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Original article

Application of Mobile Fluorescence Spectroscopy as a Method for the Analysis of Representatives of Different Varieties of Radishes (*Raphanus Sativus L.*) During Storage under Uncontrolled Conditions

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Abstract

The present study aims to establish the application of mobile fluorescence spectroscopy to determine varietal differences and water content during the storage of radishes under uncontrolled conditions. The experimental studies were carried out on the farm where the radishes were grown and stored. Fluorescence analysis was performed with a source with an emission wavelength of 285 nm using an author-developed mobile setup in a fiber-optic configuration generating fluorescence signals. Root crops from the Red Large, Espresso F1, French Breakfast, and Nacional 2 varieties are the object of this study. They were measured after harvesting after 3 and 6 months of storage. The correlation between the emission wavelengths of the samples of different varieties, as well as those of the same variety at different storage intervals, was established. This fact allows mobile fluorescence spectroscopy to be successfully applied as a rapid tool in radish breeding programs to establish the origin of unknown root crops in the presence of a rich library of spectra, as well as in the sorting of radishes in warehouses of food chains and producers. The experiment results can be used to optimize the time for the analysis of the varietal affiliation of different radish genotypes during storage under uncontrolled conditions. Fluorescence spectroscopy in a fiber-optic configuration will support the process of determining the affiliation of a particular radish variety to a given type (even for samples of unknown origin when it is necessary to qualify and sort in a short time).

Keywords: Radishes accessions, Fluorescence spectroscopy, Variety, Emission wavelength, Storage under uncontrolled conditions.

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INTRODUCTION

Radish (Raphanus sativus) is an annual root vegetable plant from the Cruciferous family. It originates in Central Asia (Kaneko et al., 2007). It has been cultivated as a vegetable crop since about 1000 BC in China, Japan, Egypt, Rome, and Greece (Perez Gutierrez et al., 2004). There are two groups of variables: European and Chinese. Radishes are for fresh consumption (Kyung-Mi et al., 2015).

Their widest application is in making fresh vegetable salads. They are not suitable for heat treatment. Radishes are easy-to-grow root vegetables. They tolerate most soil types and grow rapidly (Hyde et al., 2012).

The chlorophyll fluorescence technique is inexpensive and easy to perform. Despite these advantages, this method is very sensitive for observing the first symptoms of stress in plant organisms. Measurement data from chlorophyll fluorescence provide information about the physiological state of plants. This method informs us about photosystem II (PSII) and an electron transport chain in the light-dependent phase of photosynthesis (Kalaji et al., 2016). PSII in thylakoid membranes is the first component in the plant that can respond to even the smallest distortion in the functioning of the plant (Stirbet and Govindjee, 2016). Nutrient deficiency stress, e.g., sulfur deficiency, causes changes in the values of chlorophyll fluorescence parameters and a decrease in the photochemical efficiency of PSII in plants (Smethurst et al., 2005). The rapid chlorophyll fluorescence technique is a recently developed method used in the study of photochemical efficiency in photosynthetic organisms (Kalaji et al., 2018).

In connection with the demands of consumers for high food quality, the conducted research can serve as a basis for the creation of mobile detecting devices with which to carry out instant analysis of warehouse production of radishes in uncontrolled conditions, both in processing plants and in food retail outlets.

The present study aims to establish the function of fluorescence spectroscopy as a mobile method for the analysis of representatives of different varieties of radishes (Raphanus sativus L.) during storage under uncontrolled conditions. They will be compared in terms of determining the spectral distribution after harvesting and at different storage periods of 3 and 6 months. The accessions were stored under uncontrolled storage conditions.

This will permit the technique to be applied non-invasively in the quality control of radish production in unspecified storage and outdoors.

MATERIALS and METHODS

Material

Accessions of three standard radish varieties and one first generation hybrid variety were investigated:

• French breakfast: The variety is suitable for spring and autumn field production. The rhizomes are single and oblong, with a white five around the tail. The fleshy part is white and crispy. The vegetation period is 30 days. The sowing rate is 1.5-2.5 kg per hectare

• Nacional 2: The variety is an early field variety that produces large, round, red roots with white tips. Its flesh is white, delicate in taste and crunchy.

• Red large: The variety is medium early. It is suitable for spring and autumn field production. The fruits are single, deep red, the fleshy part is white with excellent taste qualities. The variety is resistant to cracking.

• Espresso F1: A very early variety with round rhizomes colored red. It is hardy with a fine root, a strong bond with the foliage. It has very good transportability and storage. It is recommended for growing in winter and very early in open areas

Radishesh are harvested in dry sunny weather in the morning. Radishes are sorted by size and stored. They are stored at low temperatures within + 1 ... + 2 degrees Celsius and humidity within 80%. There are times when dry air is present in the warehouse. To increase the humidity in the cellar, install a container filled with water.

Fluorescence spectroscopy

The mobile fiber-optical spectral installation for the study of fluorescence signals is designed specifically for the rapid analysis of plant biological samples. The mobile experimental setup used by fluorescence spectroscopy includes the following components:

• 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.

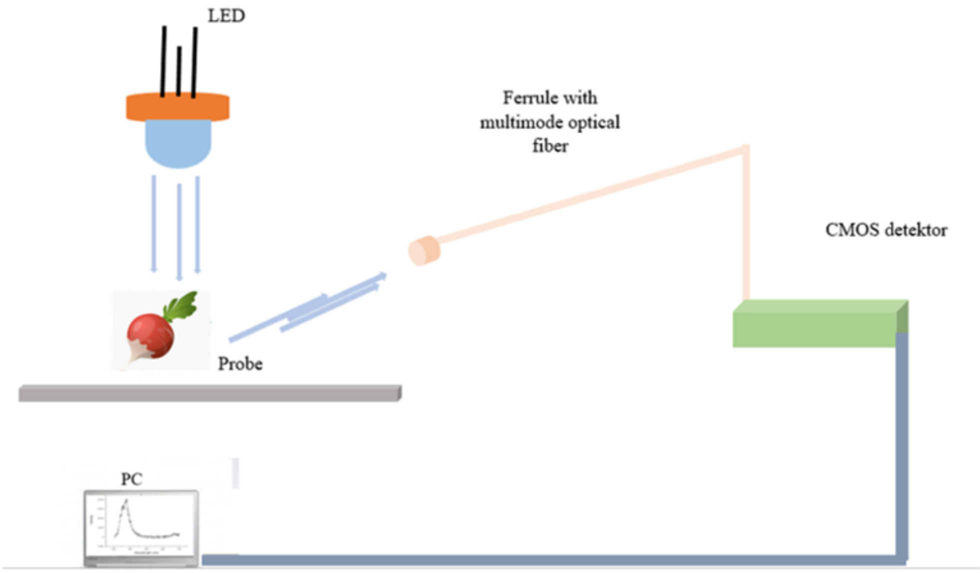

Figure 1. Mobile experimental installation used by fluorescence spectroscopy

RESULTS and DISCUSSION

Prolonged storage under controlled conditions of radish root crops leads to a decrease in their water content. This process is directly proportional to the duration of storage.

The optical properties of the radishes are determined by their 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 radishes, resulting in spectra and optical properties unique to them. Radishes contain particles smaller than the wavelength of visible light. Particles in the turbid medium, such as the radishes, act as independent light sources, emitting incoherently and causing the samples to visibly fluoresce.

Therefore, fluorescence spectroscopy finds application for analysis in this vegetable crop. The optical parameters and spectral properties also change as a function of temperature, pressure, external electric and magnetic fields, etc., which allows obtaining essential information about changes in the chemical and cellular morphological composition of the radishes.

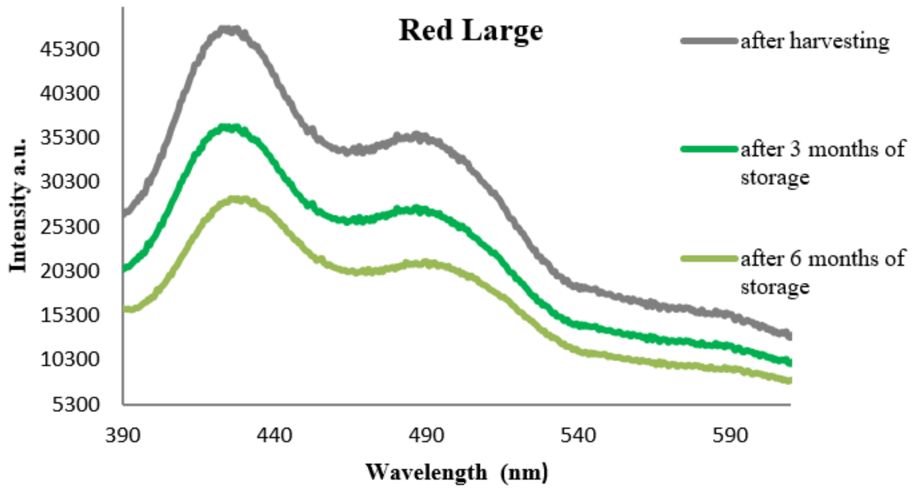

Figure 2. Difference in emission wavelengths of Red Large variety accessions radishes after harvesting and stored 3 and 6 months ago

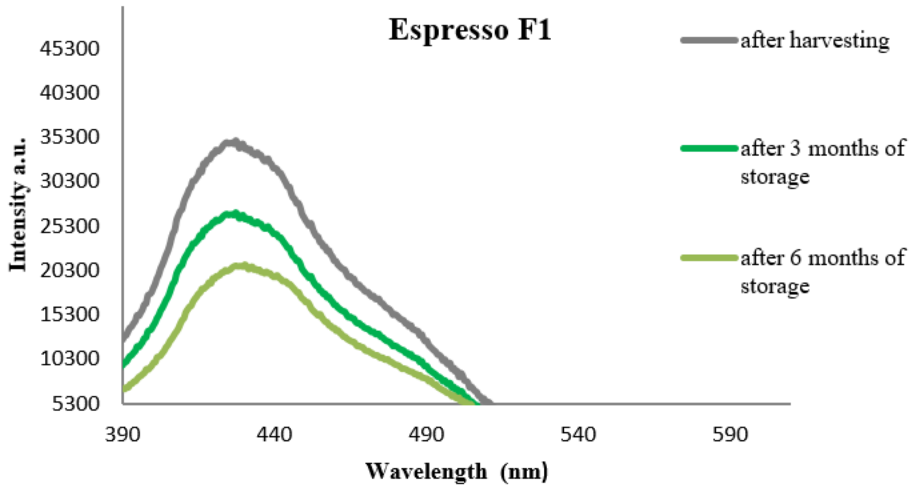

Figure 3. Difference in emission wavelengths of Espresso F1 variety accessions radishes after harvesting and stored 3 and 6 months ago

The analysis of the graphs established the application of fluorescence spectroscopy for the analysis of radishes accessions during storage in a warehouse under uncontrolled conditions for a period of 3 and 6 months (Figure,2 Figure3, Figure4 and Figure 5). The decrease in signal intensity is directly proportional to the duration of storage (and it, in turn, is related with a decrease in root water content due to evaporation).

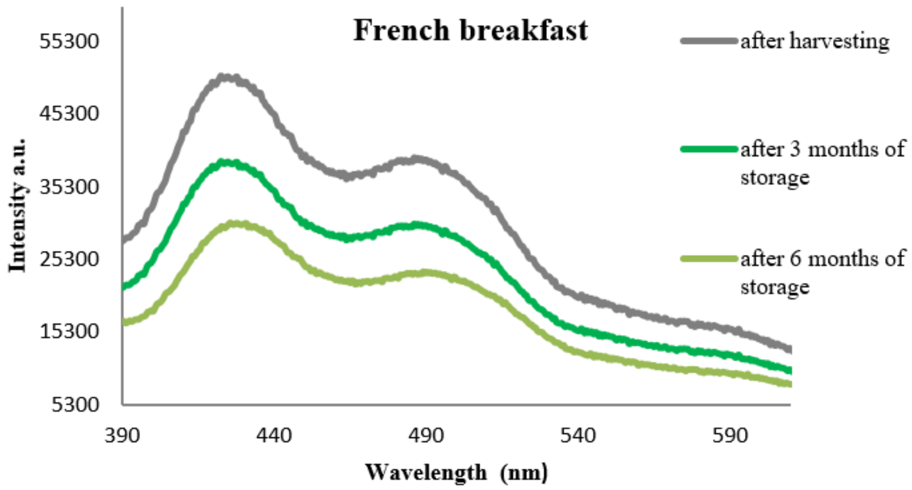

Figure 4. Difference in emission wavelengths of French breakfast variety accessions radishes after harvesting and stored 3 and 6 months ago

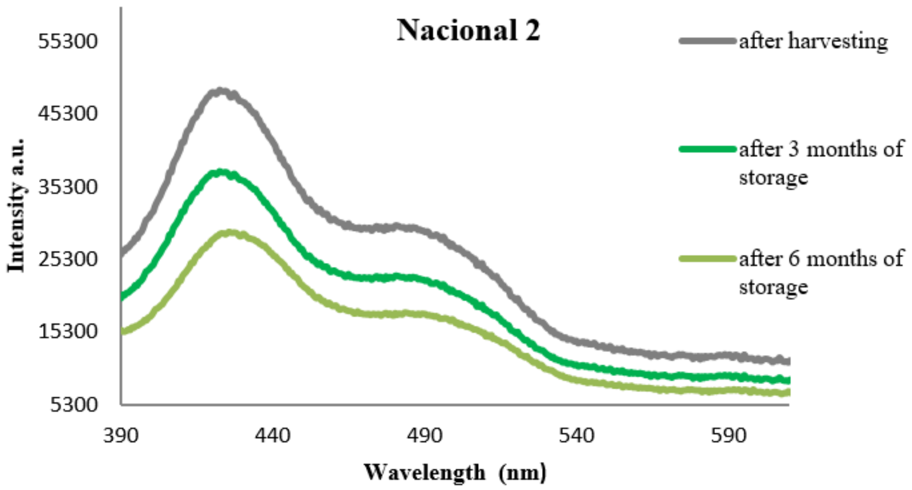

Figure 5. Difference in emission wavelengths of Nacional 2 variety accessions radishes after harvesting and stored 3 and 6 months ago

A literature survey was conducted to conduct similar research. It turned out that, until now, the described experimental approach for the analysis of radishes fruits has not been applied nationally or internationally. This gives us reason to claim that mobile fluorescence spectroscopy in a fiber optic configuration has been applied for the first time to analyze radishes samples for their water content and root stability during storage in a storage room under uncontrolled conditions. The three main advantages of fluorescence spectroscopy are that the method is fast, does not require consumables, and can be performed on site in the warehouse. The decision for local measurements was made to avoid damage to the samples during transport and, thus, to ensure fluorescence analysis with high sensitivity. The signal intensity is high enough at very low water content, which means that the method is applicable to controlling the quality of root crops during long-term storage of radishes in storage rooms under uncontrolled conditions. An essential point in fluorescence diagnostics regarding the comparison of accessions after harvesting and after a certain period of storage is that the method is highly sensitive in terms of determining the water content of root crops stored in a storage room under uncontrolled conditions. This fact allows fluorescence spectroscopy to be applied as a non-invasive method in the quality analysis of radishes production during storage in farms and commercial establishments.

Conclusion

- The method of mobile fluorescence spectroscopy is fast-acting in determining the water content of radishes during storage of the product.
- The method of mobile fluorescence spectroscopy is applicable in controlling the water content quality of radishes during storage.
- It has been proven that mobile fluorescence spectroscopy will support the selection process and the control of stock production of radishes when it is necessary to qualify a large set of samples in a short time.
- A systems engineering approach for the alignment (optical tuning) of a dedicated mobile fluorescence spectroscopy applied research facility was found to be applicable in the characterization of radishes produced during storage.

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