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Original article

Application of Mobile Fluorescence Spectroscopy as a Method in the Determination of Varietal Differences in Carrots (*Daucus Carota*) after Harvesting

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Abstract

The present study aims to establish the application of fluorescence spectroscopy as a field method in the determination of varietal differences after carrot harvesting. The experimental studies were conducted on site at the farm where the carrot accessions were grown. The fluorescence analysis was carried out with a source with an emission wavelength of 285 nm and an author-developed mobile fiber-optic experimental set-up. The subjects of this research are root crops from Nantes, Short`n Sweet, Touchon, and Flakkee.

The correlation between the emission signals of the samples was established. This fact allows mobile fluorescence spectroscopy to be successfully applied as a rapid tool to establish the origin of unknown carrot accessions in the presence of a rich library of spectra as an applied tool in breeding programs. The results of the experiment can be used to optimize the time for the analysis of the varietal differences of the carrot genotypes after harvest. Fluorescence spectroscopy in a fiber-optical configuration will support the process of determining the belonging of a specific variety to a given variety (even for samples of unknown origin when it is necessary to qualify the result of accessions in a short time).

Keywords: Mobile spectral installation, Fluorescence spectroscopy, Carrot accessions, Different varieties.

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INTRODUCTION

The carrot (*Daucus carota*) is a biennial, rarely annual or perennial herbaceous plant of the umbel family (Simon et al, 2008). It is grown mainly in the Mediterranean, but also in America, Africa, Australia, etc. (Stolarczyk and Janick, 2011). The cultivated carrot is a biennial vegetable and fodder plant. It is grown for its root, which is fleshy and, depending on the variety, has a rounded, truncated-conical, spindle-shaped or other shapes with a red, yellow-red, yellow or white color (Simon, 2010). It forms a pale yellow to red-orange root crop in the first year. It forms seeds and flowers in the second year. It is used for food, fodder and as a medicinal agent (Simon and Goldman, 2007).

The possibility of using chromameter and near-infrared spectroscopy (NIRS) to distinguish adulterated organic carrot powder that was dried with hot air (HA) and an intermittent microwave oven (IMW) was investigated. Principal component analysis (PCA) and partial least squares regression (PLSR) were used to analyze the survey data (Arslan et al., 2023).

Nanoimprint technology has been applied to design quantitative flexible biomimetic internal standard (IS) SERS substrates, in which polydimethylsiloxane (PDMS) with an intrinsic Raman signal was used as a tool to reverse-duplicate carrot surface structures and then deposited with Ag nanoparticles. The resulting four types of biomimetic SERS substrates with different surface geometries enable high-sensitivity analysis with enhancement factors (EFs) of about 106 in both droplet and in situ SERS detection modes (Sun et al., 2022).

A quantitative model was developed to predict the degree of color stability in the presence of dissolved iron in carrots using surface-enhanced Raman spectroscopy (SERS) spectra. SERS spectra of anthocyanin extracts from seven different plant sources were measured and analyzed by principal component analysis (PCA). Discrimination between different anthocyanin sources was observed in the PCA plot. Different stability indices obtained by measuring both the color intensity stability and color shade stability of each sample were established based on UV-vis analysis (Dai et al., 2022).

By applying a mobile fiber-optic setup configuration using the phenomenon of the fluorescence of light, it is possible to create non-invasive methods for the evaluation of varietal differences in carrots. Until now, there has been no data on their characterization using the proposed method.

The aim is to validate fluorescence spectroscopy in the proposed configuration as a non-invasive method for assessing carrot accessions after harvesting.

As a result of the successfully applied research, it is expected that the non-invasive method will be used to optimize the time for the analysis of the varietal differences of carrot genotypes after harvest under uncontrolled conditions.

MATERIALS and METHODS

Material

Accessions from four standard carrot varieties were investigated:

- Nantes An early variety (non-hybrid) is suitable for both greenhouse and field production. They are used for fresh consumption, for processing, for pickles, winter salads, many dishes and natural juices. Their shape is cylindrical and smooth. The average length of Nantes carrots is about 15-16 cm. The root crops are extremely sweet, orange-red, crunchy and aromatic - with very good tasty qualities.
- Short`n Sweet Suitable for growing in soil conditions that are not ideal, such as heavy or poor soil that is rich in clay or difficult to work. This rich, sweet little root is easy to grow and full of vitamins. 'Short 'n Sweet' is a 'Chanetay' type that produces compact 4-inch roots with about 68 days to harvest.
- Touchon The variety is suitable for different types of soil, which is why it is grown both in the southern and northern regions. According to the description, if the crops are properly cared for, Tushon carrots bear fruit until the end of July, but the main harvest occurs in early autumn (early September). To be harvested in early June, sowing is done in mid-autumn (October-November).
- Flakkee An early variety. It forms a smooth, deep orange-red, cone-shaped root with a blunt tip, 20 cm long and weighing 200 - 250 g. High tolerance to diseases and high temperatures. An extremely suitable variety for early production. Vegetation period - about 105 days after sowing. The roots - are cone-shaped, bright orange, sweet, 18-24 cm long. They do not tend to crack. Suitable for autumn harvest and winter storage. It grows best in cultivated, humus, unirrigated light clay or sandy soil. If the soil is heavy, germination is poor, root crops are short, branched and split.

Fluorescence spectroscopy

The mobile experimental installation used by fluorescence spectroscopy contains the following blocks:

- A laser diode (LED) with an emission radiation of 245 nm with a supply voltage in the range of 3V. It is housed in a hermetically sealed TO39 metal housing. The emitter has a voltage drop from 1.9 to 2.4V and a current consumption of 0.02A. The minimum value of its reverse voltage is – 6 V.

- Forming optic, which is a hemispherical lens made of N-BAK2 glass. The post-LED forming optics is defined mainly for its refractive, dispersive and thermo-optical properties, as well as for its transparency in the UV range [240-280 nm].
- Quartz glass area 4 cm2. Its optical properties are to be transparent to visible light and to ultraviolet rays. This allows it to be free of inhomogeneities that scatter light. Its optical and thermal properties exceed those of other types of glass due to its purity. Light absorption in quartz glasses is weak.

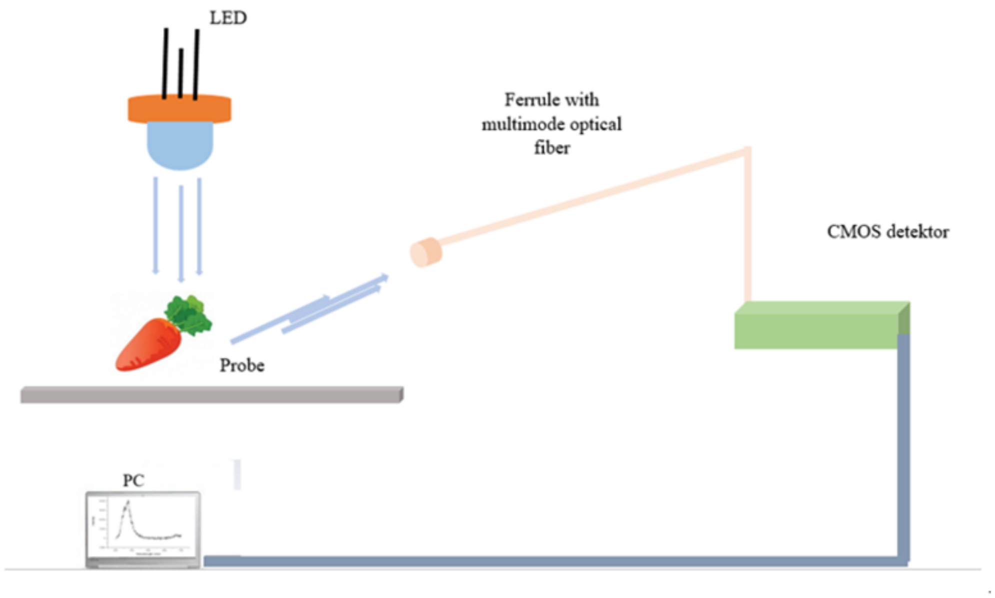

Fig. 1. Mobile experimental installation used by fluorescence spectroscopy

- CMOS detector with sensitivity ranges from 200 nm to 1100 nm. Its resolution is δλ= 5. The profile of the detector sensor projections along the X and Y axes is also designed for very small amounts of data, unlike widely used sensors.

RESULTS and DISCUSSION

The optical properties of a carrot are determined by its energy structure, which includes both the occupied and free electronic energy levels as well as the energy levels of the atomic vibrations of the molecules or the crystal lattice. The possible transitions between these energy levels, as a function of photon energy, are specific to the carrot, resulting in spectra and optical properties unique to it. Carrots contain particles smaller than the wavelength of visible light. Particles in the turbid medium, such as the carrot, act as independent light sources, emitting incoherently and causing the samples to visibly fluoresce.

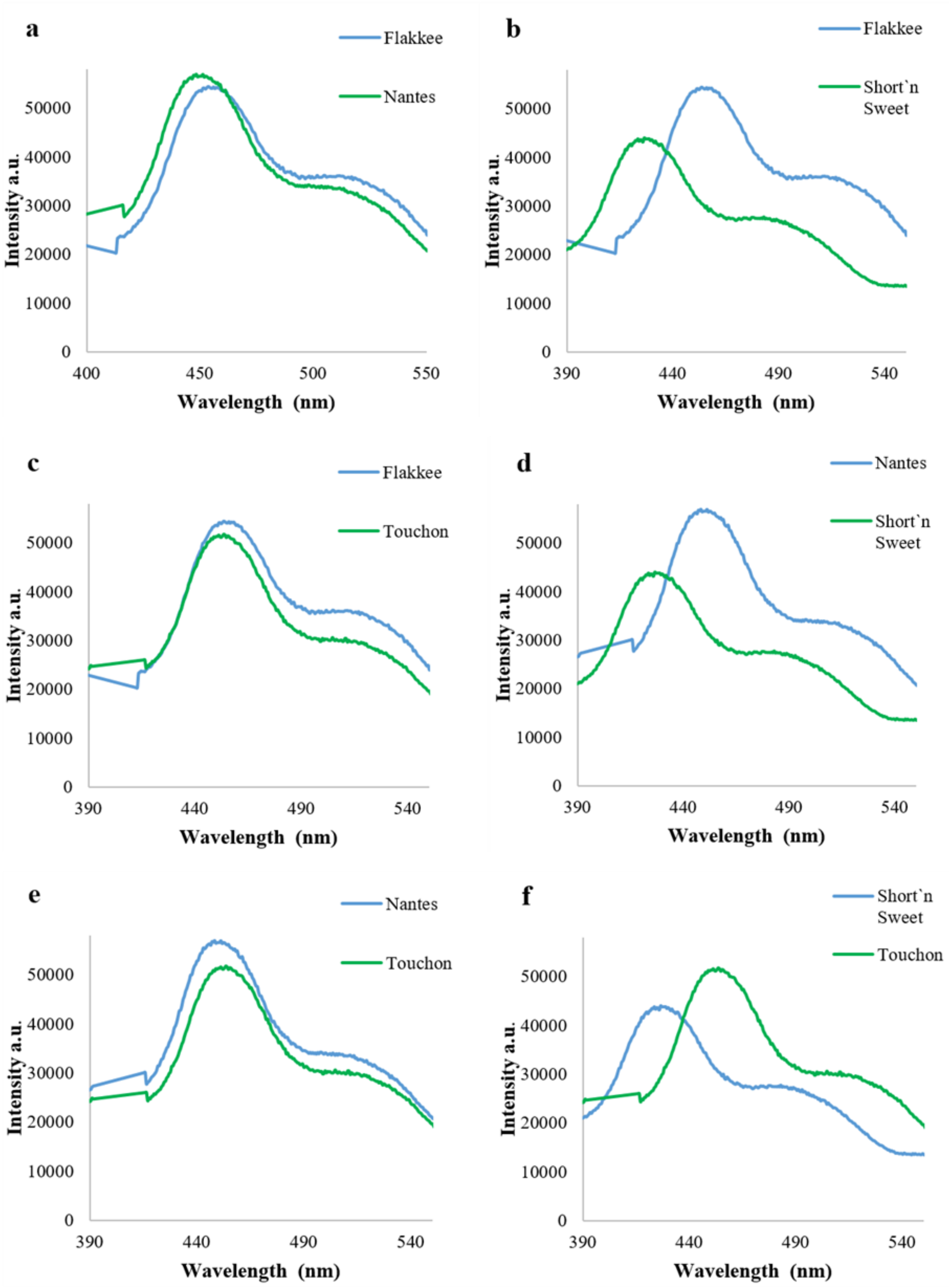

Figure 2. Difference in emission wavelength for Nantes, Short`n Sweet, Touchon, and Flakkee

The results conclude that fluorescence spectroscopy can be successfully applied as a rapid tool to establish the origin of unknown carrot accessions in the presence of a rich spectra library. This will be an applied tool in breeding programs. By tracking signal intensity, one can monitor the stability of a variety and its general characteristics compared to other varieties. The emission fluorescence signals of Nantes, Touchon, and Flakkee (Figures 2 a, c, and e) are close in terms of wavelength localization and signal intensity level.

This is expected because the cultivars have a similar cell morphological composition when grown outdoors. However, the method of fluorescence spectroscopy can be applied to distinguish the accessions of these three cultivars, since the correlation in the spectral distribution is sufficiently distinct and distinguishable to determine practically qualitatively the belonging of the accessions to a given cultivar. The method of fluorescence spectroscopy can practically be used to qualitatively determine the belonging of carrot accessions to a given variety.

A literature review aimed at conducting such research It turned out that the experimental approach described so far for the Polish method for determining varietal differences after the harvest of carrots has not been applied internationally. This gives us reason to claim that, for the first time, fluorescence spectroscopy has been applied as a field method in the determination of varietal differences after harvesting carrots under uncontrolled conditions. The method has been successfully applied to distinguish carrot accessions from different varieties. Fluorescence spectroscopy can be applied to analyze carrot accessions of unknown cultivars and establish their origin with a sufficiently well-structured data library. Because it can be applied topically to trial samples. The application of the mobile circuit eliminates sample damage during transport and provides highly sensitive analysis.

Conclusion

The fluorescence spectroscopy method is fast-acting in application as a field method in the determination of varietal differences after carrot harvesting locally under uncontrolled conditions.

It has been proven that fluorescence spectroscopy will help apply successfully as a rapid tool to establish the origin of unknown carrot root crops in the presence of a rich spectra library. This will be an applied tool in breeding programs. By monitoring the signal intensity, the stability of a breeding line and its common blacks with an established variety of the same species can be monitored.

The differentiation of related varieties is a laborious and time-consuming task. For these reasons, the development of techniques that could assist in the early, quick, and accurate differentiation of related carrot varieties is of the utmost importance.

It has been established that the system engineering approach for adjustment (optical adjustment) of a specialized installation for applied research with fluorescence spectroscopy is applicable in the determination of varietal differences during carrot breeding.

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