Improving Postharvest Handling of Pomegranate Fruit: Recent Results and Future Perspectives

Giancarlo Colelli*
Department of Agriculture, Food, Natural resources, and Engineering, University of Foggia, Via Napoli 25 71122 Foggia, Italy. *giancarlo.colelli@unifg.it

Abstract

Pomegranate (*Punica granatum L.*) has gained global attention for its exceptional health benefits and high economic value. Rich in organic acids, micro- and macro-nutrients, and bioactive compounds, pomegranate exhibits potent antioxidant, anti-inflammatory, anti-mutagenic, and anti-hypertensive properties. These attributes position it as a fruit with increasing demand in international markets. As a non-climacteric fruit with low respiration rate and minimal ethylene production, pomegranate has good potential for cold storage, typically lasting up to three months. However, maintaining optimal storage conditions is critical, as temperature and humidity significantly influence the preservation of fruit quality. Storage temperatures below 5°C can lead to chilling injury (CI), a physiological disorder characterized by internal discoloration of the arils, albedo, and surface pitting of the skin. On the other hand, storage at 5–10°C can result in husk scald (HS), a condition that manifests as superficial browning of the skin, primarily starting at the stem end, and may affect up to 60% of the skin surface. Results obtained during the last 5 years will be presented aiming to reduce the incidence of CI, microbial decay, and HS. Moreover the importance of the management of temperature, relative humidity, and atmosphere composition will be discussed.

Keywords

Atmosphere modification, chilling injury, oxalic acid, hisk scald, relative humidity, temperature.

References

Maghoumi M., Amodio M.L., Fatchurrahman D., Cisneros-Zevallos L., and Colelli, G. 2022. Pomegranate husk scald browning during storage: a review on factors involved, their modes of action, and its association to postharvest treatments. Foods, 11, 3365.
Maghoumi, M., Fatchurrahman D., Amodio M.L., Quinto M., Cisneros-Zevallos L., Colelli G. 2022. Is pomegranate husk scald during storage induced by water loss and mediated by ABA signaling? J. Sci. Food Agric. 103(6)2914-2925. https://doi.org/10.1002/jsfa.12385
Maghoumi, M., Amodio M.L., Cisneros-Zevallos L., Colelli G. 2023. Prevention of chilling injury in pomegranates revisited: pre- and post-harvest factors, mode of actions, and technologies involved. Foods, 12, 1462. https://doi.org/10.3390/foods12071462

Active Pad in Pallet bag: the Role of Essential Oils in Blueberry Storage Management

Selene Ollani[1], Luca Brondino[2], Gustavo Gonzalez[3], Serenella Piano[1] and Nicole Roberta Giuggioli[1]*

[1]Department of Agricultural, Forest, and Food Sciences, University of Turin, Largo Paolo Braccini 2, Grugliasco, 10095 Torino, Italy; selene.ollani@unito.it (S.O.); serenella.piano@unito.it (S.P.); nicole.giuggioli@unito.it (N.G.)

[2]Ortofruit Italia Soc. Agr. Coop. O.P., Via Colombaro dei Rossi 16/Bis, Saluzzo, 12037 Cuneo, Italy; l.brondino@ortofruititalia.it (L.B.)

[3]Agree NET s.r.l, Via Gioacchino Quarello 15/a, 10135 Torino, Italy; g.gonzalez@agreenet.it (G.G.)
*Corresponding author

Abstract

Background and aim: The identification and application of innovative green technologies related to the efficient use of resources is mandatory for the postharvest of berries, whose market demand is increasing a lot, particularly because of their healthy characteristics and possible functional effects. This work shows the preliminary results of the applied research collaboration among the innovative start-up Agree NET s.r.l., the producers organisation Ortofruit Italia and the fruit postharvest group from DISAFA (University of Turin) who actually met during Macfrut 2024.

The effectiveness of cloves, citronella and geranium essential oils (EOs) applied on polymeric pads into modified pallet bags were investigated for the action mechanism and efficacy in blueberry cv. Cargo storage for long time.

Materials and Methods: Blueberries freshly harvested were stored into pallet bag enriched with 10% of CO_2 (modified atmosphere). In each bag 10 active pads (containing 25% in weight of EOs mix) were positioned and stored for 15, 27 and 37 days at +2°C. The quality of berries (weight loss, firmness, titratable acidity, soluble solids content) have been evaluated. Triangular tests were carried out to analyse the sensory aspects. The analyses from this investigation (A) were compared to blueberries stored with additional SO_2 (S) and only CO_2 (control – C). The evolution of naturally occurring microbial populations was also analysed in vivo. Finally, the fruits shelf-life was considered after 15 and 37 days to evaluate the reaction in the logistic and selling environmental conditions (24 h at 20°C + 72 h at 8°C).

Results: Generally, the application of the functional pad led to results comparable to the application of SO_2, which is a strong preserving agent. In particular, this happened for mould development on berries after shelf-

life (S 22.23%; A 25.36%). Microbial analyses underlined a slight antimicrobial effect due to EOs, while the SO_2 application resulted more effective, reducing of 1 Log CFU/g the living berries' microbiota, but no statistical difference was highlighted. At each analytical time point a series of 3 triangular test was carried out to match all the possible combinations of the 3 theses (A – S; A – C; S – C) to understand the possible interference of the EOs characteristics with the blueberry smell, taste and flavour. Results showed no statistical difference ($p<0.05$) at any analytical time point (15, 27 and 37 days), meaning the absence of flavour transfer from the active pad to the product.

Conclusions: The preliminary results obtained are encouraging to improve and perfecting the system in term of EOs (%) added and active pads per pallet unit to maintain the qualitative standards of fruits and control the microbial evolution.

Keywords

Blueberry, EOs, active pad, modified atmosphere, sensory evaluation

References

Brondino, L., Cadario, D., & Giuggioli, N.R. (2021). Influence of a Sulphur Dioxide Active Storage System on the Quality of *Ribes rubrum* L. Berries. Polish Journal of Food and Nutrition Sciences, 279-288.

Potential for a low-cost greenhouse technology to optimize drying conditions of fruits and vegetable in Senegal for storage

Michel Bakar DIOP
Laboratoire des Sciences Biologiques, Agronomique, Alimentaire et Modélisation des systèmes complexes (LaBAAM), UFR des Sciences Agronomiques, de l'Aquaculture et des Technologies Alimentaires, Université Gaston Berger BP 234 Saint-Louis, Sénégal

Abstract
Senegal is a west African country in which the annual production of fruits and vegetable has significantly increased during the last two decades: determined to 905,000 tons in 2012, it reached 1,519,784 tons in 2020. However, the post-harvest losses of fruit and vegetable still remains high across the country reaching 30 to 40% of the production, because of the lack of industrial storage compared to artisanal sun drying practices for preservation. A recent microbial study conducted at the Gaston Berger university Farm (Lat 16°3'37N, 16°25' W, 5m above mean sea level), Saint-Louis, Sénégal, on indigenous dried sliced fruits and vegetables such as onion (Allium cepa), ginger (Zingiber officinale) and coconut (Cocos nucifera), collected from the marked showed a total aerobic mesophilic bacteria and fungi reaching 107 CFU/g and 106 CFU/g. The of the products humidity was between 15 to 25% of the products. In parallel to this study, measuring ambient air temperature (°C) and relative humidity (%) in a low-cost greenhouse (3 m long by 2,1 m wide, with central height of 2.5 m) was undertaken using digital temperature-RH meter (otio) for 8 h a day at interval of 05 h from morning 9:30 a.m. to evening 5:30 p.m. for evaluating the potential of this later as solar heat collector to optimize traditional sun drying of sliced fruits and vegetables.
The relative humidity and temperature recorded inside the greenhouse were between 22 to 52. 5% and 42,8 to 57,40°C. Edible bulbs of onion were sliced into 3 mm thick slices by using manual stainless-steel slicer, spread in thin layers in trays kept in the greenhouse for drying. They were dried in 16h sunshine hours to reach a humidity of 8-10%, indicating an improvement, justifying continuing the experiment with other vegetables and fruits for more in deep evaluation of the potential to improve drying storage in Senegalese agriculture.

Stand-alone LED sensors for future field monitoring of grape (Vitis vinifera L.) ripeness

Tugnolo A. *[1], Giovenzana V. [1], Cusmai A. [1], Guidetti R. [1], Beghi R. [1], and i-GRAPE Consortium[1,2,3,4,5,6]

1. Department of Agricultural and Environmental Sciences – Production, Landscape, Agroenergy (DiSAA), Università degli Studi di Milano, via Celoria 2, 20133, Milano, Italy

The i-GRAPE Consortium is integrated by the above-mentioned entity and:

2. INL, International Iberian Nanotechnology Laboratory, Av. Mestre José Veiga s/n, 4715-330 Braga, Portugal

3. Sogrape Vinhos S.A., Rua 5 de outubro, 4527, Avintes, 4430-852, Portugal

4. INESC MN - Instituto de Engenharia de Sistemas e Computadores – Microsistemas e Na-notecnologias, Lisbon, Portugal

5. Albert-Ludwigs-Universität Freiburg, Freiburg, Germany

6. AUTOMATION SRL, Milan, Italy

*Corresponding Author e-mail: alessio.tugnolo@unimi.it

Abstract

In the wine industry, grape ripening control is a complex process that is critical to the production of high quality wines, but currently ripening control is cumbersome and inefficient. This inefficient control of maturation is associated with reduced wine value. This work aims to develop a fully integrated stand-alone optical device for grape quality monitoring directly in the field. Therefore, during the 2019 sampling campaign, a first prototype version of a fully integrated optical device was developed by INL following a "stripe" design, where the spectrometric components were mounted on a long flexible substrate that can be placed on or inside the grape bunch. The multiple spectrometers were placed along the stripe, allowing simultaneous measurements at different parts of the bunch to provide more representative information of the entire bunch. Four optical bands associated with the evolution of grape ripening parameters, such as anthocyanin and sugar development, chlorophyll degradation and water content reduction, were integrated. Four light-emitting diodes (LEDs) in the Vis and SW-NIR range were used to illuminate the grapes. Close to these, but optically isolated by an opaque barrier, four photodiodes (with an active area of

520 × 520 µm^2) equipped with spectral filters to allow intensity measurements at the desired wavelengths were used. Four PLS models were developed to predict the total soluble solids and the potential alcohol (R^2 around 0.90 and RMSEP of 2.22 and 1.54 respectively). A very promising model was also obtained for the prediction of titratable acidity (R^2 of 0.93 and RMSEP of 1.39), while a pH prediction model (using 4 LVs) was developed, showing a lower performance than the previous parameters (R^2 of 0.76 and RMSEP of 0.15), but still with potential for use with further improvements.

Keywords

IoT, information technology, sensors, optical stand-alone devices, grape maturation monitoring.

Avoidable Food Waste in the Distribution Sector: Quantification and Valorisation

Cusmai A.* Narote A., Tugnolo A., Beghi R., Guidetti R., Giovenzana V.

Department of Agricultural and Environmental Sciences – Production, Landscape, Agroenergy (DiSAA), Università degli Studi di Milano, via Celoria 2, 20133, Milano, Italy

*Corresponding Author e-mail: arianna.cusmai@unimi.it

Abstract

Background and aim: Recent studies showed that a third of the produced food, globally, is lost or wasted. This is negative in terms of environmental, economic and social impact. The aim of this work is to investigate food waste in the distribution sector, in order to quantify it and explore how it can be valorised according to the Waste Hierarchy Pyramid.

Materials and Methods: To achieve this, three systematic bibliographic researches are conducted: one focuses on food waste in the GDO, another one on food waste in food service and the last one explores methodologies for the valorisation of food waste. Moreover, related to the valorisation aspect, a case study has been produced, analysing a new service that use donation of surplus food from GDO as a strategy to valorise it. The surplus food is collected, stocked in the hub and redistributed to the indigents.

Results: The state-of-the-art analysis reveals that the few articles quantifying food waste in Italian large-scale retail, are not always comparable, due to varying waste recording methodologies. Therefore, it was not possible to obtain an average value to estimate food waste in Italian supermarkets. However, it was possible to identify the food categories most prone to waste.
Regarding food waste in food service, a study on hospital cafeterias was analysed comparing two different meal preparation methods, the results show that one method produce less waste. Furthermore, studies on school cafeterias were examined, and the food waste data resulted comparable. Finally, restaurants were considered, and it resulted that consumers' food waste is greater than that generated in the kitchen.
The last research consists in the analysis of possible strategies to give a new life to food waste, valorising it according to the waste hierarchy pyramid, the solutions were evaluated considering their environmental impact, quantifies through LCA studies. Among the potential opportunities, donation emerged as an option,

though not always with the lowest environmental impact, but the articles do not consider the social aspect, while the case study conducted does it. Using SimaPro the environmental impact of the service was calculated, considering carbon credits and debits, and donation resulted the most advantageous choice. A social prospect has been made, and it resulted that thanks to this service, meals for 134 people were provided daily. Finally, the nutritional profile of the donated food was also analysed, and it was found that only the protein content is coherent with the LARN guidelines recommendations.

Conclusions: In conclusion, it would be advisable to create a clear and universal waste monitoring and recording methodology to allow data comparison. It would also be important to educate children about food waste and its consequences, to create more sensitive and informed consumers.
The case study was found to be environmentally beneficial, but it could be more ecological by optimizing transportation phase of the service. Additionally, it was observed that the nutritional profile is not aligned with the LARN values. To address this, a network, based on macronutrients, could be created between the different hubs, to obtain a balanced meal for the needy.

Keywords

Distribution Sector, Donation, Food Waste, LCA, Quantification, Valorisation

References

Boschini M., Falasconi L., Giordano C., Alboni F., (2018). Food waste in school canteens: A reference methodology for large-scale studies. Journal of Cleaner Production, 1024-1032.

Cicatiello C., Franco S., Pancino B., Blasi E., Falasconi L., (2017). The dark side of retail food waste: Evidences from in-store data. Resources, Conservation and Recycling, 273-281.

Teigiserova D.A., Hamelin L., Thomsen M., (2020). Towards transparent valorization of food surplus, waste and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy. Science of The Total Environment, 136033.

A Digital Platform for Precision Olive Grove Protection

Santo Orlando*, Pietro Catania, Mariangela Vallone, Carlo Greco
Department of Agricultural, Food and Forest Sciences (SAAF), University of Palermo, Viale delle Scienze, Bldg. 4, 90128 Palermo, Italy
*Corresponding Author e-mail: santo.orlando@unipa.it

Abstract

The project "DIGITAL Platform for Precision Olive Tree Defense" (acronym DIGILOVE) aims to introduce digital technologies for olive tree protection to optimize the use of raw materials, obtaining a reduction in the use of agrochemicals. These goals will be pursued by creating a prototype machine for crop protection using sustainable precision agriculture techniques. The project aims to develop, test and analyze advanced remote and proximal sensing techniques in order to create thematic prescription maps for the application of crop protection techniques with targeted distribution based on the pest and disease observed in the olive grove. The aim of the project is, therefore, the use of new technologies for precision spraying that will allow for limited intervention, releasing chemicals only on the target. The project is developed on two Sicilian olive cultivars: Cerasuola and Nocellara del Belice. Meteorological data on temperature, relative humidity, rainfall, solar radiation, wind direction and speed are collected from a fixed weather station. Microclimatic data are gathered using iButton sensors. Remote sensing survey operations employ multispectral sensors mounted on drones. The project involves the creation of a prototype sprayer equipped with GPS, GNSS and RTK sensors for geolocalisation, an ISOBUS system for connection to a tractor with automatic guidance, an electrical system for electrostatic volume distribution, ultrasonic sensors and proportional solenoid valves for variable-dose volume distribution, sensors for the detection of the environmental parameters, multispectral and hyperspectral sensors for the detection of vegetation indices and a hardware-software interface for processing data on the canopy. The construction of crop protection prescription maps for pest and disease control will be carried out through the application of machine learning and deep learning algorithms to determine spatial and temporal variability of the plants and the parameters linked to the diffusion and phenological intensity of the target adversities within the olive grove.

Keywords

Drones; Precision Olivicolture; Sprayer; Vegetation Indices.

References

Roma, E., Catania, P., Vallone, M., Orlando, S. (2023). Unmanned aerial vehicle and proximal sensing of vegetation indices in olive tree (Olea europaea) Journal of Agricultural Engineering, 2023, 54(3), 1536.

Roma, E., Laudicina, V.A., Vallone, M., Catania, P. (2023). Application of Precision Agriculture for the Sustainable Management of Fertilization in Olive Groves Agronomy, 2023, 13(2), 324.

Catania, P., Roma, E., Orlando, S., Vallone, M. (2023). Evaluation of Multispectral Data Acquired from UAV Platform in Olive Orchard Horticulturae, 2023, 9(2), 133.

Sensor Application in Vineyard to Improve Grape Quality

Pietro Catania*, Maria Alleri, Carlo Greco, Santo Orlando, Mariangela Vallone
Department of Agricultural, Food and Forest Sciences (SAAF), University of Palermo, Viale delle Scienze, Bldg. 4, 90128 Palermo, Italy
*Corresponding Author e-mail: pietro.catania@unipa.it

Abstract

Background and aim:

The use of sensors for the production of high-quality grapes has become increasingly important in precision agriculture. This study focuses on the application of various sensor technologies to monitor and improve grapevine vigor and, consequently, grape quality. The aim is to assess the effectiveness of microclimatic data, meteorological data, and drone-based monitoring for optimizing grape production.

Materials and Methods:

The study was conducted at Rapitalà (Palermo, Italy) agricultural farm, where meteorological data on temperature, relative humidity, rainfall, solar radiation, wind direction and speed were collected from a fixed weather station from June to August, 2024. Microclimatic data were gathered using iButton sensors. The vigor of the vineyard was monitored through drone flights using a DJI Mavic 3 multispectral drone equipped with a multispectral camera. Vegetative vigor maps were generated using the Normalized Difference Vegetation Index (NDVI), which provided detailed insights into the vineyard's health and growth.

Results:

The integration of meteorological data, microclimatic monitoring, and drone-based NDVI mapping allowed for precise tracking of vine vigor throughout the growing season. The results showed a clear relationship between environmental conditions and the vegetative health of the vineyard, with specific areas of the vineyard exhibiting higher or lower levels of vigor based on climatic influences.

Conclusions:

The combination of meteorological and microclimatic data, along with drone-based NDVI mapping, proved to be an effective method for monitoring and improving grapevine vigor. This approach can be used to optimize vineyard management practices, leading to the production of higher-quality grapes. The study demonstrates the potential of precision agriculture tools in enhancing grape production and the quality of the final product.

Keywords

Precision Viticulture; UAV; NDVI; Vigour Map; Vitis vinifera L.

References

Ferro, M.V., Catania, P. (2023). Technologies and innovative methods for precision viticulture: a comprehensive review. Horticulturae 9 (3), 399.

Ferro, M.V., Catania, P., Miccichè, D., Pisciotta, A., Vallone, M., Orlando, S. (2023). Assessment of vineyard vigour and yield spatio-temporal variability based on UAV high resolution multispectral images. Biosystems Eng. 231, 36–56. https://doi.org/ 10.1016/j.biosystemseng.2023.06.001.

Non-destructive texture prediction of persimmon texture using hyperspectral imaging

Salvador Castillo-Gironés[1]*, Marina Lopez Chulia[1], Sergio Cubero[1], Sandra Munera[2], Alejandro Rodríguez[2], Juan Gómez-Sanchís[3], Alejandra Salvador[4], Nariane Vilhena[4], Ana Moreno[4], José Blasco[1]

[1] Centro de Agroingeniería, Instituto Valenciano de Investigaciones Agrarias (IVIA), CV-315, km 10,7, 46113 Moncada Valencia (Spain)
[2] Departamento de Ingeniería Gráfica. Universitat Politècnica de València. Camino de Vera, s/n, 46022, Valencia (Spain)
[3] IDAL, Departamento de Ingeniería Electrónica, Universidad de Valencia, Av. de la Universidad , S/N, 46100Burjassot, Valencia (Spain)
[4] Centro de tecnologia post-recoleccion, Instituto Valenciano de Investigaciones Agrarias (IVIA), CV-315, km 10,7, 46113 Moncada Valencia (Spain)
*Corresponding Author e-mail: castillo_salgirb@gva.es

Abstract

Changes in the texture of persimmon fruit flesh during storage can affect consumer perception and acceptance, especially if the flesh becomes rubbery or excessively soft. To explore this issue, this study utilized hyperspectral imaging to predict pulp firmness in a non-destructive manner. A total of 3,340 'Rojo Brillante' persimmons were stored at temperatures of 0 ºC, 1°C and 5°C for up to three months. Hyperspectral imaging was conducted on 500 fruits at harvest, 250 one month later stored at 0°C, 250 at 1°C, and 250 stored at 5°C. The same measurements were taken at months 2 and 3 of storage. From the images, the average spectra of each persimmon were extracted, and spectra were randomly split into a 70% training set and a 30% external validation set. Once images were acquired, the texture analyser measured the force required to break the flesh, measuring the force required to break the flesh. With the mean spectra dataset and the texture data, three predictive models were built using three machine learning methods: Partial Least Squares Discriminant Analysis (PLS-DA), a Support Vector Machine (SVM), and an Extra Trees Regressor, which is based on Decision Trees.

All models achieved prediction R^2 at the validation set higher than 090 in predicting the flesh-breaking force. Differences between models were minimal, with SVM obtaining an R^2 of 0.91 and MAE of 0.35, Extra Trees Regressor an R^2 of 0.37 and MAE of 0.37, and PLS with also an R^2 of 0.90 and MAE of 0.40. Thus, hyperspectral imaging is an effective tool to measure in a non-destructive way the texture of persimmon fruit, which can be very useful for storage houses.

Keywords

Hyperspectral imaging; Persimmon; Texture

How Smart Viticulture Technologies Can Enhance Sustainability and Reduce Environmental Impacts

Francesco Giacopelli[1], Filippo Vigo[1], Lorenzo Rossi[2], Jacopo Bacenetti[1]*
[1] Via Celoria 2, 20133 Milan, Italy
[2] Fondazione Edmund Mach, Via E. Mach 1, 38098 San Michele all'Adige (TN), Italy
*Corresponding Author e-mail: jacopo.bacenetti@unimi.it

Abstract

Background and aim:

Precision Viticulture (PV) is a dynamic management strategy integrating information and technology to optimize vineyard operations through data-driven decision-making.

Despite the increasing adoption of PV, the understanding of its environmental benefits remains limited.

This study presents the outcomes of two projects - Winery Farming 4.0 "*Farming Data Implementation: definition of smart solutions for the effective implementation of Agriculture 4.0 in winery production*" and smartDEFENSE "*Tecnologie digitali innovative per aumentare l'efficienza e la sostenibilità dei sistemi di difesa in vigneto*", both the projecs focus on the implementation of smart solutions to improve vineyard sustainability. In detail, using the LCA approach, the environmental benefit related to the adoption of a smart technology designed to optimize fungicide use in viticulture were evaluated. This tecnology, called PocketSPRAY®, is a smart application for smartphones and can support the farmers with regard about timing and application dose of funcides.

Five farms located in Lombardy - three managed conventionally and two under organic farming - were evaluated and, in each farm, two different scenarios were compared: (i) a baseline scenario, representing conventional management and (ii) smart scenario, where PocketSPRAY® was used to optimize fungicide applications.

Materials and Methods:

1 hectare of vineyard was used as a functional unit and a gate-to-gate perspective was considered concerning system boundary. Consequently, only the phytosanitary protection phase was included, considering diesel, fungicide and machinery (tractor and sprayer) as inputs and the emissions of fungicide active ingredients as well as the emissions related to fuel combustion.

Primary data were collected by means of field trials on vineyards, while secondary data on pesticide emissions were estimated according to PEFCR (2020), background data were retrieved from Ecoinvent v.3.9. The Environmental Footprint (EF 3.1 v.1.03) characterization method was used.

Results:

The adoption of PocketSpray® leds to an average reduction of 10% in fungicide use. This reduction involves lower environmental impacts, particularly in toxicity-related impact categories. Smaller benefits were observed for other environmental impact categories. For climate change, an average reduction of 1.14% was observed when comparing the Smart scenario to the Baseline scenario across all vineyards. The reductions ranged from a minimum of 5.51 kg CO_2 eq./ha to a maximum of 23.83 kg CO_2 eq./ha.

Conclusions:

The adoption of the tested smart app to support fungicide application allows interesting environmental benefits, strictly related to the reduction of pesticide use. Further implementation and scale-up of this kind of technologies could contribute to broader sustainability improvements in viticulture, making crop protection more efficient and environmentally friendly.

Keywords

Environmental sustainability, Pesticide, Precision agriculture, Vineyard.

References

A. Fusi, R. Guidetti, and G. Benedetto, “Delving into the environmental aspect of a Sardinian white wine: From partial to total life cycle assessment,” Science of the Total Environment, vol. 472, 2014, doi: 10.1016/j.scitotenv.2013.11.148.

G. Maesano, M. Milani, E. Nicolosi, M. D’amico, and G. Chinnici, “A Network Analysis for Environmental Assessment in Wine Supply Chain,” Agronomy, vol. 12, no. 1, 2022, doi: 10.3390/agronomy12010211.

N. Peña, A. Antón, A. Kamilaris, and P. Fantke, “Modeling ecotoxicity impacts in vineyard production: Addressing spatial differentiation for copper fungicides,” Science of the Total Environment, vol. 616–617, pp. 796–804, 2018, doi: 10.1016/j.scitotenv.2017.10.243.

Controlling Malaxation Atmosphere in Olive Oil Processing Plant

Mariangela Vallone*, Maria Alleri, Santo Orlando, Pietro Catania
University of Palermo, Department of Agricultural, Food and Forest Sciences, Viale delle Scienze, Ed. 4, 90128 Palermo, Italy.
*Corresponding Author e-mail: mariangela.vallone@unipa.it

Abstract

Aroma is a crucial attribute for the overall perception of extra virgini olive oil (EVOO) and it is greatly influenced by the malaxation condition. Today, there is a need for relevant studies to establish the optimal processing parameters in order to enhance EVOO quality, both from the nutraceutical and the sensory point of view. The research aimed at implementing a new digital malaxer to perform malaxation in a controlled environment. The system was designed by the Mechanics Section of The Department of Agricultural, Food and Forest Sciences of the University of Palermo. The main objective was to real time monitor and control the oxygen inside the malaxer headspace during the malaxation phase, even with the possibility to regulate time and temperature of this processing step that is crucial for EVOO quality. The concentration of gases (O2 and N2) inside the malaxation machine was performed. Olives of the cultivar Biancolilla Centinara were processed in October 2024 to perform the experimental tests.

Malaxation was first performed in in unmodified atmosphere to have a control test. Then, two differente tests were carried out: T1 and T2 where the malaxation chamber was first made inert by filling N2 before the olive paste entry, and then O2 was introduced respectively once at 20 min and twice i.e. at 10 and 20 min. Malaxation lasted 40 min in total. Chemical analyses were carried out on the obtained EVOOs to evaluate their main quality parameters including volatile composition. Overall, an optimized approach to control the main process parameters for obtaining high-quality EVOOs was successfully obtained.

Keywords

Malaxation, phenolic compounds, real time, technology, volatile compounds.

References

Altieri, G.; Genovese, F.; Matera, A.; Di Renzo, G.C. A comparison among innovative plants for high quality extra-virgin olive oil production. J. Sci. Food Agric. 2020, 100, 5283–5291. https://doi.org/10.1002/jsfa.10579.

Trapani, S.; Breschi, C.; Cecchi, L.; Guerrini, L.; Mulinacci, N.; Parenti, A.; Canuti, V.; Picchi, M.; Caruso, G.; Gucci, R.; et al. Indirect indices of oxidative damage to phenolic compounds for the implementation of olive paste malaxation optimization charts. J. Food Eng. 2017, 207, 24–34. https://doi.org/10.1016/j.jfoodeng.2017.03.012.

Prediction of Acidity and Soluble Solid Content Changes In Loquat Fruit During Cold Storage through Non-Destructive Spectral Methods

M. Lopez-Chulia[1], S. Castillo-Girones[1], A. Salvador[2], P. Talens[3], J. Blasco[1*]

[1]Agricultural Engineering Centre, Instituto Valenciano de Investigaciones Agrarias (IVIA), Valencia, Spain;
[2]Postharvest Technology Centre, Instituto Valenciano de Investigaciones Agrarias (IVIA), Valencia, Spain;
[3]Instituto Universitario de Ingeniería de Alimentos - FoodUPV, Universitat Politècnica de València (UPV), Valencia, Spain.

*blasco_josiva@gva.es

Abstract

Background and Aim: Monitoring physicochemical changes in fruits during cold storage without causing damage remains a key challenge in postharvest technology. Loquat fruits are particularly vulnerable to mechanical injury, making non-destructive spectral sensors a valuable tool for improving such assessments (Ding et al., 1998; Zhou et al., 2009). This research explores the feasibility of near-infrared spectroscopy (NIRS) (Walsh et al., 2020) for tracking physicochemical variations in loquats during cold storage.

Materials and Methods: A total of 540 loquats from two cultivars (Algerie and Xirlero) were harvested at their commercial maturity stage. Upon arrival at the laboratory, 120 fruits (60 per cultivar) were immediately analysed to determine their initial characteristics. The remaining fruits were split into two storage conditions: 1°C and 3°C. Over four weeks, 60 fruits were sampled weekly, with 30 analysed immediately and another 30 stored for five days at 20°C to simulate commercial conditions. Non-destructive NIR reflectance spectra were collected for each fruit using a multi-channel spectrometer equipped with three detectors spanning the visible to near-infrared range (450–1700 nm). Destructive analyses followed to measure soluble solid content (SSC) and titratable acidity (TA), serving as reference parameters. To establish correlations between NIR spectra and the reference values, predictive models were developed using partial least squares (PLS) regression. Spectral pre-processing techniques included multiple scatter correction, standard normal variate, and first derivative transformations.

Results: Storing Algerie loquats at 1°C minimized acidity loss compared to 3°C under both cold storage and commercialization conditions. In contrast, for Xirlero, no significant differences were observed during cold storage; however, after five days at 20°C, acidity loss was more pronounced in fruits previously stored at 3°C. Initial predictive models achieved R^2 values ranging from 0.65 to 0.70 for SSC and TA estimations across both cultivars.

Conclusions: The findings point out the significance of monitoring physicochemical changes in loquats under different storage conditions, including post-refrigeration commercialization. This study underscores the potential of NIRS for non-destructive postharvest quality evaluation, presenting it as a viable alternative to conventional destructive techniques.

Keywords

Chemometrics, Near-infrared (NIR) spectroscopy, Postharvest, Storage temperatures

References

Ding, C. K., Chachin, K., Hamauzu, Y., Ueda, Y., & Imahori, Y. (1998). Effects of storage temperatures on physiology and quality of loquat fruit. *Postharvest Biology and Technology*, *14*(3), 309–315. https://doi.org/10.1016/S0925-5214(98)00053-2

Walsh, K. B., Blasco, J., Zude-Sasse, M., & Sun, X. (2020). Visible-NIR 'point' spectroscopy in postharvest fruit and vegetable assessment: The science behind three decades of commercial use. In *Postharvest Biology and Technology* (Vol. 168, p. 111246). Elsevier. https://doi.org/10.1016/j.postharvbio.2020.111246

Zhou, Y., Ying, Y., Xie, L., Niu, X., & Yan, Z. (2009). Determination of soluble solid content and acidity of loquats based on FT-NIR spectroscopy. *J Zhejiang Univ Sci B*, *10*(2), 120–125. https://doi.org/10.1631/jzus.B0820097

Extending the Marketing Period of Persimmon by a Little Reduction in Storage Temperature. The Role of Antioxidant Enzyme Modulation

Ana Moreno[1], Alejandra Salvador[1], Empar Llorca[2], Amparo Quiles[2], Fany Carrasco[3], Nariane Q. Vilhena[1, *]

[1]Centro de Tecnología Postcosecha, Instituto Valenciano de Investigaciones Agrarias, 46113, Moncada, Valencia, España.

[2]FoodUPV. Universitat Politècnica de València. Camino de Vera. s/n. 46022, Valencia, España.

[3]Centro de Agroingeniería, Instituto Valenciano de Investigaciones Agrarias, 46113, Moncada, Valencia, España.

*quaresma_narvil@gva.es

Abstract

Background and aim: Persimmon cv. 'Rojo Brillante' is sensitive to low temperatures, with the main symptom of chilling injury (CI) being pulp softening when the fruit is transferred from cold temperature to shelf-life conditions. Currently, fruit intended for storage is postharvest treated with 1-Methylcyclopropene (1-MCP), as this treatment reduce CI symptoms by maintaining fruit firmness during cold storage and subsequent shelf-life. The storage temperature usually employed is 1 °C, although recent studies suggest that storage at 0 °C could extend the storage period. A key factor in the development of chilling injury is oxidative stress, which occurs when there is an imbalance between the production of reactive oxygen species and the fruit's antioxidant mechanisms. The objective of this study was to evaluate the effect of reducing storage temperature to 0ºC on flesh firmness maintenance as well as to examinate the changes in the activity of antioxidant enzymes associated with the reduction of chilling injury.

Materials and Methods: 'Rojo Brillante' persimmon fruit were stored at 0 °C or 1 °C with or without 1-MCP treatment. After 60 and 90 days of cold storage, and after the subsequent shelf-life period of 5-days at 20 °C, flesh firmness and the activity of catalase (CAT), peroxidase (POD), and ascorbate peroxidase (APX) were determined. The activity of cell wall degrading enzymes (Polygalacturonase (PG) and Pectinmethylesterase (PME)) was also assessed.

Results: Throughout cold storage, fruit at 0 °C maintained significantly higher firmness than fruit at 1 °C. The temperature effect was more pronounced after the shelf-life periods. As expected, the 1-MCP treatment

reduced the flesh softening at both temperatures tested. Nevertheless, while the 1-MCP-treated fruit stored at 0 °C maintained very high firmness values after 90 days of cold storage plus shelf-life, at 1 °C the fruit presented non-commercial values. The firmness maintenance in fruit stored at 0 °C with 1-MCP was linked to an increase in the activity of CAT and APX enzymes and a reduction in POD enzyme activity. Moreover, the changes in flesh structure were related to the activity of cell wall degrading enzymes. Fruit stored at 0 °C exhibited lower PG and PME activities than at 1 °C.

Conclusions: The combination of 1-MCP treatment and the storage at 0 °C improve the persimmon storage potential by modulating the activities of cell wall-degrading and antioxidant enzymes.

Keywords

Cold conservation, firmness, Rojo Brillante, shelf life.

References

Novillo, P., Salvador, A., Navarro, P., & Besada, C. (2015). Involvement of the redox system in chilling injury and its alleviation by 1-methylcyclopropene in 'Rojo Brillante' persimmon. *HortScience, 50*(4), 570-576.

Salvador, A., Arnal, L., Monterde, A., & Cuquerella, J. (2004). Reduction of chilling injury symptoms in persimmon fruit cv. 'Rojo Brillante' by 1-MCP. *Postharvest Biology and Technology, 33*(3), 285-291.

Vilhena, N. Q., Quiles, A., Gil, R., Llorca, E., Fernández-Serrano, P., Vendrell, M., & Salvador, A. (2022). Slight changes in fruit firmness at harvest determine the storage potential of the 'Rojo Brillante' persimmon treated with gibberellic acid. *Horticulturae*, *8*(2), 140.

Acknowledgements

This research was funded by the European Union through the European Regional Development Fund (FEDER) through Projects ERDF 2021-2027, PID2021-127975OR and CIPROM/2021/014. Ana Moreno thanks the Spanish Ministry of Science and Innovation for Grant FPI-INIA (PRE2022-102487).

Characterization of avocados cv. Lamb-Hass from the Mediterranean area in Spain and the relationship among quality attributes.

Paloma Quintanilla[1,2,*], Nariane Q. Vilhena[1], Jose Blasco[2], Rebeca Gil[1], Alejandra Salvador[1]
[1]Centro de Tecnología Postcosecha, Instituto Valenciano de Investigaciones Agrarias (IVIA), 46113, València, Spain
[2]Centro de Agroingeniería, IVIA, 46113, València, Spain

*Corresponding Author e-mail: quintanilla_pal@gva.es

Abstract

Background and aim: In recent years, avocado production and consumption have doubled. Although it is a tropical crop, avocado has successfully adapted to the Mediterranean climate. In countries like Spain, its cultivation, offers a strategic advantage by shortening the supply chain to the European market, compared to inter-oceanic transport. This not only reduces the carbon footprint but also provides an alternative crop for local farmers. Now, the market prefers hard-skinned varieties, such as 'Hass' and 'Lamb Hass'. 'Lamb Hass' is a late-harvest variety with increasing production allowing for a continuous supply to European markets during the summer after the 'Hass' season. Therefore, this study aimed to evaluate the evolution of the key physicochemical parameters of avocados cv. Lamb Hass at harvest and during the subsequent ripening trought the season. Also, it seeks to identify potential correlations among parameters assessed.

Materials and Methods: Three avocado harvests were conducted in Castellón, Spain, between March and May. Quality parameters (non-destructive and destructive) were assesed after harvest. Avocados were stored at 20ºC-90% RH, with quality analyses performed every two days until they reached commercial ripeness (flesh firmness ≤ 20N). The analyses included: dry matter (through Near-infrared spectroscopy (Felix, F-750) and oven methods), external color, flesh firmness (non-destructive and destructive methods).

Results: Dry matter content, used as an indicator for harvest time, was consistently high across all three harvests. However, fruit from the first harvest had lower coloration compared to later ones. The time required to reach commercial firmness varied depending on the harvest date. More than 50% of the fruit achieved commercial firmness levels (≤ 20N) after 14, 8, and 6 days at 20°C for the March, April, and May harvests, respectively. Moreover, significant correlations among firmness and external color parameters was found during maturation.

Conclusions: The `Lamb Hass' variety opens the possibility of extending the Spanish avocado for a longer period in the European market. These results can help to direct efforts towards the determination of new non-destructive methods to determine the ripening stage of avocados during maturation period.

Keywords

Avocado, fruit quality, Lamb Hass, postharvest.

This research was funded by the European Union through the European Regional Development Fund (FEDER) and Project IVIA-GVA-52201 and CIPROM/2021/014.

Microbiomes, Edible Packaging, and Biocontrol Application in Fresh-Cut Fruit and Vegetables: a General Perspective

M.L.V. de Chiara[1*], M. Cefola[1], V. Capozzi[1]
[1]National Research Council of Italy - Institute of Sciences of Food Production (CNR-ISPA) c/o CS-DAT, Via Michele Protano, 71121 Foggia, Italy
*Corresponding author e-mail: marialuciavaleria.dechiara@cnr.it

Abstract

Background and Aim: Packaging solutions are critical in limiting microbial growth, a key factor in preserving fresh produce. Traditional approaches such as modified atmosphere packaging and antimicrobial coatings aim to inhibit spoilage microbes, thereby extending shelf life, ensuring food safety and quality, and reducing waste. However, recent innovations suggest that microorganisms can be integrated into packaging solutions, offering novel approaches and improving sustainability in the food industry. Lactic Acid Bacteria (LAB) and microbiomes incorporated into packaging materials show potential biocontrol activity, spoilage reduction, and support eco-friendly food systems. This review explores the integration of microbiomes in food packaging, with a focus on edible packaging containing LAB and solutions enhancing microbial biocontrol activities. Additionally, it evaluates the strengths and limitations of microbiome-based packaging compared to conventional approaches within the framework of ongoing projects "INTelligent, ACTive MicroBIOmebased, biodegradable PACKaging for Mediterranean food (INTACTBioPack)" funded by the PRIMA Programme Section 2 2023 multi-topic and the project "ON Foods-Research and innovation network on food and nutrition Sustainability, Safety and Security–Working ON Foods (OnFoods) (Project code PE00000003), NextGeneration EU [PNRR], in the framework of the Mission 4 Component 2 Investment 1.3. Furthermore, hurdle technology and integrated solutions with physical postharvest strategies are discussed, highlighting their impact on fresh-cut produce (de Chiara et al. 2024).

Materials and Methods: This study systematically reviews current literature, focusing on microbiome-integrated packaging solutions and biocontrol applications in postharvest management. Data from recent scientific publications and findings from the INTACTBioPack and OnFoods projects are analyzed to assess the efficacy and potential of emerging technologies. Specific emphasis is placed on the combination of physical treatments, edible packaging solutions, and biocontrol applications. The review compares the performance of innovative packaging with conventional methods, considering safety, quality, and sustainability in fresh-cut fruit and vegetable manufacturing.

Results: The analysis reveals that integrating microbiomes into packaging materials presents a promising strategy for sustainable food preservation. Edible packaging containing LAB demonstrates the potential for extending shelf life while reducing reliance on synthetic substances. When combined with mild physical treatments, biocontrol applications enhance the effectiveness of microbial interventions, improving food safety and quality. The hurdle technology approach, which strategically combines different preservation methods, shows significant potential for improving the quality and safety of minimally processed products, allowing for reduced intensity of individual treatments while preserving product freshness. Unlike conventional solutions, microbiomes provide a dynamic strategy, exploiting biodiversity to enhance food preservation. Overall, this study underscores the transformative potential of microbiome-integrated packaging and biocontrol strategies in the postharvest sector. However, challenges such as regulatory constraints, microbial stability, and large-scale implementation must be addressed.

Conclusions: Future research should focus on optimizing the compatibility of microbiomes with packaging materials, ensuring controlled microbial activity, and evaluating consumer acceptance. By advancing these innovative approaches, the food industry can move towards more sustainable, effective, and eco-friendly solutions for fresh-cut produce preservation.

Keywords

Biocontrol Activity, Fruit and Vegetables, Lactic Acid Bacteria, Microbiome, Minimally Processed Products, Packaging Solutions.

References

de Chiara, M.L.V., Castagnini, J.M., & Capozzi, V. (2024). Cutting-edge physical techniques in postharvest for fruits and vegetables: Unveiling their power, inclusion in 'hurdle' approach, and latest applications. Trends in Food Science & Technology, 151, 104619.

MIGRATION OF VOLATILE COMPOUNDS FROM PACKAGING FOR FRESH VEGETABLES

Sandra Pati*, Jahan Zaib Ashraf, Flora Macolino, Danial Fatchurrahman, Maria Luisa Amodio, Giancarlo Colelli

Dip.to di Scienze Agrarie, Alimenti, Risorse Naturali, Ingegneria (DAFNE), Università di Foggia, Via Napoli 25, 71122 Foggia (Italy)

*Corresponding Author e-mail: sandra.pati@unifg.it

Abstract

This study intended to investigate the migration pattern of non-intentionally added volatile compounds from various plastic packaging materials commonly used for fresh vegetables. Initially, an extensive screening of volatile compounds was conducted by solid phase micro-extraction followed by gas-chromatography coupled to mass spectrometry analysis from various packaging materials including polypropylene (PP), polyethylene terephthalate (PET), polypropylene/polyamide (PP/PA), polyethylene-terephthalate/polyethylene (PET/PE), PP/PET, polypropylene/ethylene-vinyl-alcohol (PP/EVOH) and PET/PE/EVOH. The investigation revealed significant variations in both number and structural composition of emitted volatile compounds, which were found to be dependent on the material composition and producer. The predominant compounds identified were polyolefin oligomeric saturated hydrocarbons (POSH).

Subsequently, the emission of certain volatiles from the bilayer PET/PE was examined at 5 °C, 15°C and 35°C. The emission of hexanal and dodecane remained constant throughout time, indicating rapid release kinetics; conversely, the release of 2,2,4,6,6-pentamethylheptane, increased over time until attaining a steady state. The potential for volatiles to transfer from the packaging to the packaged fresh vegetables was assessed by preserving some vegetables in the studied packaging. The findings of this study encourage the development of advanced packaging solutions which minimize the emission of volatile compounds while ensuring optimal protection for fresh produce.

Effect of Packaging Materials and Micro-perforation on the VOCs equilibrium of Packaged Broccoli raab (*Brassica rapa L.*)

Aysha Saleem[1], Pramod V. Mahajan[2], Maria Luisa Amodio[1], Sandra Pati*, Giancarlo Colelli[1]

Dip.to di Scienze Agrarie, Alimenti, Risorse Naturali, Ingegneria (DAFNE), Università di Foggia, Via Napoli 25, 71122 Foggia (Italy)

*Corresponding Author e-mail: sandra.pati@unifg.it

Abstract

This work aimed to find the effect of packaging materials polyethylene terephthalate (PET), polylactic acid (PLA) and number of micro-perforations (0, 2, 20) on VOC's composition in packaged vegetable broccoli raab (Brassica rapa L.). Fresh 'Di Gennaio' broccoli raab florets were cut, packaged and stored at 5°C for 17 days. The packaged samples were assessed for various quality parameters, including weight loss, color, headspace O_2, CO_2, VOCs, sensory attributes, and respiration rate at 0, 8, 9, 11, 14, 15 and 17 days. In order to assess the influence of packaging material on volatile equilibrium, headspace gas was collected from inside the packages (with and without product) and from outside the packages by keeping them in closed glass jars. Results showed that PLA0 maintained gas compositions close to recommended levels, reaching about 2 kPa O_2 and 9 kPa of CO_2. In contrast, in PET0 exhibited complete O_2 depletion after 8 days, leading to CO_2 accumulation. Not only perforation levels but also the type of packaging material itself had a significant impact on maintaining gasses inside the packages, primarily due to differences in permeability properties. After 17 days of storage, weight loss of broccoli raab packaged in PLA was 5-6 %, similar to PET with high perforation. VOC analysis identified 37 volatile compounds belonging to fourteen chemical groups, with eight primary volatiles common in both PET0 and PLA0 packets; while PET showed 6 additional compounds. A total of 23 secondary VOCs formed during shelf-life storage showing significant concentration differences between packaging materials. Furthermore, 13 new compounds were detected in the glass jar environment, apart from 28 compounds found in both inside package and glass jar environment. By day 9, dimethyl disulfide was found in higher concentration in PET20 compared to PLA20, indicating faster degradation and high permeability properties as compared to PET20. While PLA0 maintained quality throughout the study, off-odor score on

day 18 limited the shelf-life to 14 days. The study highlights the crucial role of barrier properties and micro-perforation in maintaining volatile equilibrium within packaging. PLA0 and PET2 are recommended for further research on VOC dynamics in broccoli raav packaging. This analysis not only served to understand the volatile comparison but also played a crucial role in evaluating the safety aspects of the packaging materials.

Keywords: Cime di rapa, Postharvest factors, Micro perforation, Volatile Profile, quality characteristics

Hyperspectral analysis to predict the maturity index of fresh strawberries.

Maria Cefola[1]*, Michela Palumbo[1], Ilde Ricci[1], Antonia Corvino[1] , Bernardo Pace[1], Roberto Romaniello [2]

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

[2]Department of Agriculture, Food and Natural Resources and Engineering, University of Foggia, Via Napoli, 25, 71122 Foggia, Italy.

*Corresponding Author e-mail: maria.cefola@ispa.cnr.it

Abstract

Background and aim.

Strawberries (*Fragaria × ananassa Duch*.) are worldwide popular fruits, highly appreciated for their colour, delicious taste, pleasant flavour and for their richness in nutrients, including flavonoids, anthocyanins, vitamin C and ellagic acid Yan et al., 2018; Weng et al.; 2020). In recent years, time-/cost-effective, non-destructive, contactless, user-friendly, and green non-targeted methods have been increasingly introduced to perform fingerprinting studies aimed at monitoring the degree of ripening and the quality traits of fruit on an objective basis (Palumbo et al., 2022). The practical advantages of these methods consist of minimizing potential losses for growers and packers, as well as fast decay for the end consumer. The quality parameters or the index of ripening assessed by non-destructive methods can also be designed to predict the optimal harvest time (Li et L., 2018). The aim of this study is to develop a statistical model to identify the ripening stages of strawberries using as predictors near infrared spectral data.

Materials and Methods

Candonga strawberries (*Fragaria × ananassa Duch.*) var. Sabrosa, were provided by a cooperative company of fresh fruit (APOFRUIT Italia Soc. Coop., Scanzano Jonico, Italy) at three different consecutive harvest times (indicated as H1, H2 and H3, respectively), and at two maturity stages, indicated as half-red (in ripening phase, fully expanded and 50% red) and red (in ripening phase, fully expanded and 100% red). Fruits (in ten replicates) were analysed for the maturity index (total soluble solid, titratable acidity) and vitamin C content,

while colour parameters were assessed using a computer vision system equipped with Matlab to manage the data analysis. Moreover, the FT-NIR (Fourier Transform near infrared) spectroscopy were used as no-destructive tool to predict the maturity index.

Results.

The spectra obtained were used to build partial least square regression (PLSR) models of the strawberry's maturity index, suing the Unscrambler software. The best performances were obtained, using data in the 700-850 nm range, building a PLSR model predictive of soluble solids having an R^2 of 0.9 in the calibration phase and 0.8 in validation. In detail, the spectral acquisitions in the 700-850 range allow a clear separation of the maturation levels in all the harvests considered.

Conclusions.

In conclusion, the use of hyperspectral analysis could be a valid non-destructive method for estimating the level of ripeness of strawberries to optimize harvesting.

Keywords. cv. Sabrosa, *Fragaria × ananassa Duch*, maturity index, partial least square regression, Fourier Transform near infrared.

Reference

Li, B.; Lecourt, J.; Bishop, G. Advances in non-destructive early assessment of fruit ripeness towards defining optimal time of harvest and yield prediction—A review. Plants **2018**, 7, 3.

Palumbo, M.; Cozzolino, R.; Laurino, C.; Malorni, L.; Picariello, G.; Siano, F.; Stocchero, M.; Cefola, M.; Corvino, A.; Romaniello, R.; et al. Rapid and Non-Destructive Techniques for the Discrimination of Ripening Stages in Candonga Strawberries. Foods 2022, 11, 1534

Weng, S.; Yu, S.; Guo, B.; Tang, P.; Liang, D. Non-destructive detection of strawberry quality using multi-features of hyperspectral imaging and multivariate methods. Sensors **2020**, 20, 3074.

Yan, J.W.; Ban, Z.J.; Lu, H.Y.; Li, D.; Poverenov, E.; Luo, Z.S.; Li, L. The aroma volatile repertoire in strawberry fruit: A review. J.Sci. Food Agric. **2018**, 98, 4395–4402.

Effects of the storage at different temperatures on postharvest quality of Citrus medica L. (cv. Liscia-diamante)

Laura Quintieri[1]*, Ilde Ricci[2], Francesco Siano[3], Michela Palumbo[2], Bernardo Pace[1], William Schirinzi[1], Angelo Adduci[4], Anna Luparelli[1], Rosaria Cozzolino[3], Leonardo Caputo[1], Maria Cefola[2]

[1]Institute of Sciences of Food Production, National Research Council (CNR), Via G. Amendola, 122/O, 70126 Bari, Italy;
[2]Institute of Sciences of Food Production, National Research Council (CNR), c/o CS-DAT, Via M. Protano, 71121 Foggia, Italy
[3]Institute of Food Science, National Research Council (CNR), Via Roma 64, 83100 Avellino, Italy
[4]Consorzio del Cedro di Calabria, Corso del Tirreno, 353 - 87020 S. Maria del Cedro (CS)

*Corresponding Author e-mail: laura.quintieri@ispa.cnr.it

Abstract

Background and aim: *Citrus medica* L. (cv. Liscia-diamante), which recently received the European PDO (protected designation of origin) certification (Reg. Ue 2023/971, 10/05/2023), is among the most popular citron varieties (Continella, 2023). It is exclusively produced on a short stretch along the coast of 70 high Tyrrhenian sea, known as “Riviera dei Cedri” (Calabria, southern Italy). This fruit is generally harvested immature to exploit its special fragrance in confectionery and cosmetic industries; mature citrons are usually used in the production of jams and beverages (Gabriele et al., 2009, Gullo, 2012). Currently, the main problem faced by farmers is to preserve fresh citrons as long as possible, avoiding any loss of their organoleptic and textural characteristics. Although several postharvest technologies and storage temperatures (4-14 °C) have been extensively applied to citrus species, no information regarding the effect of storage temperature on citron fruit has been reported up to now. Thus, in order to establish the optimal storage conditions to preserve post harvest quality, citron fruits were stored at different temperatures for 2 weecks.

Materials and Methods: Whole fruits were stored at 5, 10, 20 °C in open boxes for two weeks; then, the main postharvest quality traits (visual quality, color attributes, respiration rate) at 7 and 14 days were evaluated. Changes in volatile profile in essential oils (EOs) were also investigated by GC-FID.

Results. Results showed that the lowest temperature (5 °C) applied to citrons during storage preserved the green color of their peel; by contrast, higher temperatures (10 and 20 °C) seem to promote degreening, probably due to a putative production of low amount of endogen ethylene; likewise, the fruits preserved at

20 °C showed the highest value of respiration rate. Overall, data on the respiration rate confirmed the no climacteric nature of citron fruits, in line with the other Citrus species (El-Otmani et al., 2011).

The most abundant volatile compounds retrieved in EOs collected from peels of fruits were monoterpene hydrocarbons (ranging from 87.1 to 96.3 %.), regardless of the treatment applied; the oxygenated metabolites were about 9.7-3.1 % of wich monoterpene aldehydes and monoterpene alcohols were 1.7-7.8 % and 0.4-1.5 %, respectively. Two-way Anova experiment performed on the GC-FID semi-quantitative data showed that significant differences were found among the EOs from fresh fruit compared to EOs from samples stored at different temperatures (5, 10 and 20 °C) at 7 and 14 d.

Conclusions. This is a preliminary study to establish the optimal storage conditions of citron fruit to extend its shelf postharvest storage life, before its use for food and cosmeceutcal purposes.

Keywords

Citrus medica L. cv. Liscia-diamante; storage conditions; respiration rate; GC-FID; low temperatures; postharvest quality.

References

Continella, A. (2023). The Citron in Italy and Its Cultivation in Calabria. In The Citron 451 Compendium: The Citron (Etrog) Citrus medica L.: Science and Tradition (pp. 265-286). 452 Cham: Springer International Publishing.

Gabriele, B., Fazio, A., Dugo, P., Costa, R., & Mondello, L. (2009). Essential oil composition of Citrus medica L. cv. Diamante (Diamante citron) determined after using different extraction methods. Journal of Separation Science. 32, 99–108.

Gullo, G. (2012). Ricerca: Cedro. In: Gli agrumi: botanica, storia e arte, alimentazione, paesaggio, coltivazione, ricerca, utilizzazione, mondo e mercato. Tribulato E., Inglese P. Eds. - Collana Coltura & Cultura - Angelini R. Bayer CropScience E. Script, Bologna, pp. 386-395.

El-Otmani, M., Ait-Oubahou, A., & Zacarías, L. (2011). Citrus spp.: Orange, mandarin, tangerine, clementine, grapefruit, pomelo, lemon and lime. In Postharvest biology and technology of tropical and subtropical fruits (pp. 437-516e). Woodhead Publishing.

Innovative semantic segmentation approach for non-destructive contactless quality evaluation of packaged and unpackaged fresh-cut apples by a Computer Vision System

Michela Palumbo[1]*, Maria Cefola[1], Bernardo Pace[1], Giancarlo Colelli[2], Giovanni Attolico[3]
[1]Institute of Sciences of Food Production, National Research Council of Italy (ISPA-CNR), c/o CS-DAT, Via M. Protano, 71121 Foggia, Italy
[2]Department of Agriculture, Food and Natural Resources and Engineering, University of Foggia, Via Napoli, 25, 71122 Foggia, Italy.
[3]Institute of Intelligent Industrial Systems and Technologies for Advanced Manufacturing, National Research Council of Italy (STIIMA-CNR),Via G. Amendola, 122/O, 70126, Bari, Italy

*michela.palumbo@ispa.cnr.it

Abstract

Background and aim:

Apples represent an important part of healthy diets and have a large commercial share. They are often marketed as ready-to-eat pieces inside proper packaging. The non-destructive and contactless assessment of their quality, in terms of both visual appearance and internal characteristics, is an open issue especially on fresh-cut packaged products (Cavallo et al. 2018). Computer vision systems (CVSs) represent a powerful tool to provide fast, objective, non-destructive and contactless evaluation of fruit and they have proved to be effective even through the packaging under proper design of the processing component (Palumbo et al. 2023).

Marketing and consumers' acceptance of fresh-cut apples strongly correlate to the browning of the pulp. The robust application of CVS to evaluate quality and internal properties of apples requires the identification and selection of regions corresponding to pulp inside the images to minimizes the interferences of other parts of the fruit on the performance of classification or regression modules (Vadukkal, Palumbo and Attolico, 2023).

Materials and Methods:

A methodology based on a convolutional neural network model (CNN) has been successfully developed to properly solve this semantic segmentation problem. Training deep learning models normally requires a large number of annotated samples that are hardly available in this context. An approach to reduce the number of manually segmented images has been developed and verified. The segmentation approach was applied to four varieties of packaged and unpackaged fresh-cut apples. Two different kind of packaging have been used: a common polypropylene (PP) bag and a compostable and biodegradable polylactic acid (PLA) film. The cultivars adopted in the experiment exhibit different colors that make more challenging the segmentation

tasks: Granny Smith apples have greenish peel; Golden apples have yellowish peel while Fuji and Pink Lady apples have reddish peel.

Results:

A first version of the segmentation network, trained on manually labeled data, has been used to annotate further images, properly evaluating and exploiting the results to extend the training set that, in the new version, has been able to significantly improve the performance of the segmenting network performed by the previous CNN approach. Moreover, the approach has been able to generalize from one kind of package to the other. The approach copes with a serious problem of deep learning models that require the costly and slow creation of very large set of annotated data. Moreover, it addresses a problem that is relevant to select the most significant part of images of products but that lacks sound and effective solutions.

Conclusions:

The segmentation approach is part of predictive models based on color features extracted from segmented images: they have been developed to assess the quality level of fresh-cut apples during the cold storage in order to forecast the shelf life of the product even through the package. The relevance of the segmentation on the complete analysis made by the CVS has been evaluated.

As future approach, the new segmentation module will be applied to develop predictive models able to forecast the shelf life of fresh-cut apples even through further types of packaging material.

Keywords

Non-destructive quality assessment, computer vision system, fresh-cut apples, segmentation approach, shelf life prediction

References

Cavallo, D. P., Cefola, M., Pace, B., Logrieco, A. F., & Attolico, G. (2018). Non-destructive automatic quality evaluation of fresh-cut iceberg lettuce through packaging material. Journal of Food Engineering, 223, 46-52.

Palumbo, M., Cefola, M., Pace, B., Attolico, G., & Colelli, G. (2023). Computer vision system based on conventional imaging for non-destructively evaluating quality attributes in fresh and packaged fruit and vegetables. Postharvest Biology and Technology, 200, 112332.

Vadukkal, U. K. V., Palumbo, M., & Attolico, G. (2023). Semantic Segmentation of Packaged and Unpackaged Fresh-Cut Apples Using Deep Learning. Applied Sciences, 13(12), 6969.

Remote Sensing For Fruit Tree Monitoring: Angular Effect Correction In Orange Orchards

César José Guerrero Benavent[1*], Belen Franch[1,2], Javier Tarín-Mestre[1], Fatima Della[1], Italo Moletto-Lobos[1], Andreu Guillem[1], Katarzyna Cyran[1], Victor Betti[1], Eric Vermote[3], Sebastien Saunier[4]

[1] Global Change Unit, Image Processing Laboratory (UCG-IPL). Parque Cientifico, Universitat de Valencia, Spain
[2] Department of Geographical Sciences, University of Maryland, College Park MD 20742, United States;
[3] NASA Goddard Space Flight Center Code 619, 8800 Greenbelt Road, Greenbelt, MD 20771, USA;
[4] Telespazio France, Satellite System and Operation, 26 Avenue JF Champollion, BP 52309, CEDEX 1, 31023 Toulouse, France

*cesar.guerrero@uv.es

Abstract

Background and aim:

The orange tree is one of the most popular and widespread crops globally. In Spain, orange production and exportation play a crucial role in the agri-food sector.

Remote sensing is a valuable tool for monitoring and optimizing the management of these crops, improving agronomic decision-making. However, orange trees are typically arranged in separated rows, which directly affects data collection through remote sensors. Since orange trees are evergreens, the publicly available remote sensing systems, which have a minimum resolution of 10 meters, are significantly influenced by annual variations in light conditions, particularly due to shadow projections. This phenomenon impacts the measured signal, with higher reflectance values recorded during summer (low solar angles) and lower values in winter (high solar angles).

These angular effects can be corrected using the Bidirectional Reflectance Distribution Functions (BRDF), whose coefficients are surface-specific. However, its aplication in citrus agriculture remains unexplored in the existing literature.

Materials and Methods:

The HABA algorithm (High Resolution Adjusted BRDF Algorithm), proposed by Franch et al. (2019), is currently used to correct angular effects in the European Space Agency (ESA) Sen2like product. The application of this algorithm in previous studies on orange trees have shown that BRDF effects significantly impact woody crops,

and HABA only partially corrects them (Della et al., 2024), highlighting the need for a more detailed characterization.

This study presents the main findings from an angular measurements campaign funded by the AGROALNEXT COFRUT-MONITOR, with the goal of characterizing BRDF parameters in an orange orchard located at an experimental farm in Polinyà del Xúquer (Valencia, Spain) during July 2024.

A hyperspectral spectroradiometer (ASD) was used to collect five types of data:

1. Crane-based angular measurements (field-scale BRDF characterization):
    - Varying observation angles at different times of the day (to capture different sun-view angles).
    - Fixed observation angle (0°) with repeated measurements at different times.
2. Goniometer-based angular measurements (tree-scale BRDF characterization):
    - Varying observation angles at different times of the day.
3. Multispectral drone measurements using the MAIA sensor (same VNIR bands as Sentinel-2):
    - Circular flight pattern to capture multi-angular data.
4. LIDAR drone measurements:
    - Assessing orange tree roughness and structure before and after pruning.

Additionally, routine Sentinel-2 multispectral satellite acquisitions and EnMAP hyperspectral satellite acquisitions (requested from the German Aerospace Center - DLR) complemented the in-situ data collection.

Results:

The angular sampling at different scales allowed for the derivation of different BRDF coefficients. These coefficients were used to normalize EnMAP observations to a common geometry, evaluating their effectiveness compared to the HABA correction algorithm.

Conclusions:

The direct comparison of different satellite observations highlighted the importance of applying BRDF correction. Normalization based on each set of BRDF coefficients confirmed the effectiveness of hyperspectral coefficient inversion through multispectral coefficient interpolation. Among the evaluated methods, the BRDF correction derived from crane-based measurements proved to be the most efficient, providing a basis for improving the HABA correction algorithm.

Keywords

BRDF, hyperspectral, multispectral, orange, remote sensing

References

Franch, B., Vermote, E., Skakun, S., Roger, J. C., Masek, J., Ju, J., ... & Santamaria-Artigas, A. (2019). A method for Landsat and Sentinel 2 (HLS) BRDF normalization. Remote Sensing, 11(6), 632.

Della Bellver, F., Franch, B., Moletto-Lobos, I., Guerrero Benavent, C. J., San Bautista Primo, A., Rubio, C., Vermote, E., & Saunier, S. (2024). Pest Detection in Citrus Orchards Using Sentinel-2: A Case Study on Mealybug (Delottococcus aberiae) in Eastern Spain. Remote Sensing, 16(23), 4362. https://doi.org/10.3390/rs16234362

Monitoring Mealybug Progression in Valencian Citrus Trees Using Remote Sensing: Insights from the Co-Fruit AGROALNEXT Project

Fàtima Della Bellver [1,*], Belen Franch Gras [1,2], Italo Moletto-Lobos [1], César José Guerrero Benavent [1], Alberto San Bautista Primo [3], Constanza Rubio [4]

1: Global Change Unit, Parc Científic, Universitat de València (Paterna), 46980 Paterna, Spain.
2: Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA
3: Departamento de Producción Vegetal, Universitat Politécnica de València (Valencia), 46022 Valencia, Spain
4: Centro de Tecnologías Físicas, Universitat Politécnica de València (Valencia), 46022 Paterna, Spain
*Corresponding Author e-mail: fatima.della@uv.es

Abstract

Background and aim:

The Cotonet de les Valls is a mealybug insect which is increasing its presence on citrus orchards in Castellón, Spain, causing serious economic losses in agricultural sector. The study aim is to understand how surface reflectance behave according to the mealybug pest presence, to do it, remote sensing data is used.

Materials and Methods:

The images are retrieved by employing the Sen2Like (version 4.3.0) processor, with the atmospheric correction of Sen2Corr (version 3.1.0). The Bidirectional Refectance Distribution Function (BRDF) (Nicodemus et al., 1977) is employed to minimize the shadows effects and also to reduce the detected seasonality in the spectral responses, because the disordered morphology of the crop trees induce some angular effects that can cause an overestimatimation or underestimation of the real reflectance.

This study examines roughly 60 fields situated near the municipality of Vall d'Uixó in Castellón, Spain. In these fields, a monthly survey was conducted to record the cotonet population during the 2020, 2021, and 2022 seasons. The investigation aims to understand the correlation between the level of cotonet infestation and several optical bands—particularly the RED, NIR, and SWIR bands—along with the Normalized Difference Vegetation Index (NDVI).

Results:

Due to residual seasonal effects, monthly linear regressions were employed to focus on trend analysis. This approach initially revealed a subtle distinction between healthy and affected groups, with the SWIR channel notably capable of differentiating between them starting in July. Additionally, anomalies were assessed, from which a more robust separability criterion can be derived. The most promising results were also achieved

using the SWIR channel during the latter half of the year. Furthermore, the results obtained in the year-on-year anomalies study are consistent with the increase in the mealybug population from 2019 onwards.

Conclusions:

The results suggest that remote sensing data can play a crucial role in the e cient and objective management of the mealybug pest. Notably, specific spectral ranges, particularly the SWIR, prove effective in distinguishing between affected and healthy elds throughout the year, with notable differentiation in the latter half. Overall, this study contributes to the development of innovative surveillance tools for combating agricultural threats effectively and sustainably.

Keywords

BRDF; Delottococcus aberiae; NDVI; Pest detection; Sen2Like;

References

Nicodemus, F. E., Richmond, J. C., Hsia, J. J., Ginsberg, I. W., Limperis, T., Harman, S., & Baruch, J. J. (1977). *Geometrical considerations and nomenclature for reflectance*. U.S. Department of Commerce, National Bureau of Standards.

Combined Immersion and Microwave Treatment to Extend the Shelf Life of Different Varieties of Artichokes

Danial Fatchurrahman[a], Noelia Castillejo[a], Ayoub Fathi-Najafabadi[a], Maria Luisa Amodio[a], Giancarlo Colelli[a]
[a]Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente, Università di Foggia, Via Napoli 25, 71122 Foggia, Italy
*Corresponding Author e-mail: danial.fatchurrahman@unifg.it

Abstract

Artichoke (*Cynara scolymus* L.) is considered a healthy food because of its phytochemical and nutritional composition. However, the high polyphenol content makes artichoke difficult to commercialize as fresh-cut product due to high enzymatic browning. The objective of this work was to apply a combined treatment with an antibrowning agent (1.5% lactic acid for 1 hour) and the minimum microwave power (675 J/g) to inactive the polyphenol oxidase (PPO) and extend the shelf life of different green and purple varieties of artichoke stored under modified atmosphere packaging (CO_2 10% and N_2 90%). Of the eight varieties studied, the two green varieties (Madrigal and Green Triump) showed good results in terms of color, firmness and sensory appreciation. Within the purple varieties, Brindisino and Spinoso Sardo showed the best results of firmness, however, Brindisino and Violetto di Manfredonia showed better results of color, also with good sensory scores. The weight losses were less than 1% for all varieties after 28 days at 5ºC. The gas composition in the bags remained at the initial settings but there was a slight increase in O_2 (up to 0.6%) after 13 days at 5ºC. Total phenolic content decreased by 20-50% and antioxidants by 10-58% after MW treatment. In conclusion, treatment with 1.5% lactic acid + microwave was effective to inactive the PPO enzyme in all varieties studied and maintaining the quality of artichoke in a ready-to-eat format.

Keywords

ready-to-eat, antibrowning, polyphenols, PPO

Proximal Hyperspectral Imaging May Support Decisions on Irrigation Strategy on Tomatoes

Danial FATCHURRAHMAN*, Maria MATLOOB, Lucia RUSSO, Maria Luisa AMODIO, Giancarlo COLELLI

[a]Dipartimento di Scienze Agrarie, Alimenti, Risorse Naturali e Ingegneria (DAFNE)
Università di Foggia, Via Napoli 25, 71122 Foggia, Italy

*Corresponding Author Email: danial.fatchurrahman@unifg.it (Danial Fatchurrahman)

Sustainable irrigation benefits the environment by reducing water consumption and contributes to the long-term viability of agriculture by balancing resource utilization and preservation. This study employed a hyperspectral camera to capture high-resolution images (range: 400–1000 nm; bandwidth: ~3.2 nm) to distinguish among tomato fields subjected to three irrigation treatments: (T1) time-based irrigation managed by the farmer, (T2) sensor-based irrigation supplying 100% of the plant's water needs, and (T3) deficit irrigation providing 70% of the plant's water requirements. Approximately 60 fruits were randomly collected from each treatment, and quality parameters, including firmness, total soluble solids (TSS), total acidity (TA), dry mass (DM), total polyphenols, total antioxidant activity, and total carotenoids, were evaluated. Vegetation indices, such as Normalized Difference Vegetation Index (NDVI) and Water Band Index (WB), were assessed. No significant differences were found among treatments for WB; however, T1 showed the highest NDVI value (0.6 ± 0.02), followed by T2 (0.5 ± 0.02) and T3 (0.41 ± 0.02). These trends were further supported by partial least square discriminant analysis (PLS-DA), which successfully classified both plant and fruit images across treatments, achieving cross-validation sensitivity and specificity of 0.89 and 0.90 for plant, and slightly lower values of 0.78 and 0.77 for fruits. While differences were observed in vegetation indices, no significant differences were found among treatments on fruits for firmness, DM, TSS, acidity, or total antioxidant activity. However, differences were observed in other parameters, such as total carotenoids, which were 0.73 ± 0.02 g/kg, 0.80 ± 0.02 g/kg, and 0.82 ± 0.04 g/kg for T1, T2, and T3, respectively. Total polyphenols were 0.09 ± 0.00 GAE g/kg for T1 and T2, and 0.08 ± 0.01 GAE g/kg for T3. These results demonstrate that proximal hyperspectral imaging can support agriculture by providing information on irrigation treatment and fruit quality, promoting the diffusion of sustainable irrigation practices. Sustainable irrigation management can be, in fact, adopted without compromising fruit quality.

Keywords: proximal sensing, irrigation, hyperspectral, quality

Advancements in Hyperspectral Imaging Technology for Enhancing the Detection and Control of Fruit Quality and Safety

Da-Wen Sun
Food Refrigeration and Computerised Food Technology, Agriculture and Food Science Centre, University College Dublin, National University of Ireland, Belfield, Dublin 4, Ireland
Email: dawen.sun@ucd.ie; Websites: http://www.ucd.ir/refrig, http://www.ucd.ie/sun

Hyperspectral imaging technology combines the strengths of mature optical sensing techniques—imaging and spectroscopy. This integration enables the capture of both spatial and spectral information for every pixel in an image, distinguishing it from traditional color imaging systems. This advanced capability has led to extensive exploration and advancement of hyperspectral imaging in various fields. Particularly in the food industry, hyperspectral imaging has gained momentum due to its ability to capture physical attributes like color, size, shape, and texture, as well as intrinsic chemical and molecular properties (e.g., water, fat, protein) of food products. This technology has found successful applications in ensuring fruit quality and safety control.
This presentation aims to provide an introduction to the fundamental principles and theoretical underpinnings of hyperspectral imaging. It then delves into a comprehensive exploration of recent advancements and applications in the realm of fruit quality and safety control, including grading of fruits (banana, lychee, kiwifruit, pear, citrus, strawberry, cucumber), visualization of kiwi sugar distribution, tracking tomato ripening, etc.

Keywords: hyperspectral imaging; fruit quality; food safety; nondestructive detection

References

[1] Da-Wen Sun (editor), Computer Vision Technology in the Food and Beverage Industries, Woodhead Publishing Limited, Cambridge, UK, 528 pp., ISBN 978 0 85709 036 2 (2012).
[2] Da-Wen Sun (editor), Hyperspectral Imaging for Food Quality Analysis and Control, Academic Press / Elsevier, San Diego, California, USA, 528pp., ISBN 978-0123747532 (2010).
[3] Da-Wen Sun (editor), Infrared Spectroscopy for Food Quality Analysis and Control, Academic Press / Elsevier, San Diego, California, USA, 424 pp., ISBN 978-0-12-374136-3 (2009).
[4] Da-Wen Sun (editor), Computer Vision Technology for Food Quality Evaluation, Academic Press / Elsevier, San Diego, California, USA, 583 pp., ISBN 978-0-12-373642-0 (2008).34, 276-285.

The Development of Yolov8 Algorithm for A Real-time Model of Grapes Cutting Point Detection

Maria Matloob*, Claudio Perone, Danial Fatchurrahman, Maria Luisa Amodio, Giancarlo Colelli

[a]Dipartimento di Scienze Agrarie, Alimenti, Risorse Naturali e Ingegneria (DAFNE)

Università di Foggia, Via Napoli 25, 71122 Foggia, Italy

*Corresponding Author Email: maria.matloob@unifg.it (Maria Matloob)

Background and aim:

Agriculture has gone through transformational changes because of the rapid growth of artificial intelligence (AI) technologies. The traditional harvesting methods are time consuming, costly and labour intensive, therefore, the use of innovative technologies is very needful for agriculture system (Barbole et al., 2022). These difficulties could be overcome by the robots equipped with the automatic fruit detection system that can detect and harvest fruit automatically (Lin et al., 2020). It's crucial to develop robust machine vison model for automated robotic harvesting in an unstructured environment of vineyard (Chen et al., 2024). This study aims to design machine learning model of grape detection and optimal picking point determination on peduncle that can be integrated into robotic harvesting system.

Materials and Methods:

The model was developed using RGB images. The RGB images were taken in the field near Foggia, Italy using iPhone 13 mobile camera with the resolution of 3024 × 4032 pixels. The vertical and horizontal resolution were 72 dpi. The camera settings included an exposure time of 1/354 seconds, an f/1.6 aperture and a focal length of 5 mm (equivalent to 26 mm in 35 mm format). The images were taken at different angles and under varying natural lighting conditions to make the model more robust. Then these images were annotated using bounding boxes algorithm. The two classes were labelled in each image i.e. Picking Point and Grapes. The 165 annotated images then divided into training set (70%), validation set (20%) and test set (10%). The YOLOv8 deep learning architecture was used to train the object detection model.

Results:

The performance efficiency of model was evaluated using 100 epochs. The results show the model achieves a maximum of mean Average Precession (mAP) of 90 %. The precession curve steadily improves across training while recall curve remains lower. Overall, the model shows steady learning and convergence.

Conclusion:

This shows that that model is detecting object with good accuracy and can be improved to be adapted to any vision system.

Keywords: picking point detection, precision agriculture, robotic harvesting, YOLOv8

References:

Lin, G., Tang, Y., Zou, X., Cheng, J. and Xiong, J., 2020. Fruit detection in natural environment using partial shape matching and probabilistic Hough transform. Precision Agriculture, 21, pp.160-177.

Chen, J., Ma, A., Huang, L., Li, H., Zhang, H., Huang, Y., & Zhu, T. (2024). Efficient and lightweight grape and picking point synchronous detection model based on key point detection. Computers and Electronics in Agriculture, 217, 108612.

Barbole, D. K., Jadhav, P. M., & Patil, S. B. (2022). A review on fruit detection and segmentation techniques in agricultural field. In Second International Conference on Image Processing and Capsule Networks: ICIPCN 2021 2 (pp. 269-288). Springer International Publishing.

Detection of Pesticide Residues in Table Grapes by mean of Hyperspectral Imaging

Maria MATLOOB*, Danial Fatchurrahman, Claudio Perone, Maria Luisa AMODIO, Giancarlo Colelli

[a]Dipartimento di Scienze Agrarie, Alimenti, Risorse Naturali e Ingegneria (DAFNE)

Università di Foggia, Via Napoli 25, 71122 Foggia, Italy

*Corresponding Author Email: maria.matloob@unifg.it (Maria Matloob)

Background and aim:

The detection of pesticide residue levels is critical for food safety assessment. The damage resulting from pesticide could be avoided with the use of quick and precise measurement of residue levels (Ye et al., 2022). The chemical detection methods relied on sample pretreatment, time-consuming, laborious and costly (Hu et al., 2023). Hyperspectral imaging is one of the advanced technologies used to detect the pesticide residues rapidly and non-destructively (Mohite et al., 2017). This research focuses on the time-series hyperspectral imaging of red grapes to classify pesticide residue levels with the passage of days.

Materials and Methods:

A combined solution of two pesticides, “Flint” (Bayer) and “Switch” (Syngenta) was used in a ratio of 1:5.33 in water; the initial 100% (T1) solution was then diluted into the required low levels of concentration by 80% (T2), 60% (T3), 40% (T4) and 20% (T5). The pesticide solution was sprayed on grapes in the lab and after drying the grapes were stored at 0° C. The hyperspectral images were taken with the hyperspectral line-scan scanner (Version 1.4, DV srl, Padova, Italy) with two sensors, in the visible near-infrared (Vis-NIR) range from 400 to 1000 nm and near-infrared (NIR) from 900 to 1700 nm. The hyperspectral images were taken 24 hours, 8 days, 15 days and 19 days after treatment. For each day 10 grape berries were taken from each treatment so 200 samples were imaged. After that berries were frozen for further chemical analysis of residues. For classification, the data set was divided into five classes according to treatments, 100% (class1), 80% (class2), 60%(class3), 40% (class4) and 20% (class5). The partial least square discriminant analysis (PLSDA) method was used for each sampling.

Results:

The Vis-NIR spectra didn’t discriminate well among classes and showed accuracy for most classes lower than 70%, while the NIR spectra showed better discrimination for most classes. The cross-validation (CV) accuracy for treatments after 24 hours was lower than 70% while for the remaining days the average CV accuracies for T1, T2, T3, T4 and T5, were 98%, 88%, 75%, 70 and 94%, respectively.

Conclusions:

Pesticide analysis is still running but the results show that the pesticide residue could be detected at very low concentrations, even after 19 days from the application, suggesting that prediction may also be achievable.

Keywords: pesticide residue, hyperspectral imaging, grapes quality assessment, non-destructive detection, Vis-NIR and NIR spectroscopy

References:

Ye, W., Yan, T., Zhang, C., Duan, L., Chen, W., Song, H., ... & Gao, P. (2022). Detection of pesticide residue level in grape using hyperspectral imaging with machine learning. Foods, 11(11), 1609.

Mohite, J., Karale, Y., Pappula, S., TP, A. S., Sawant, S. D., & Hingmire, S. (2017). Detection of pesticide (Cyantraniliprole) residue on grapes using hyperspectral sensing. In Sensing for agriculture and food quality and safety IX (Vol. 10217, pp. 192-199). SPIE.

Hu, Y., Ma, B., Wang, H., Zhang, Y., Li, Y., & Yu, G. (2023). Detecting different pesticide residues on Hami melon surface using hyperspectral imaging combined with 1D-CNN and information fusion. Frontiers in Plant Science, 14, 1105601.

Sensors and Modelling Applied To Fresh Fruit Packaging and Storage

Pramod Mahajan*, Akshay Sonawane, Tuany Hoffmann, Yogesh Kalnar
Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Potsdam, Germany
*Corresponding Author e-mail: pmahajan@atb-potsdam.de

Abstract

The optimization of fresh fruit packaging and storage is crucial for maintaining quality, reducing waste, and improving energy efficiency in cold storage facilities. This work presents integration of sensor-based data collection, mathematical simulations, and predictive modelling to optimize airflow, temperature, humidity, and gas exchange in fresh fruit storage systems. To achieve this, various sensor technologies were deployed, including a gas sensor for real-time respiration monitoring, an airflow sensor to measure airspeed between apples in a large storage bulk bins, condensation sensor to track moisture accumulation on apple, and a heat flux sensor to monitor thermal exchange during cooling. These sensors were incorporated into apple storage, where real-time data was collected to assess the influence of temperature fluctuations, air circulation, and metabolic heat from fruits on storage conditions. Additionally, mathematical models were developed to simulate and predict fruit respiration, gas exchange, condensation behavior, mass loss, and ethylene accumulation in fruit packaging, providing valuable insights for optimizing packaging design and cooling protocols. The model helped design equilibrium modified atmosphere packaging by optimizing perforation size and moisture transmission rates to extend fruit freshness. A separate ethylene transmission model was developed to predict ethylene accumulation in fruit packaging, aiding in gas scavenger placement and packaging material selection. Lastly, the miniature micro-controller system was developed for the dynamic control of O_2 and CO_2 in a fresh produce storage box under varying temperature. The integration of sensor technologies with predictive modelling presented a comprehensive approach to fresh fruit storage optimization, providing real-time insights that enable data-driven decision-making. The findings will contribute to the development of next-generation storage systems, reducing postharvest losses while ensuring consistent fruit quality throughout extended storage periods.

Keywords: Respiration, transpiration, fruit quality, cooling, modified atmosphere

Kalnar, Y. B., Jalali, A., Weltzien, C., & Mahajan, P. V. (2024). Mathematical model and electronic system for real-time O_2 control in storage boxes: Development and validation under fluctuating temperatures. Biosystems Engineering, 242, 67-79.

Sonawane, A. D., Chaiwong, S., Weltzien, C., & Mahajan, P. V. (2024). A model integrating fruit physiology, perforation, and scavenger for prediction of ethylene accumulation in fruit package. Postharvest Biology and Technology, 209, 112734.

Hoffmann, T. G., Linke, M., Praeger, U., Sonawane, A. D., Büchele, F., Neuwald, D. A., ... & Mahajan, P. V. (2025). Heat transfer in large bins during the apples cool-down process. International Journal of Refrigeration, 170, 60-69.

The Use of Hyperspectral Imaging to Assess Pulp Redness Level of Blood Oranges (cv. Tarocco Sant'Alfio)

Lucia Russo[1], Danial Fatchurrahman[1], Ayoub Fathi-Najafabadi[1], Fernando Garrido-Auñón[2], Giancarlo Colelli[1], Maria Luisa Amodio[1]*

[1]Dipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente, Università di Foggia, Via Napoli 25, 71122 Foggia, Italy
[2]Department of Food Technology, CIAGRO, University Miguel Hernández, Ctra. Beniel km. 3.2, Orihuela, 03312 Alicante, Spain

*Corresponding Author Email: marialuisa.amodio@unifg.it (Maria Luisa Amodio)

Abstract

The global fruit industry continually faces technological challenges to meet the increasing consumer demand for high-quality produce. For hiqh quality blood oranges it's very critical the insurance of intensity and uniformity of the pulp red color, not discernible from the external surface. Nowadays color can be assessed only cutting the fruit and on a limited number of randomly selected fruit, but non-destructive techniques have proved to be effective in predicting internal quality and composition of fruit and vegetables. This study aimed to investigate the potential of VIS-NIR (400-1000 nm) and NIR (900-1800 nm) hyperspectral imaging combined with Partial Least Squares Discriminant Analysis (PLS-DA) and machine learning algorithms including artificial neural networks (ANN), and k-nearest neighbors (kNN) to classify Tarocco Sant'Alfio oranges into two classes of redness, namely Red and Non-Red. A total of 400 oranges were scanned using a hyperspectral imaging system. Following image acquisition, the fruits were longitudinally cut and RGB image of the internal section was taken to assess redness index. Among the algorithms used, the best performance was achieved by PLS-DA. Fruit classification was obtained using the preprocessing of the first derivative combined with the mean center, for VIS-NIR spectra, resulting in classification accuracies of 80% and 80% for calibration and prediction, respectively. Similar performance was achieved in the NIR region reaching 83 and 77% in calibration and prediction, respectively. These results demonstrate the potential of hyperspectral imaging as an effective, non-destructive method for assessing internal color variations in Tarocco Sant'Alfio oranges which can be implemented on selection line for fruit classification.

Keywords: Hyperspectral images, Oranges, VIS-NIR, PLS-DA, Machine Learning.

Comparison of spectral-optical sensors for whole canopy and fruit analysis in apple production

Manuela Zude-Sasse*
Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Max-Eyth-Allee 100, 14469 Potsdam, Germany
*Corresponding Author e-mail: mzude@atb-potsdam.de

Abstract

The non-destructive analysis in fruit production can be approached at different scales for monitoring of entire orchards using satellite data, at the tree level employing close-range remote sensing technologies (CRRS), and at the fruit level either by segmenting data from CRRS data or fruit sensors. In this study a data set from an experimental apple orchard (*Malus* x *domestica* Bork. Gala-Brookfield / M9), located in Brandenburg, Germany, is presented. Various sensor systems were applied in parallel, capturing satellite data, light detection and ranging, thermal imaging, RGB imaging, RGB-D data, and various stationary sensors measuring directly on the fruit. Data are completed with laboratory data on the leaves and fruit.

Measuring uncertainties will be presented for leaf area and fruit analyses, pointing out the potential and drawbacks when measuring at different scales.

Keywords

Fruit quality, Leaf area index, Non-invasive

References

Chanzy, A., Zude-Sasse, M., Bchir, A., Vercambre, G., Höhne, M., …, Diaz, A. (2025). Low-cost sensors for assessing the plant water needs: A two-year data set capturing fruit crops in three climate conditions under various water management strategies. Data-in-Brief, submitted

Tsoulias, N., Khosravi, A., Herppich, W.B., Zude-Sasse, M. (2024). Fruit water stress index of apple measured by means of temperature annotated 3D point cloud. Plant Phenomics, article 0252, https://spj.science.org/doi/pdf/10.34133/plantphenomics.0252

Zude-Sasse, M., Jörissen, S., Bignardi, M., Regen, C., Tsoulias, N. (2024). Fruit surface temperature data analysed by means of temperature-annotated 3D point clouds of apple fruit trees. Data in Brief 55: 110762. https://doi.org/10.1016/j.dib.2024.110762

Zude-Sasse, M., Bignardi, M., Steffen, L., Höhne, M., Regen, C., (2025). Data set - Seasonal leaf area data of apple trees (3 years) read by satellite, reference LiDAR and lowcost RGB-D sensors. Hugging Face X, under submission

Hemp Seed Press-Cake Flour as a Sustainable Food Ingredient: Chemical Composition, Antioxidant Properties, and Functionality

Concetta Condurso*[1], Maria Merlino[1], Francesca Malvano*[2], Fernanda Galgano[3], Nicola Condelli[3], Rosaria Costa[4], Rossana Rando[4], Anthea Miller[1], Fabrizio Cincotta[1], Antonella Verzera[1] and Donatella Albanese[2]

[1]Department of Veterinary Sciences, Polo Universitario dell'Annunziata, University of Messina, via G. Palatucci, 98168 Messina, Italy.

[2]Department of Industrial Engineering, University of Salerno, Via Ponte Don Melillo, 84084 Fisciano, Italy

[3]Department of Agricultural, Forestry, Food and Environmental Sciences (DAFE), University of Basilicata, Viale Dell'Ateneo Lucano, 10, 85100, Potenza, Italy

[4]Department of Biomedical, Dental, Morphological and Functional Imaging Sciences, Polo Universitario dell'Annunziata, University of Messina, Viale Palatucci, 98168 Messina, Italy.

*Corresponding Author e-mail: francesca.malvano@unisa.it

Abstract

Background and aim:

The industrial hemp production chain is expanding significantly, especially in hemp seed oil production, driven by the increasing use of oil in food, cosmetics, nutraceuticals, and pharmaceuticals, along with growing consumer awareness of its health benefits. This process generates a large volume of waste, primarily in the form of press cake, which can account for up to 85% of the original seed weight. Typically used in animal feed, this by-product could also serve as a human food source, particularly given the rising global population and demand for plant-based foods. In this context, the current study aimed to evaluate the potential of hemp seed press-cake flour (HSCF) as a food ingredient by assessing its chemical composition, techno-functional properties, bioactive compounds, and antioxidant activity.

Materials and Methods:

The HSCF was chemically characterized by analyzing its proximate composition, phytate level, and the profiles of tocopherols, sterols, fatty acids, and polyphenols. Furthermore, pH, colour, particle size distribution and bulk density were studied. To evaluate the flour functionality, the following parameters were assessed: oil absorption capacity (OAC), water holding capacity (WHC), water absorption and solubility indices (WAI, WSI), swelling index (SI), least gelation concentration (LGC), emulsion capacity (EC) and stability (ES), foam capacity (FC) and stability (FS), and protein solubility (PS). Finally, the primary antioxidant activity was measured using the DPPH, FRAP, and ABTS tests.

Results:

The HSCF presented high levels of proteins and fibres and a moderate content of lipids. The predominant fatty acid was linoleic acid followed, in descending order, by oleic, palmitic, and α-linolenic acid. Additionally, the w6/w3 ratio was optimal for healthy human metabolism. The sterol fraction amounted to 1066 mg/Kg of fat, with β-sitosterol and campesterolì being the most abundant. Among the tocopherols, the predominant form is δ-tocopherol, which far exceeds the more commonly found α-tocopherol. The hemp seed press-cake flour showed a pH value of 6.26, a bulk density of 0.603 g/cm3, and a greenish-brown colour. The majority of flour particles ranged from 180 µm to 280 µm in size. Regarding the techno-functional properties, assessed at the flour's natural pH, the HSCF exhibited high values of WHC, OHC and EC but low FC and FS; these properties are linked to the levels and characteristics of proteins, such as surface hydrophobicity and solubility. In addition, due to the low starch content in the flour, low values of SI, WAI and WSI were found and a low ability to gelatinization. The flours also showed good antioxidant activity, with a high concentration of total phenolic compounds. The phenolic profile was primarily composed of N-trans-caffeoyltyramine, cannabisin B, and N-Feruloyltyramine.

Conclusions:

HSCF is a highly valuable nutritional food ingredient that offers elevated levels of protein, fibre, and polyunsaturated fatty acids, along with significant amounts of antioxidant compounds such as polyphenols and tocopherols. For its functionality, HSCF is effective in developing food products that require moisture retention, fat binding, and emulsion stabilization, while not needing gelatinization, such as bakery and confectionery items, sauces and dressings, soups, meat products, and beverages.

Keywords

Antioxidant activity, Hemp seed by-products, Polyphenol profile, Press-cake flour, Technofunctional properties, Tocopherols.

References

Burton, R. A., Andres, M., Cole, M., Cowley, J. M., & Augustin, M. A. (2022). Industrial hemp seed: From the field to value-added food ingredients. Journal of Cannabis Research, 4(1), 45.

Šťastník, O., Mrkvicová, E., & Pavlata, L. (2022). Industrial hemp in animal feed applications. In Industrial Hemp (pp. 341-365). Academic Press.

Application of Biostimulants in Tomato Subjected to Water Deficit: Evaluation of Plant Productivity and Fruit Quality

Maria Merlino*[1], Stefania Toscano[1], Fabrizio Cincotta[1], Martina Buda[1], Marco Torre[1,2], Francesca Calderone[1], Tommaso La Malfa[1], Aurora Maio[1], Anthea Miller[1], Antonella Verzera[1], Fabio Gresta[1], Concetta Condurso[1]

[1]Department of Veterinary Sciences, Polo Universitario dell'Annunziata, University of Messina, via G. Palatucci, 98168 Messina, Italy.

[2]Department of Agricultural, Forestry and Food Sciences—DISAFA, University of Turin, Via Verdi 8, 10124 Torino, Italy

*Corresponding Author e-mail: mmerlino@unime.it

Abstract

Background and aim:

Tomato (*Solanum lycopersicum* L.) is an important horticultural crop widely spread all over the world. However, water stress may adversely affect its growth and productivity, resulting in lower fruit yields. Biostimulants have been recognized as innovative tools for the sustainable development of plant production and for mitigating the drastic effects of climate change which can significantly reduce agricultural yields. These are substances or micro-organisms whose application is beneficial for plant growth and productivity. These natural formulations can be easily applied by foliar application and may be a valuable tool in several vegetables. The present study aimed to compare the effectiveness of different doses of biostimulants on plant productivity and fruit quality in tomato plants subjected to water stress treatments.

Materials and Methods:

The experiment was conducted in an unheated greenhouse located in Milazzo (ME, Italy) on datterino tomato (*Solanum lycopersicum* L.) 'SV1201TC'. Plantlets (with 3 true leaves were transplanted into an open soilless system made up of 5 L cylindrical black plastic pots (20×20 cm), filled with a coconut fibre-based substrate. The study included six treatments resulting from the factorial combination of two water conditions (100% and 50% of field capacity) and three biostimulant application levels (control or two concentrations of biostimulant). The concentrations used were 1.5 g L−1 and 3.0 g L−1 for the first treatment (D1), and 2 g L−1 and 4 g L−1 for the second treatment (D2). At the end of the trial, the agronomic and qualitative parameters of the fruits were evaluated. Fruits were analysed for total soluble solids (TSS), pH, titratable acidity, and sugar content. Additionally, lycopene, total phenolic content, and antioxidant activity were measured using spectrophotometric methods. All analyses were conducted in triplicate, and the data were subjected to two-way ANOVA to determine significant differences based on the biostimulant dose and irrigation treatment.

Results:

The growth inhibition of tomato plants induced by the water stress treatment was evident in significant reductions in both total and above-ground dry biomass. The treatment with the biostimulant improved the growth of tomato plants, particularly those subjected to drought stress. Significant differences in total dry biomass were observed in plants treated with D1 at 100% water capacity (WC) and with both doses at 50% WC. Water deficit significantly reduced the total number of fruits per plant. However, the D2 treatment partially mitigated the effect of water deficit (50%WC), as indicated by the higher number of fruits per plant. Regarding the fruit quality, the data obtained revealed a significant reduction in acidity, an increase in pH value, and higher lycopene content in tomato fruits from plants subjected to water stress. Among the biostimulant applications, only the highest dose reduced fruit titratable acidity and increased total phenolic content under both water treatment conditions.

Conclusions:

The results indicated that the biostimulant application improved the productivity of tomato plants and the quality of the fruits compared to control plants, both under optimal and stressed irrigation conditions.

Keywords

Biostimulant, Lycopene content, Plant yield, Tomato quality, Water stress.

References

Lau, S.E., Teo, W.F.A., Teoh, E.Y., Tan, B.C. (2022). Microbiome engineering and plant biostimulants for sustainable crop improvement and mitigation of biotic and abiotic stresses. Discov. Food, 2 (9). https://doi.org/10.1007/s44187-022-00009-5.

Sanjuán, J., Nápoles, M. C., Pérez-Mendoza, D., Lorite, M. J., & Rodríguez-Navarro, D. N. (2023). Microbials for agriculture: Why do they call them biostimulants when they mean probiotics? Microorganisms, 11(1), 153. https://doi.org/10.3390/microorganisms11010153

Development of Non-Fermented Probiotic Beverages: Evaluation of Probiotic Viability and Assessment of Physicochemical and Sensory Properties During Cold Storage.

Concetta Condurso*[1], Maria Merlino[1], Anthea Miller[1], Mattea M.A. Lauceri[1], Ambra Rita Di Rosa[1], Francesca Accetta[1], Alessandra Giusy Arena[2], Michelangelo Leonardi[2], Nicola Cicero[2], Fabrizio Cincotta[1], Antonella Verzera[1], and Teresa Gervasi[2]

[1]Department of Veterinary Sciences, University of Messina, 98168 Messina, Italy;
[2]Department of Biomedical and Dental Sciences and Morphofunctional Imaging, University of Messina, 98168, Messina, Italy
*Corresponding Author e-mail: ccondurso@unime.it

Abstract

Background and aim:

Foods supplemented with edible probiotics are among the most popular and widely used functional foods. Probiotics are live microorganisms, primarily Lactobacillus and Bifidobacterium species, that can provide health benefits on their hosts. Indeed, they can enhance intestinal health and play a role in addressing various diseases. To achieve the desired beneficial effects, a standardised probiotic food must contain a minimum of 10^6 CFU/g (or CFU/mL) active and live probiotics at the time of consumption. Most probiotic foods available on the market are dairy-based, which limits their consumption among individuals who are lactose intolerant, allergic to milk proteins, or who follow a vegan or strict vegetarian diet. Consequently, the food industry is increasingly interested in non-dairy probiotic alternatives made from fruits, vegetables, cereals, or legumes. In this context, the current study aimed to develop non-fermented probiotic beverages utilizing three different species of lactic acid bacteria and three fruit or mixed fruit and vegetable juices. The study focused on evaluating the survival of probiotics and the maintenance of juice quality during both the primary (PSL) and secondary (SSL) shelf-life.

Materials and Methods:

Three cold pasteurized juices based on 1) avocado, apple and spinach, 2) a mix of tropical fruits, and 3) apple and ginger were selected. Each juice was supplemented with 10^7 CFU/mL of *L. casei* (strain isolated from a commercial drinking yoghurt), *L. reuteri* ATCC 53608, and *L. plantarum* LP09, as a single strain (9 probiotic juices, plus 3 control samples). The juices were packaged in PET bottles under nitrogen and stored at + 4°C over time, i.e. before (PSL) and after the package opening (SSL). The gross chemical composition and total phenol content of the juice samples were determined within 24 hours post-packaging (t=0). Additionally, the probiotic viability, pH, titratable acidity, colour, and volatile aroma compounds were periodically monitored

throughout the PSL, starting from t=0 and up to 2 months. Finally, microbial counts, probiotic viability, physicochemical parameters, volatile profile and sensory consumer tests were assessed daily after package opening and up to 4 days (SSL). Volatile compounds were analyzed by headspace SPME-GC-TQMS technique whereas, for colour measurement, an E-Eye device was used.

Results:

The results demonstrated the viability of all tested probiotic bacteria and the stability of pH and acidity across all samples throughout the entire storage period. Slight colour modifications were observed in both control and probiotic juices during the PSL, with the most significant differences observed in *L. reuteri*-added juices; whereas no significant colour changes occurred during the SSL, except for a slight increase in brightness. Additionally, variations in the volatile profile were observed throughout both PSL and SSL, influenced by the juice type and probiotic strain used. Nevertheless, the sensory evaluation conducted by the consumer panel revealed no significant effects on the odour and flavour of the probiotic juices.

Conclusions:

The selected juices proved to be valuable matrices for delivering the tested probiotic lactic acid bacteria. Additionally, the probiotic juices preserved their quality throughout both PSL and SSL, achieving high consumer acceptability.

Keywords

E-Senses, Primary shelf-life, Probiotic fruit and vegetable juice, Probiotic lactic acid bacteria, Secondary shelf-life, Sensory consumer test.

References

1. WHO; FAO. Probiotics in Food Health and Nutritional Properties and Guidelines for Evaluation; FAO: Rome, Italy; WHO: Geneva, Switzerland, 2006.

2. Naseem, Z., Mir, S. A., Wani, S. M., Rouf, M. A., Bashir, I., & Zehra, A. (2023). Probiotic-fortified fruit juices: Health benefits, challenges, and future perspective. Nutrition, 115, 112154.