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Sustaining low-impact practices in horticulture through non-destructive approach to provide more information on fresh produce history and quality: the SUS&LOW project

M. Amodio [1], G. Attolico [2], L. Bonelli [3], M. Cefola [4], H. Fazayeli [1], F.F. Montesano [3, 5], B. Pace [4], M. Palumbo [1, 4], F. Serio [3], A. Stasi [1], G. Colelli [1 (*)]

[1] *Department of Science of Agriculture, Food and Environment, University of Foggia, Via Napoli, 25, 71122 Foggia, Italy.*

[2] *Institute on Intelligent Industrial Systems and Technologies for Advanced Manufacturing, National Research Council (CNR), Via G. Amendola, 122/O, 70126 Bari, Italy.*

[3] *Institute of Sciences of Food Production, National Research Council (CNR), Via Giovanni Amendola, 122/O, 70125 Bari, Italy.*

[4] *Institute of Sciences of Food Production, National Research Council of Italy (CNR), c/o CS-DAT, Via Michele Protano, 71121 Foggia, Italy.*

[5] *Department of Soil, Plant and Food Sciences, University of Bari, Via Aldo Moro, 70126 Bari, Italy.*

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(*) **Corresponding author:**
giancarlo.colelli@unifg.it

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Abstract: The general aim of the project SUS&LOW is to increase the sustainability of fresh produce by testing and implementing low-input agricultural practices (LIP) with positive impact on product quality with the support of non-destructive (ND) tools for real-time quality assessment and for product discrimination. Additionally, new marketing strategies are generated to better support the added value of the products and to satisfy the final consumers' preferences. The SUS&LOW project consists of three work packages (WP) and the adopted methodology used two model crops: rocket salad and tomato. The WP1, focused on the reduction of agricultural inputs, showed that sensor-based fertigation management might improve sustainability of soilless cultivation. Results coming from WP2, aimed to the evaluation of ND techniques, outlined the high potentiality of hyperspectral imaging (HSI) and Fourier transformed-near infrared (FT-NIR) techniques for the authentication of sustainable growing methods. Moreover, project activities' proved computer vision system (CVS) as an effective tool for evaluating the product quality also through the bag. The WP3, dealing with marketing strategies, indicated a positive approach of consumers compared to LIP products certified through a visual storytelling platform.

1. Introduction

Production of vegetable crops under controlled environments (i.e. greenhouses) has expanded considerably over recent decades in

Mediterranean areas (FAO, 2013). Initially, research efforts and the related introduction of technical innovations focused on high-quality, healthy products. However, concern with environmentally-sustainable production has risen in the last decade as industrial greenhouse crops are usually seen as entailing high environmental impact (Torrellas *et al.*, 2012). On the other hand, there is also plenty of evidence that greenhouse vegetable production may decrease the environmental impact compared to the field cultivation (Stanghellini, 2014).

The efficient use of resources (water and fertilizers), in irrigated greenhouse agriculture, is a promising and increasingly adopted strategy to achieve better crop performance, improved nutritional and sensorial quality (Montesano *et al.*, 2015; Montesano *et al.*, 2018). With respect to traditional systems, soilless cultivation and, particularly, closed-cycle with recycling of nutrient solution (NS) produce a number of benefits, including the possibility to standardize the production process, to improve plant growth and yield, and to obtain higher efficiency in water and nutrients use. In addition, it is also possible to modulate the regulation of the secondary metabolism of plants through an optimal control of the nutrient solution composition, or by imposing controlled stresses, or through biofortification treatments, generally leading to an improvement in the nutritional value of products (Rouphael and Kyriacon, 2018; Renna *et al.*, 2022). Innovative technologies based on the use of sensor networks for fertigation management may considerably reduce water and fertilizers consumption and increase the overall use efficiency of those inputs, and may lead to qualitative and quantitative improvements while preventing both under- and over-irrigation.

The most used instrumental techniques to measure quality attributes of fruits and vegetables are destructive and involve a considerable amount of manual work, primarily due to sample preparation. In addition, most of these analytical techniques are time consuming and sometimes may require sophisticated equipment. Finally, they can be performed only on a limited number of specimens (samples) and therefore their statistical relevance may be limited (Amodio *et al.*, 2017 a). Research has been focused on developing non-contact, rapid, environmental-friendly, and accurate methods for non-invasive evaluation of quality in fruits and vegetables. Nowadays, there are a few emerging non-destructive analytical instruments and approaches for this task, including spectroscopy, hyperspectral imaging, and computer vision (Liu *et al.*, 2017).

Near infrared spectroscopy has gained wide attention in the food sector due to its capacity of providing fingerprints of different products on the base of the interaction between their molecular structure and the incident light (Workman and Shenk, 2004) which is the result of different pre-harvest factors that also affect the final composition and quality. The feasibility of NIRS-based analysis to evaluate quality attributes of fresh fruits for commercial application have been reported by numerous authors (Arendse *et al.*, 2018; Palumbo *et al.*, 2022 a).

Hyperspectral imaging (HSI) combines the principles of spectroscopy and conventional imaging or computer vision. It is mainly used for internal bruise and defect detection in fruits and vegetables (Ariana and Lu, 2010; Babellahi *et al.*, 2020; Tsouvaltzis *et al.*, 2020) but also to predict the internal composition (Piazzolla *et al.*, 2013; Yang *et al.*, 2015; Liu *et al.*, 2017; Piazzolla *et al.*, 2017). Amodio *et al.* (2017 a) showed the potentiality of hyperspectral imaging in the Vis-NIR spectral range to predict internal content of soluble solids, phenols, and antioxidant activity of fennel heads. In addition, this technique provided important information about the maturity of fennel heads which may be used to determine the optimal harvest time. Some studies successfully applied these methods for the discrimination of production origin and agricultural practices, as revised in Amodio *et al.* (2020). NIR and HIS were in fact used for the classification of apples (Guo *et al.*, 2013), persimmon (Khanmohammadi *et al.*, 2014), and arabica coffee (Bona *et al.,* 2017) from different origins. As for production systems (Sánchez *et al.*, 2013) investigated the potentiality of NIRS technologies to discriminate green asparagus grown under organic and conventional methods. More recently, Amodio *et al.* (2017 b) successfully discriminated conventionally and organically grown strawberries, being also able to identify two different types of organic production systems applied to the same genetic material on the same site, soil, unheated tunnel.

All these studies have suggested multispectral and hyperspectral systems as valid tools to evaluate quality of different agricultural products and, more interestingly, as tools for product authentication.

Finally, Computer Vision Systems (CVS) may be applied to extend quality prediction and discrimination along the whole supply chain from harvesting up to consumers. CVS combine mechanics, optical instrumentation, electromagnetic sensing, and digital image processing technology (Patel *et al.*, 2012). Recently, CVSs have been used to assess quality and marketability of tomatoes (Arias *et al.,* 2000), artichokes (Amodio *et al.,* 2011), fresh-cut nectarines (Pace *et al.,* 2011), fresh-cut lettuce (Pace *et al.,* 2014), fresh-cut radicchio (Pace *et al.,* 2015), and rocket leaves (Cavallo *et al.,* 2017). Moreover, they have been applied for the prediction of internal quality of colored carrots (Pace *et al.,* 2013). Even more interesting is the application of these systems during the post-packaging phase and along the whole distribution chain. Despite the relevance of quality evaluation of packaged products, few investigations were reported in literature. Multi-spectral reflective image analysis has been applied to monitor the evolution and spoilage of leafy spinach covered by plastic materials (Lara *et al.,* 2013); more recently, Cavallo *et al.* (2018) have proposed an application of image analysis by CVS for non-destructive and contactless evaluation of quality of packaged fresh-cut lettuce. Therefore, the interest of investigating the application of CVS to detect quality and shelf-life of packaged products.

Finally, the possibility of using non-destructive technique for increasing the information on product history (e.g. growing location and agricultural practices) may be considered as baseline to develop marketing tools to promote the diffusion of sustainable production system. Cost barrier is an obstacle for choosing low input products instead of the conventional, even if environment is mentioned as a strong commitment (Krystallis and Chryssohoidis, 2005). Therefore, the knowledge about consumer preferences for the adoption of LIP is still matter of debate.

The general aim of the project is to increase the amount of sustainably-produced food by testing and implementing low-input agricultural practices with positive impact on product quality with the support of non-destructive tools for real-time quality assessment and product discrimination, which may inspire new marketing strategies to better support the added value of the products and increase incomes of potential users.

2. Project activities and main results

The SUS&LOW project structure consists of three work packages (WP). WP1 focused on research activities aimed to reduce agricultural inputs (water and fertilizers) in greenhouse cultivation, chosen as a strategic high-value sector for Mediterranean agriculture. This WP was also in charge of making available to the project team vegetables products (rocket and tomato) different for the level of sustainability characterizing the cropping system adopted, to be used in other WPs for the related investigations. Then, WP2 was aimed to the quality assessment and to the implementation of new tools to acquire information about quality and history of fresh produce obtained with LIP (WP1). Non-destructive methods (including NIR, hyperspectral imaging and image analysis by CVS) have been used for food authentication, showing interesting and promising results. Finally, WP3 realized ad hoc survey to analyze the consumer behaviour with respect to the possibility of purchasing fruit and vegetables LIP certified (WP1) and identified by ND technologies (WP2) with the aim to implement adequate marketing strategies. In this section, an overview of the research strategies and approaches adopted in the three WPs is provided. The main results are reported and discussed.

WP1: quality crops through low-impact practices

Based on the overall project structure, this WP was focused on soilless cultivation, since it has the potentiality to achieve extremely high water and fertilizers use efficiency, beside high yield and quality, in intensive cropping systems. However, the adoption of free-drain open cycle with empiric fertigation schedule management operated by timers (the predominant case in Mediterranean area), may compromise the sustainability of soilless culture. Therefore, the adoption of strategies aimed to rational use of water and fertilizers and excess leaching prevention is a key-factor for increased sustainability and reduced environmental impact of soilless culture (Massa *et al.*, 2020). In this context, substrate moisture/EC (electrical conductivity) sensor-based irrigation is a promising and increasingly adopted strategy to reduce water and fertilizers consumption and losses, and to improve the overall crop performance, product quality and production process sustainability in soilless greenhouse cultivation (Palumbo *et al.*, 2021 a).

Several experiments were carried out at the Experimental Farm La Noria (Mola di Bari, BA) of the CNR-ISPA (Bari), with the common approach to compare treatments providing traditionally adopted empirical fertigation management techniques with treatments in which advanced sensor-based fertigation management was implemented. The main results of selected experiments carried out during the project are reported hereafter.

The research activities focused on two model species [rocket salad (*Diplotaxis tenuifolia* L.) and tomato (*Solanum lycopersicum* L.) selected for their relevance in Mediterranean greenhouse vegetable production. In particular, rocket is reported as an emerging leaf vegetable which cultivation is widespread and in further expansion (Schiattone *et al.*, 2017), while tomato is the most important greenhouse crop grown in soilless cultivation systems (Montesano *et al.*, 2015).

A study was carried out to test two irrigation scheduling approaches (timer- or sensor-based) and two fertilization levels (high or low, with reference to the standard dosage range recommended for the specific fertilizers used) of open-cycle soilless rocket in Mediterranean autumn-winter unheated greenhouse conditions (Montesano *et al.*, 2021). Rocket plants (cv. Dallas, Isi Sementi) were grown in a peat:perlite (3:1) mixture in 4.5 L plastic pots. Four treatments were compared: timer with high or low fertilization (T-HF, T-LF), and sensor-based with high or low fertilization (S-HF, S-LF). In timer-based treatments, irrigation schedule was periodically adjusted based on leaching fraction measurements (≈35% was set as a target, according to common practice). In sensor-based treatments, on-demand irrigation was operated based on substrate EC/temperature/moisture sensors (GS3, Decagon Devices). These were connected to a CR1000 datalogger programmed to automatically open irrigation valves and supply water enough to constantly maintain volumetric water content to a pre-defined set-point (0.35 m^3 m^{-3}, close to maximum water holding capacity), with no leaching. Slow-release fertilizers (Osmocote Exact and CalMag, ICL) were mixed with the substrate at high (3.75 and 1 g L^{-1}, respectively) or low dosage (2.25 and 0.6 g L^{-1}). Yield, quality, water use and substrate parameters trends were evaluated. Sensors improved water use efficiency compared to timer (34.4 vs 21.4 g FW L^{-1}, on average) matching water supply with plant needs, and preventing leaching (Fig. 1) (no interactive effects of fertilization treatments were observed on those parameters). Sensor-based irrigation also provided the best plant growth conditions, with interesting interactive effects with fertilization rate. In particular, the highest and the lowest cumulative (three harvests) yield values were obtained in S-HF and T-LF respectively (144.8 and 102.2 g FW pot^{-1}), while similar values were observed in S-LF and T-HF (131.4 g FW pot^{-1}, on average) (Fig. 1). The partial fertilizer factor productivity (g product fresh weight / g fertilizers applied) was higher at low dosage, and, with the same dosage, when the sensors were used (Fig. 1). After each harvest time the fresh-cut rocket leaves were immediately transported in refrigerate conditions to the postharvest laboratory (see WP2 section below) (Palumbo *et al.*, 2021 b).

In another set of studies, we aimed to apply approaches for the sustainable fertigation management of soilless tomato (semi-closed cycle recirculation; sensor-based nutrient solution supply management) in comparison with a traditional open cycle free-drain nutrient solution management providing the use timer for fertigation schedule. Experiments were conducted with different tomato types (cherry - cv. Carminio, Seminis-Bayer, and intermediate type - cv. Mose, Syngenta), and in different environmental conditions typical of Mediterranean areas (including the use of brackish water for nutrient solution preparation). In general, both approaches (semiclosed-cycle cultivation and open cycle with sensor-based fertigation management) reduced the environmental impact of the production process (reduced water/fer-

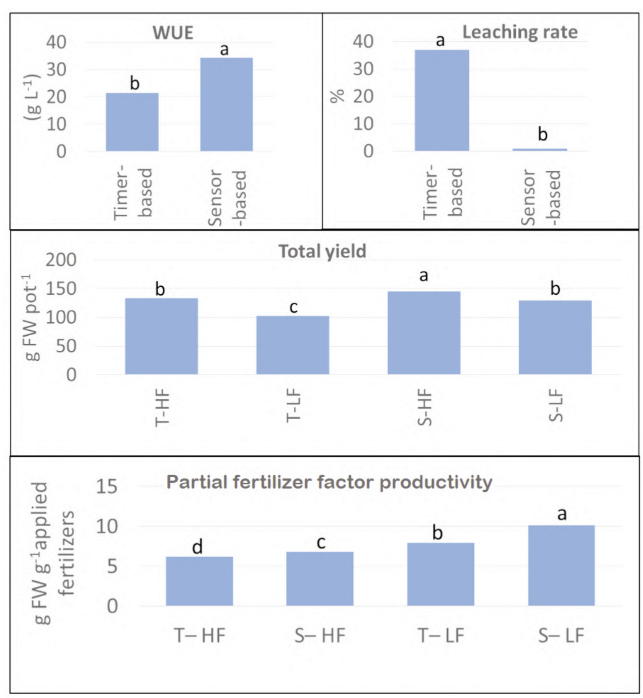

Fig. 1 - Water use efficiency (WUE), leaching rate, total yield, and partial fertilizer factor productivity of rocket (*Diplotaxis tenuifolia*) grown in open free drain soilless system with timer- (T) or sensor-based (S) irrigation management, and subjected to high (HF) or low (LF) fertilization rate.

tilizers usage; less nutrient solution released into the environment, increased water use efficiency) and positively affected tomato quality traits, compared to empirically management open-free drain cultivation.

WP2: non-destructive discrimination for low-impact practices and non-destructive quality assessment

NIR spectroscopy and Hiperspectral imaging. In this WP, the objective of the tasks was to assess the potentiality of Fourier transformed-near infrared (FT-NIR) spectrometry and hyperspectral imaging (HSI) to discriminate tomatoes and rocket leaves produced with different level of input as described in WP1, taking also into account the degree of efficiency in water and fertilizers used efficiency (WUE and FUE indexes). A hyperspectral line-scan scanner (Version 1.4, DV srl, Padova, Italy) equipped with two spectrographs, one in the Vis-NIR range, and the second in the NIR range, was used to obtain the HS images. The Vis-NIR spectrograph (400-1000 nm) has a spatial resolution of 1000 × 2000 pixels with a spectral resolution of 5 nm and was connected to a CCD camera. As for the NIR spectrograph (900-1700 nm), the spatial resolution was 600 × 320 pixels with a spectral resolution of 5 nm; and a CMOS (Specim Spectral Imaging Ltd., Oulu, Finland) with 50 frames per second equipped with C-mount lenses was used. As for FT-NIR spectrometry an MPA Multi-Purpose (FT-NIR Analyzer, Bruker Optics, Ettlingen, Germany), was used during spectral acquisition over the range of 800-2777 nm (sphere macrosample re-solution 1.71 nm, scanner velocity 10 kHz, sample scan time 64 scans, background scan time 64 scans). After image processing and spectra extraction for the HSI, all spectra belonging to HSI and FT-NIR were tested in discrimination using the agronomic treatments as discriminant classes and Partial Least Squares-Discriminant Analysis (PLS-DA) as classification technique. As for rocket leaves, PLS-DA was conducted with the 4 classes (T-HF; T-LF; S-HF, S-LF) described in the paragraph related to WP1, using 70 percent of samples for calibration purpose and the remaining 30% for the external validation. The model performance was evaluated based on the accuracy, which is an average of the sensitivity calculated over the various classes, and gives an overall idea of the goodness of the classification. Results indicated HSI as a promising technique for the discrimination of rocket produced with different cultural techniques, with an accuracy of classification in the prediction phase of 97.2% in Vis-NIR and 99.5% in NIR range. In figure 2, the results of the discrimination models can be observed.

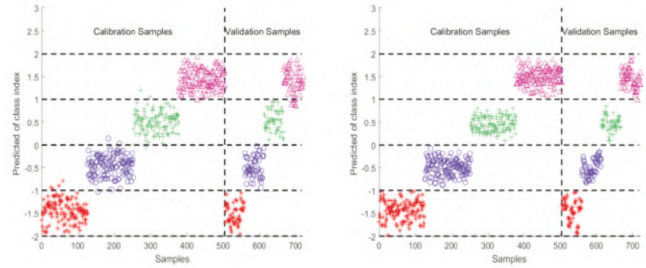

Fig. 2 - Estimated class index values in the calibration and in the prediction process for the classification based on PLS-DA modes shown on table 2 in a) VNIR range (left) b) NIR range (right).

Regarding tomato, where 2 experiments with 2 different varieties were conducted (WP1), for each trial a first PLS-DA was aimed to discriminate the three treatments of cultivation and a second discrimination was performed for different levels of WUE and FUE. According to the efficiency of use of water and fertilizers we could individuate 2 levels (high and low) in each experiment and 3 levels (High, medium, and low) merging the data of both experiments. Therefore, a PLS-DA with 3 levels of WUE (and FUE) was also generated with the full dataset. Among the different non-destructive techniques, FT-NIR and HIS in the VIS-NIR range gave comparable performances in discriminating tomato according to cultural practices and different use of sources. Discrimination for WUE for each variety improved the classification results, respect to the individual treatments, but the highest accuracy was obtained when the discrimination was based on 3 levels of WUE merging the 2 datasets, reaching 92.1%. In literature there are no studies aimed to discriminate crops for WUE or FUE, while we may find the application of HSI for the classification of water-stressed plants, as for the case of tomatoes (Rinaldi *et al.*, 2015). In comparison to this study, reporting a mean accuracy of around 77% for discrimination of the two differently irrigated areas, our findings showed higher accuracy, exploring new area of the application for these techniques.

Application of CVS for non-destructive quality evaluation on packaged products

A research activity was carried out to develop and validate an innovative CVS integrating a Random Forest model for classification: this model automatically selects from the image the most relevant colour features for the task of interest. The developed CVS was applied to digital images of fresh-cut rocket leaves cultivated with LIP (WP1) to objectively estimate the evolution of their quality levels (QL) during storage and to discriminate the cultivation approach applied on field. At harvest, rocket leaves were stored at 10°C in open polypropylene (PP) bags for a number of days required to reach the lowest QL, according to the rating scale from 5 (very good) to 1 (very poor), as reported in figure 3.

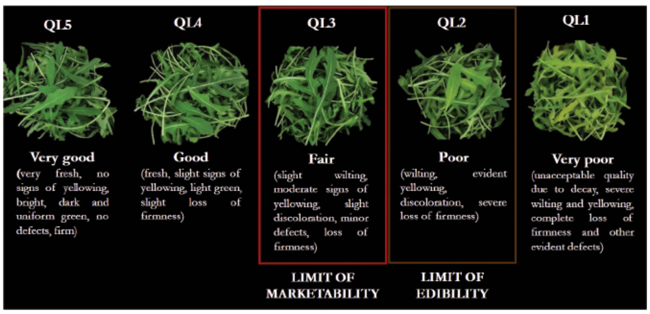

Fig. 3 - Changes in the sensory quality level (QL) of fresh-cut rocket leaves during the storage at 10°C according to the 5 to 1 rating scale reported by Palumbo *et al*. (2021 b). In detail, QL5= very good; QL4= good; QL3= fair; QL2= poor; QL1= very poor.

At each QL, all the samples were subjected to postharvest quality evaluation, detecting colour parameters by a traditional colorimeter (CR400, Konica Minolta, Osaka, Japan) and physical and chemical parameters, in detail respiration rate (Kader, 2002), electrolyte leakage (Kim *et al.*, 2005) and total chlorophyll content (Cefola and Pace, 2015). Then, images of the same samples were acquired by the CVS for non-destructive quality assessment and for recognizing traits related to the sustainability of the cultivation management used on the field, with specific reference to water and nutrients use (WP1). Image pre-processing was applied: to separate the product from the background; to identify the colour-chart placed in the scene to estimate the effects of lights and of the sensors and to correct colours to minimize these effects. Three colour correction methods (white balance, linear correction, and polynomial correction) with increasing level of complexity were evaluated and compared in terms of consistency of colour measurements and of classification performance. Linear colour correction proved to be the best trade-off between efficacy and efficiency providing a slightly lower performance than polynomial correction with significantly simpler computation. Finally, a Random Forest model was used to train classifiers to assess the QL of rocket leaves and to identify the treatments used during the cultivation.

All the postharvest quality parameters measured by traditional destructive methods were significant in QL assessment of fresh-cut rocket leaves. The proposed classifier based on the Random Forest model was able to identify and select the most relevant colour traits for both the tasks (QL assessment and treatment identification) without human intervention. The accuracy achieved in evaluating QLs of rocket leaves during storage was high (about 95%), while the performance in discriminating the cultivation approach was lower and not sufficient for practical applications (about 65-70%). Indeed, the different cultivation approaches did not significantly affect the visual characteristics of the product and the destructive measures: this task needs further investigations.
Another research activity was carried out to develop and validate the capability of the non-destructive and contactless CVS to assess the visual quality changes during the cold storage of fresh-cut rocket leaves coming from soil and soilless growing systems (WP1) and to estimate some internal quality attributes (chlorophyll and ammonia content) also through the packaging material. Evaluating quality through the package is critical to identify the regions of the bag where the product is visible without shadows or highlights created by illumination: this is mandatory to measure colour properties in a reliable and meaningful way. At harvest, rocket leaves, cultivated on soil or soilless system (WP1), were packed in open PP bags and stored at 10°C for about 18 d. During storage, all samples were observed to attribute the QL according to the rating scale reported in figure 3 and the postharvest quality traits were evaluated by destructive conventional methods [colour parameters, chlorophyll content, ammonia content (Fadda *et al.,* 2016) and electrolyte leakage]. Then, images of unpackaged and packaged samples were acquired by the CVS. During image acquisition, no constraints were imposed on the position of the product in the bag, on the position of the bag in the scene or on the highlights created by the illumination on the surface of the bag: this was necessary to demonstrate the applicability of this technology into a real industrial line. Colour correction was performed by the linear model, identified as the best trade-off between effectiveness and computational complexity in the previous research activity. Packed and unpacked products were processed using exactly the same phases apart from the artefacts' elimination step applied to the images of packaged products to select the regions where the colour information was meaningful, without interference from light artefacts and reflections. At last, the Random Forest model was used to solve

both the classification problem (assessment of the QLs) and the regression problems (estimation of quality marker parameters such as chlorophyll and ammonia contents). The same architecture was used for all the tasks, by simply changing the training data. The histogram of the image, evaluated in the a-b plane of the CIELab colour space, was used as the set of features. The Random Forest model was able to automatically select the subset of values more suitable for solving each task.

All the postharvest quality parameters detected by conventional analysis during the storage of fresh-cut rocket leaves were significant in the QL assessment and, among them, chlorophyll and ammonia contents proved to be useful marker parameters for the objective separation of each QL considered, both on soil and soilless cultivation approach.

The CVS was able to operate without relevant differences on unpackaged and packaged products. The test was done joining all the samples, regardless of the cultivation approach: the results showed a not significant performance loss on packaged leaves (Pearson's linear correlation coefficient of 0.84 for chlorophyll and 0.91 for ammonia) with respect to unpackaged ones (0.86 for chlorophyll and 0.92 for ammonia) (Fig. 4).

Finally, three Partial Least Square (PLS) models were performed to predict the QL using as predictors chlorophyll and ammonia contents obtained by destructive methods (Model I), by CVS on packaged products (Model II) and by CVS on unpackaged ones (Model III) (Table 1).

The results showed high performances in terms of R^2 and the model obtained by predictors estimated non-destructively by the CVS (Model II and III) provided better performances in the QL prediction than one obtained by destructive analysis, in both calibration and validation.

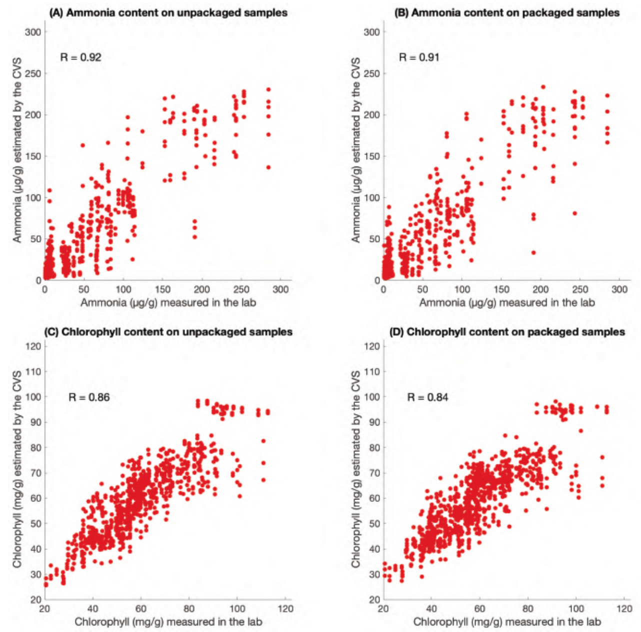

Fig. 4 - Values estimated by the CVS (abscissa) vs. values measured in the laboratory (ordinate) for ammonia content on unpackaged (A) and packaged (B) rocket leaves and for total chlorophyll content on unpackaged (C) and packaged (D) samples (Palumbo *et al*., 2022 b).

WP3: marketing strategies to support the added value of the products LIP and ND certified

Implementing a marketing strategy, based on often intangible characteristics to consumers such as LIP and ND, it is not an easy task. Low impact practices do not have a highly distinctive impact on product characteristics nor determine unique taste, flavour, or look elements to consumers. However, certifications could be used to signal quality through the application of standards of quality and practices. Whether certifications could be effective in terms of marketing in the case of products LIP and ND, or for signalling quality in general is matter of discussion. Vecchio and Annunziata (2011), for instance, in their work question the possibility of effective understanding of certification by consumers. At this purpose the research team of WP3 decided to implement a different strategy and test it on the market. Visual storytelling certifying LIP and ND has been then hypothesized to better communicate the importance and the impact of those practices on food.

The research activity, therefore, has been organized in three steps: identifying the communication

Table 1 - Root Mean Square Error (RMSE) and the coefficient of determination (R2) in calibration (c) or validation (v) of the Partial Least Square (PLS) Models predicting visual quality of rocket leaves (Palumbo *et al*., 2022 b)

PLS Models	Predictors	$RMSE_c$	R^2_c	$RMSE_v$	R^2_v
I	Total chlorophyll and ammonia obtained by destructive methods	0.45	0.9	0.86	0.70
II	Total chlorophyll and ammonia obtained by CVS on packaged rocket leaves	0.46	0.89	0.75	0.77
III	Total chlorophyll and ammonia obtained by CVS on unpackaged rocket leaves	0.46	0.89	0.7	0.8

strategy and set-up; testing through focus-groups the opportunity conditions for farms and companies; testing though a survey and an econometric analysis the consumers' preference and their willingness to pay for products with LIP and ND. Therefore, a draft platform has been developed containing basic communication rules in order to highlight sustainability attributes of products through storytelling. Workflow has been established and a simulation has been conducted (Fig. 5). Focus group with producers has allowed verifying the general appreciation for the marketing approach and allowed a better set-up of the strategy. Finally, a picture-based simulation has been produced for the final test and the survey to consumers (Fig. 6).

As last activity, a questionnaire based survey has been prepared and administered to 467 consumers and an econometric model to estimate willingness to pay and consumers orientation has been set up and then estimated. The whole set of activties within the research project allowed understanding how important is a correct communication of products and how different could be the perception of a product based on how you certify or narrate the production method. Result allow understanding that older conumsers are more aware of sustainability and are more willing to pay for LIP products. Psicological profile such as traditionalism and benevolence identify the consumer that, more than other profiles, would be willing to pay a higher price.

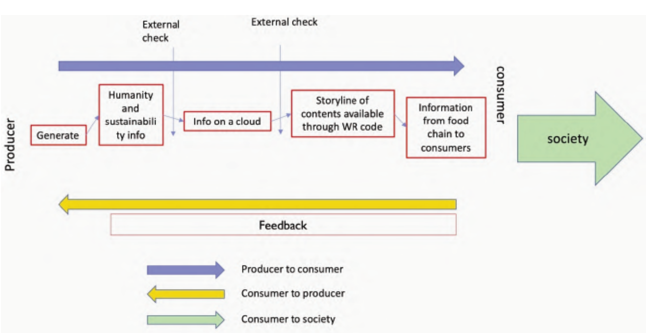

Fig. 5 - Workflow for products LIP and ND certified platform.

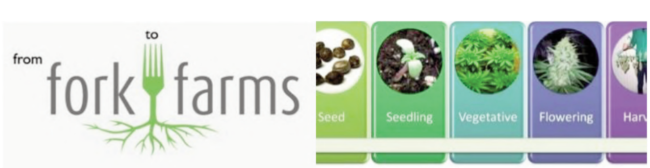

Fig. 6 - Picture based simulation of visual storytelling certification for LIP producs and ND.

3. Conclusions

Sensor-based fertigation management applied to rocket leaves and tomato confirmed to be a feasible approach to improve sustainability of soilless cultivation, also in cases where the complete and rapid switch to closed cycle recirculation systems is still impaired by economic, social, and environmental factors such as in Mediterranean area.

The results of this project related to non-destructive discrimination of tomatoes and rocket leaves, according to cultural practices using different levels of inputs (water and fertilizers), indicated the high potentiality of HSI and FT-NIR techniques for the authentication of sustainable growing methods. Moreover, project activities' proved CVS as an effective tool for evaluating the product quality also through the bag, even working only on the regions of the image that provide meaningful colour information about the product's surface. The integration of machine learning modules inside the CVS confirmed to be useful to simplify the design and tuning, done mostly automatically without human intervention. Moreover, the flexibility introduced by machine learning makes the resulting architecture more flexible in adapting to different products and applications.

As regards the marketing approach, consumers resulted willing to pay a higher price for LIP products certified through a visual storytelling platform. In the next future, there could be a good chance that sustainability-oriented practices coupled with a visual storytelling certification style could gain shares on food markets.

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