

VERTICAL FARMING

Leafy vegetables shelf life



AGRICOLA
MODERNA



The monitoring of the degradation process of leafy vegetables enables the determination of their shelf life: a crucial characteristic to be studied for food safety.

Through the use of the HERA hyperspectral camera it's possible to **detect senescence or illness signs** in the sample's spectra in advance with respect to visual monitoring of the plant. Interestingly, information about the chemical and nutrient composition of the sample can be derived from the spectral read-out, such as **chlorophyll, anthocyanin and phenol concentration**. Samples for this study were provided by Agricola Moderna, a vertical farm based in Milan.

These features can be obtained by using both reflectance and fluorescence hyper spectral measurements.

ADVANTAGES OF USING HERA

- Staring technique (ideal for static objects)
- High sensitivity
- Fluorescence measurements
- High spatial and spectral resolution
- Plug & Play
- Non destructive measurements



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EXPERIMENTAL SETUP

The experimental setup is shown in Figure 1. The HERA camera is set on a tripod placed above the sample and the light source is composed of two 20 W halogen lamps.

The HERA is connected via USB to a computer, in which the acquisition software enables the user to set measurement parameters such as integration time, number of averages, and spectral resolution.

The focus and the iris aperture can be finely adjusted manually by using two sliders directly on the camera.



Figure 1: Experimental setup for shelf life monitoring.

RESULTS

The degradation over time of mustard wasabina leaves was analyzed. During the overall measurements period (19 days post-harvest), the samples were kept in a box and stored in the refrigerator at 4°C. The experimental conditions as described in the previous paragraph were maintained constant throughout all the senescence process.

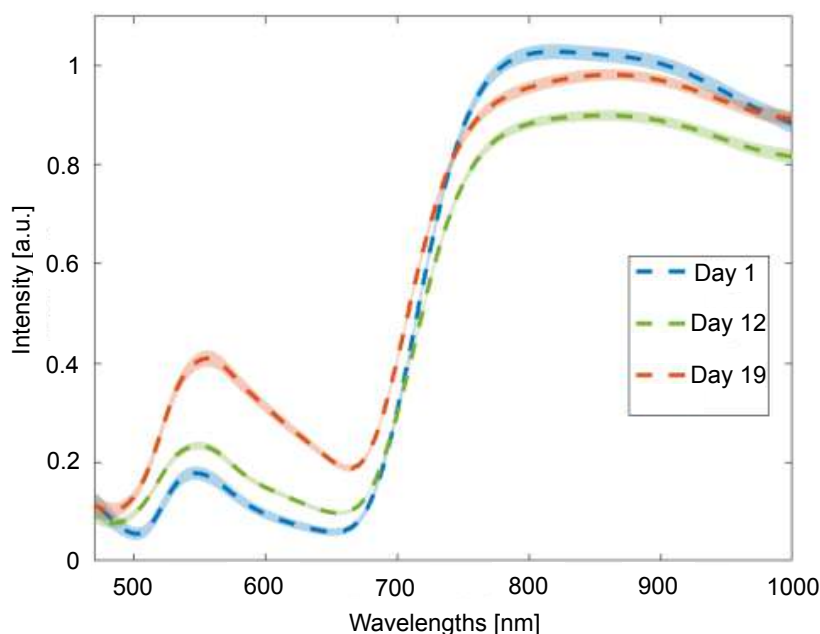


Figure 2: Reflectance spectra referring to a leaf in different days after harvesting.

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The spectra in Figure 2 are referred to the 1st, 12th and 19th day after harvesting. **Senescence-related changes in the spectra are clearly visible.** Firstly, the growth of the peak between 500 nm and 700 nm relates to the leaves' hue shifting from green to yellow, as visually confirmed.

Secondly, it's possible to observe that the absorption in the infrared region around 970 nm with respect to the *plateau* observed in the range 825 - 875 nm diminishes with time. Since one of the absorption peaks of water resides in that region this is most likely the sign that the leaf undergoes a process of **dehydration** during degradation, as it is actually confirmed by visual inspection of the sample (Figure 4).

To confirm this trend, a NIR index has been developed (Equation 1) comparing the intensity of the spectrum at the *plateau* and the absorption around 970 nm. The results confirm the reduced absorption around 970 nm (Figure 3).

$$NIR_{index} = \frac{\rho_{[825-875nm]}}{\rho_{[960-1000nm]}}$$

Equation 1: NIR index formula.

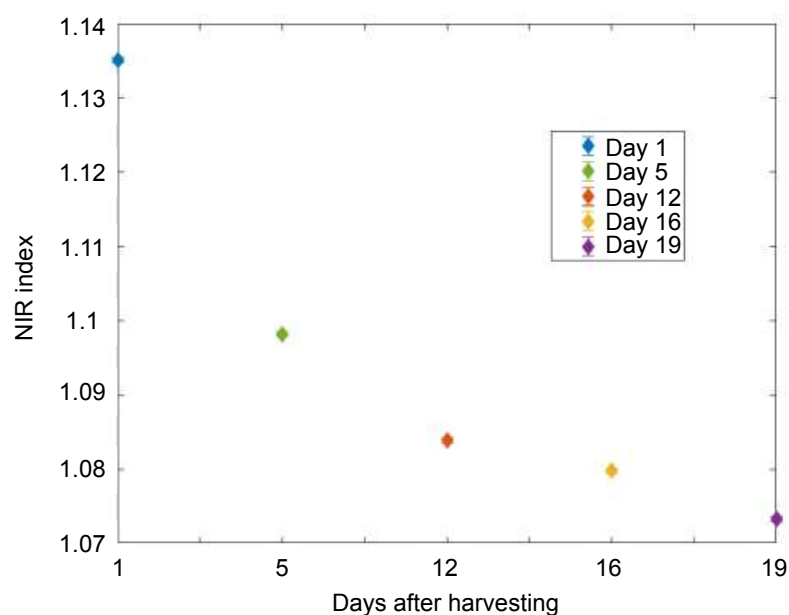


Figure 3: NIR absorption index.

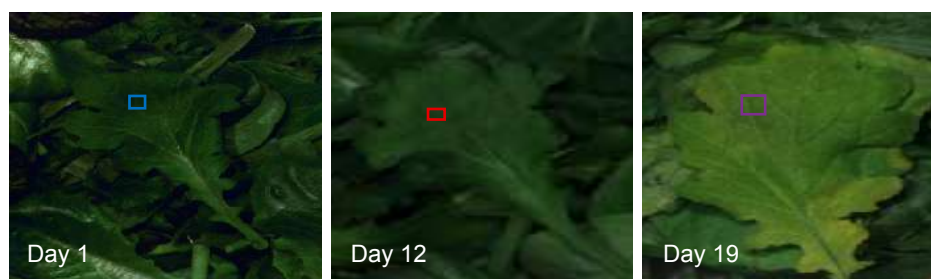


Figure 4: RGB reconstruction of the monitored leaves. The colored squares refer to the areas analyzed for the NIR index calculation in Figure 3.

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FLUORESCENCE HYPERSPETRAL IMAGING

Thanks to its high sensitivity, it is very easy to measure fluorescence hyperspectral images with the HERA camera. The same samples used for reflectance measurements were excited via a 20 W blue LED at 400 nm and a long pass filter was employed in detection to cut off the excitation light (experimental setup is shown in Figure 5). Fluorescence spectra related to the 1st, 12th and 19th day after harvesting are displayed hereafter (Figure 6).

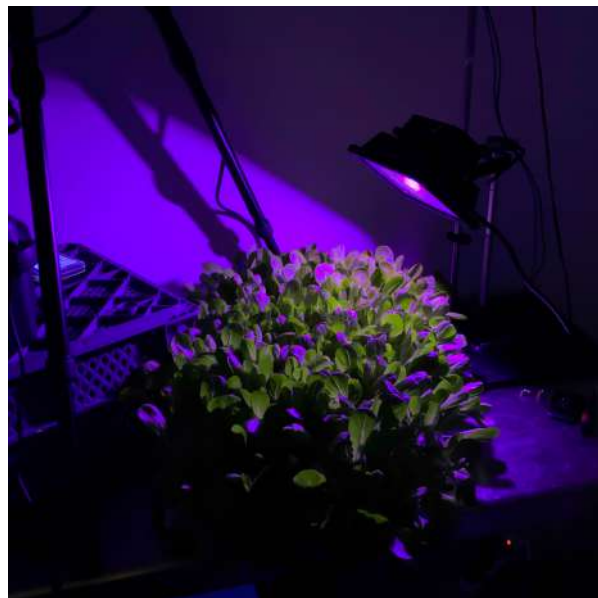


Figure 1: Experimental setup for fluorescence measurements.

The principal peak at around 750 nm is related to the presence of **chlorophylls** in the leaf and, clearly, its degradation over time is detected. Instead, the secondary, smaller peak, is likely connected to **phenols** concentration. Phenolic compounds are responsible for the antioxidant properties of lettuce; however, their production is also connected to plant stress and senescence. Indeed, as displayed in Figure 6, the phenolic peak increases over time as the sample in consideration degrades.

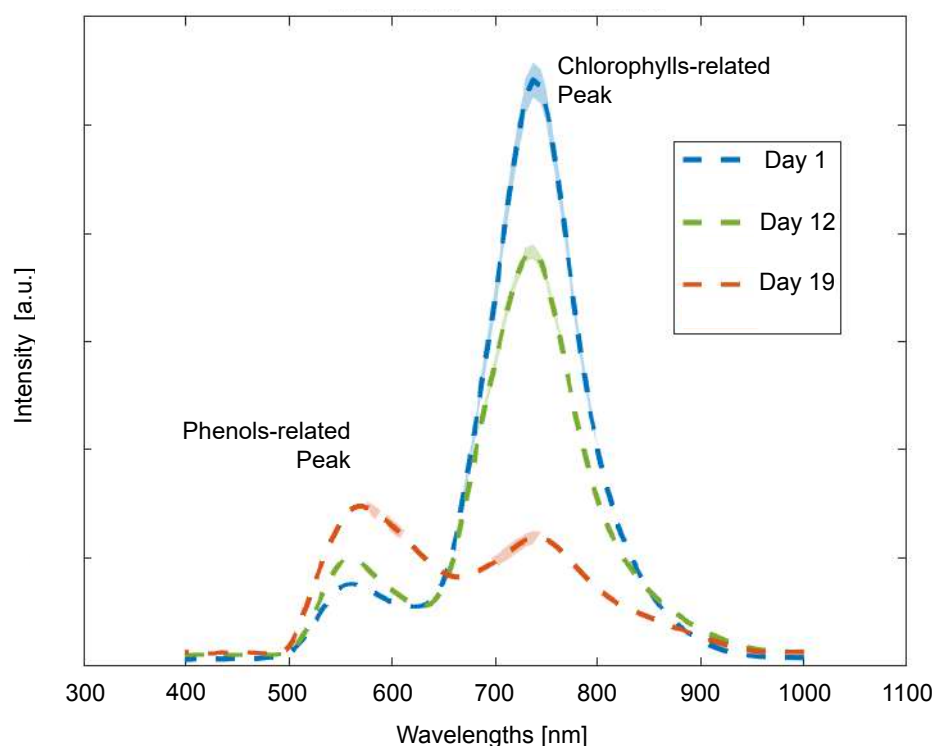


Figure 6: Fluorescence spectra of the leaf in different days after harvesting.

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The results regarding the diminished **chlorophyll concentration** over time obtained with fluorescence hyperspectral measurements were also validated through analysis of the reflectance data. An index correlated to the chlorophyll concentration was developed (Equation 2) and a reconstruction, based on this index, of the analyzed leaves is displayed hereafter (Figure 7). As expected by fluorescence measurements, the chlorophyll-related index shows that the concentration of this molecule drops as the leaves degrade.

$$Chl_{index} = 1 - \frac{\rho_{[660-680nm]}}{\rho_{[760-800nm]}}$$

Equation 2: Chlorophyll index formula.

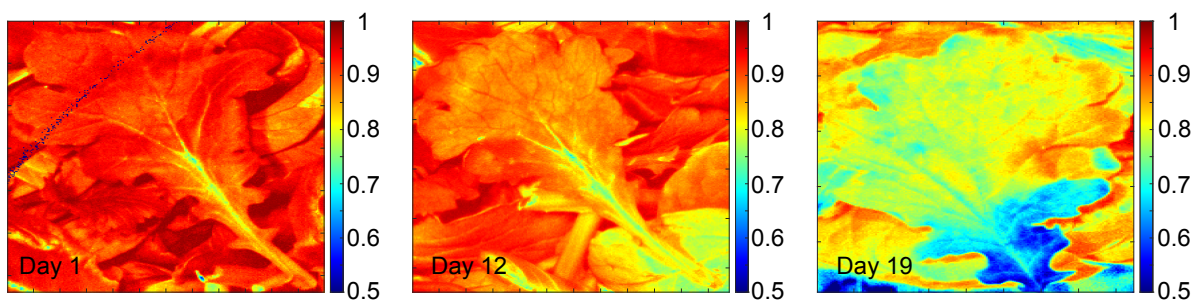


Figure 7: Chlorophyll index calculated over the monitored leaves.

More info on Agricola Moderna at <https://agricolamoderna.com/>