitan J.N., Pelletero M.H.S. 12th International Conference on Humanoid ... 2020 IEEE.