Application of mobile fluorescence spectroscopy as a method in the determination of varietal differences in black radish (*Raphanus sativus* L. var. Niger) during storage under uncontrolled conditions

V. Slavova

Department of Plant Breeding, Maritsa Vegetable Crops Research Institute, Agricultural Academy, 32, Brezovsko Chaussee, Plovdiv 4003, Bulgaria

Received: September 19, 2023; Revised: January 10, 2024

The present study aims to establish the application of mobile fluorescence spectroscopy as a method to determine varietal differences and water content during storage of black radish (*Raphanus sativus* L. var. Niger) under uncontrolled conditions. The experimental studies were carried out on the farm where the black radish was grown and stored. Fluorescence analysis was performed with a source with an emission wavelength of 285 nm, using an author-developed mobile set up in a fiber-optic configuration generating fluorescence signals. The subject of this research were root crops from Black Spanish round, Black Spanish long, Rattail and Nero Tondo. 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 black radish breeding programs in establishing the origin of unknown root crops in the presence of a rich library of spectra, as well as in the sorting of black radishes in warehouses of food chains and producers. The results of the experiment can be used to optimize the time for the analysis of varietal affiliation of different black 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 black radish variety to a given variety (even for samples of unknown origin when it is necessary to qualify and sort in a short time).

Keywords: black radish accessions, fluorescence spectroscopy, variety, emission wavelength, storage under uncontrolled conditions.

INTRODUCTION

The black radish (*Raphanus sativus* L. var. Niger) is a two-year root plant, which in the first year forms a rosette of leaves and a root, and in the second forms a flower-bearing stem [1]. Black radish is common in many places in Europe and Asia (mostly in Korea, China and Japan) [2]. This cultivated plant has a rich chemical composition. It is a source of vitamin A, vitamin B2, vitamin C, vitamin P and vitamin K. The root vegetable contains potassium, calcium, magnesium, phosphorus, etc [3, 4]. This type of turnip is a source of glucosides, pectin, etc [5].

Using liquid chromatography, the oil content of the seeds of selected vegetable crops was found to vary between 15.89 g/100 g (purslane) and 38.97 g/100 g (black radish) [6]. The palmitic acid content of the oil samples was between 2.2 g/100 g (turnip) and 15.0 g/100 g (purslane) [7]. The linoleic acid content of the oils was between 8.9% (black radish) and 57.0% (onion) [8].

The present study aims to establish the function of fluorescence spectroscopy as a mobile method for the analysis of representatives of different varieties of black radish (*Raphanus sativus* L. var. Niger J. Kern) during storage under uncontrolled conditions. The accessions were kept under uncontrolled storage conditions. This will permit the technique to be applied non-invasively in the quality control of black radish production in unspecified storage outdoors.

MATERIALS AND METHODS

Materials

Accessions from four standard black radish varieties were investigated:

Black Spanish round - root crops are globose, up to 2-1/2 inches in diameter, with crisp hot white flesh that holds well after picking. The variety can be sown from early spring, and the harvest is in winter if sown in July-August.

Black Spanish long - a large-root crop vegetable, dark brown with long pointed roots and white flesh. It can be left in the ground and harvested in winter or stored in dry sand in a frost-free shed. It is believed to aid digestion and is high in antioxidants.

Rattail - root crops are flat-oval to oblong, with an intensively obtuse eye on the surface, with a diameter of 10-12 cm. The covering of the roots is black, and the core is a white, dense and spicy flesh. The accessions of this variety withstand more severe winter conditions during the growing season.

* To whom all correspondence should be sent:
E-mail: *vania_plachkova@abv.bg*

Nero Tondo - this elite variety is much more uniform and resistant to curling than the common black Spanish variety. Large 2–4" (depending on harvest date) black, round roots with crisp, hot, white flesh. Suitable for mid-spring sowing (soil temperature 60°F/16°C or higher, to prevent warping) until autumn, medium long storage.

Black radishes are harvested in dry sunny weather in the morning. After they are washed, they are spread out on a linen cloth and left to dry well, being turned periodically. The black radishes are dried for 2-3 hours in the sun and then for 7-10 days in a well-ventilated place. Their tops are cut in two stages. The first stage is to cut off just above the root crop, the second stage is to cut off the top of the black radish by 1 cm. Immediately before storage, the black radishes are sorted and only healthy and undamaged root vegetables are set aside for long-term storage. They are stored in a dry warehouse at an average temperature of 4-7 ºC.

Fluorescence spectroscopy:

Accessions of four different varieties of black radish storage under uncontrolled conditions were subjected to fluorescence spectroscopic measurements. The mobile spectral installation (Fig. 1) for the study of fluorescence signals was designed specifically for the rapid analysis of plant biological samples.

The mobile experimental installation for 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 3c V. It is housed in a hermetically sealed TO39 metal housing. The emitter has a voltage drop from 1.9 to 2.4 V and a current consumption of 0.02 A. 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 optic 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 of 4 cm^2. 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.
- CMOS detector with photosensitive area of 1.9968×1.9968 mm. Its sensitivity ranges from 200 nm to 1100 nm. Its resolution is $\delta\lambda = 5$. 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.

The obtained fluorescence spectroscopic data were subjected to statistical analysis to distinguish 4 different varieties of black radish during storage under uncontrolled conditions.

RESULTS AND DISCUSSION

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

The optical properties of the black radish 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 black radish, resulting in spectra and optical properties unique to it. Black radishes contain particles smaller than the wavelength of visible light. Particles in the turbid medium, such as the black radish, act as independent light sources, emitting incoherently, causing the samples to visibly fluoresce.

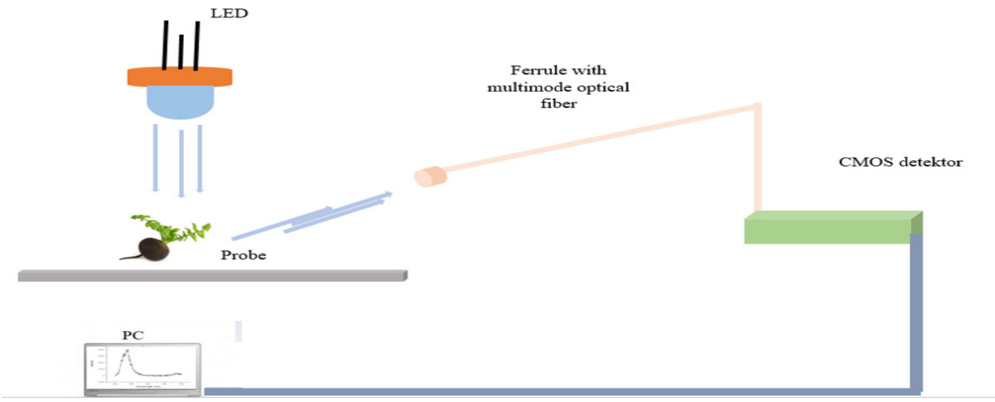

Fig. 1. Mobile experimental installation for fluorescence spectroscopy

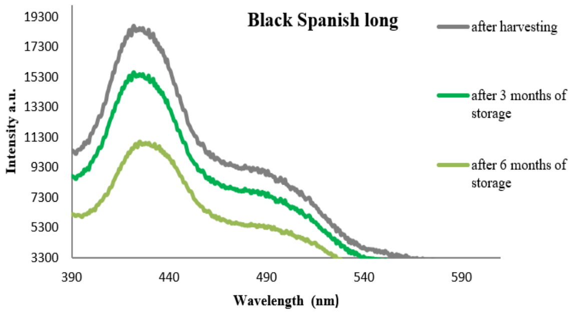

Fig. 2. Difference in emission wavelengths of Black Spanish long variety accessions after harvesting and storage for 3 and 6 months.

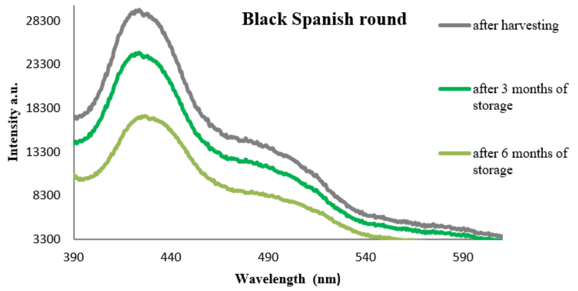

Fig. 3. Difference in emission wavelengths of Black Spanish long variety accessions after harvesting and storage for 3 and 6 months.

Therefore, fluorescence spectroscopy finds application for analysis of 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 black radish. The analysis of the graphs established the application of fluorescence spectroscopy for the analysis of root crops during storage in a warehouse under uncontrolled conditions for a period of 3 and 6 months (Figures 2, 3, 4 and 5). The decrease in signal intensity is directly proportional to the duration of storage (and it, in turn, is related to a decrease in root water content due to evaporation).

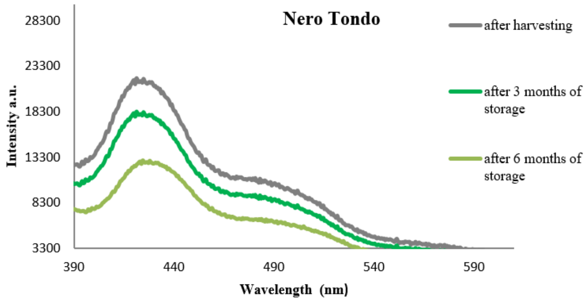

Fig. 4. Difference in emission wavelengths of Nero Tondo variety accessions after harvesting and storage for 3 and 6 months.

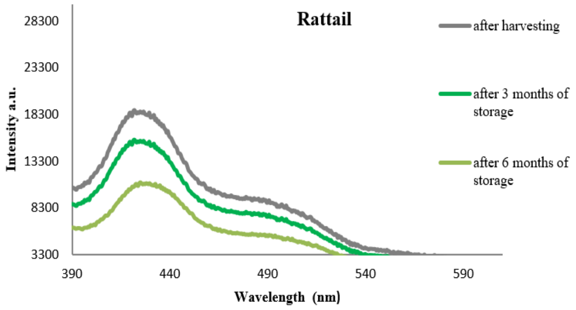

Fig. 5. Difference in emission wavelengths of Rattail variety accessions after harvesting and storage for 3 and 6 months.

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 black 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 of black radish stored in a storage room under uncontrolled conditions. This fact allows fluorescence spectroscopy to be applied as a non-invasive method in quality analysis of black radish production kept in storage rooms of farms and commercial establishments.

A literature survey was performed to conduct similar research. It turned out that until now the described experimental approach for the analysis of root crops of black radish has not been applied nationally and 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 black radish samples for their water content and root stability when kept 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.

CONCLUSIONS

- The method of mobile fluorescence spectroscopy is fast-acting in determining the water content of black radishes during storage of the product.
- The method of mobile fluorescence spectroscopy is applicable in controlling the

germination quality of root crops from black radish during storage.

- It was proven that mobile fluorescence spectroscopy will support the breeding process and the control of stock production of black radishes when it is necessary to qualify a large set of samples in a short time.
- A systematic 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 produced black radish during storage.

Acknowledgement: I express my gratitude to Mrs. Minka Serinska, in whose farm the black radishes were grown and stored, as well as to the entire team of the farm. Without their help, the research would not have been carried out.

REFERENCES

1. B. Matthäus, E. E. Babiker, M. M. Özcan, F. Y. Al-Juhaimi, I. A. Mohamed Ahmed, K. Ghafoor, *J. Oleo Sci.,* **70** (11)**,** 1607 (2021).
2. B. K. Singh, *Vegetable Crops*, 275 (2021).
3. E. Sipeniece, I. Misina, A. Grygier, Y. Qian, M. Rudzinska, E. Kaufmane, D. Seglin, A. Siger, P. Gornas, *Scientia Horticulturae*, **275**, 1083 (2021).
4. H. Jeon, S. Oh, E. Kum, S. Seo, Y. Park, G. Kim, *Pharmaceuticals*, **15**, 1376 (2022).
5. A. Grygier, S. Chakradhari, K. Ratusz, M. Rudzińska, K. S. Patel, D. Lazdiņa, P. Górnaś, *Industrial Crops and Products*, **186**, 251 (2022).
6. E. Njumbe Ediage, J. D. Di Mavungu, M. L. Scippo, Y. J. Schneider, Y. Larondelle, A. Callebaut, J. Robbens, C. Van Peteghem, S. De Saeger, *Journal of Chromatography A*, **1218**, 4395 (2011).
7. A. Yücetepe, G. Altin, B. Özçelik, *Food Science and Technology*, **56**, 1376 (2021).
8. F. Barimani, A. A. Gholami1, M. Nabili, *International Journal of Molecular Microbiology*, **10**, 1360 (2020).