Società Chimica Italiana
Divisione di Spettrometria di Massa

Lepore mare
Passione dal 1948

Torre Canne (Brindisi, Italy)

October 16-18, 2024

P56

Integrated approach for the evaluation of food loss and waste of fresh spinach during its storage

Iuliia Khomenko[1], Michele Pedrotti[1], Emanuela Betta[1], Danny Cliceri[2], Isabella Endrizzi[1], Eugenio Aprea[2], Flavia Gasperi[2], Franco Biasioli[1]

[1] Research and Innovation Centre, Fondazione Edmund Mach, via E. Mach 1, San Michele all'Adige (TN, Italy)
[2] Center for Agriculture Food Environment C3A, University of Trento, San Michele All'Adige (TN, Italy)

Summary: *This study investigated "BulkBox" (BB) container performance in preserving spinach quality during transport and storage. Mass spectrometry-based techniques were coupled to other instrumental and sensory methods to evaluate spinach quality in three different experiments. BB better preserved spinach freshness, reducing weight loss and some volatile organic compound emissions over 19 days of refrigerated storage.*

Keywords: *Proton Transfer Reaction Mass Spectrometry, Gas Chromatography Mass Spectrometry, volatile organic compounds*

Introduction

Food loss and waste (FLW) remains an environmental, economic, and social issue with about 131 kilograms of FLW pro capita generated in the EU in 2021 (Eurostat 2023). Following the Agenda 2030 SDGs, the EU aims to halve per capita FLW by 2030. As part of the EU project "SISTERS - Innovative systematic interventions for a sustainable reduction of food waste in Europe" (Horizon 2020, Grant Agreement No. 101037796 [1]), a smart container - the BulkBox (BB) – has been developed to reduce FLW and quality degradation during transportation and storage by exploiting passive modified atmosphere and the implementation of a sensor kit to monitor products' conditions in real time.
In this work spinach (*Spinacia oleracea L.*) which is a widely consumed leafy vegetable was selected as a case study to compare the BB and conventional approaches for bulk transportation. Different quality indicators, including volatile organic compounds (VOCs) were assessed to validate spinach freshness.

Experimental

Baby spinach of cultivars Lagiga and Meerkat was harvested in Andalusia region (Spain) and was transported to Fondazione Edmund Mach (FEM, Trentino, Italy) inside 2 BB and 2 standard bulk pallets (STD) during three different refrigerated shipments. Once the load arrived at FEM, the STD and BB were put at refrigerated temperature (2°C, 90-95% RH) and stored for up to 19 days. Headspace analysis of baby spinach leaves was performed by PTR-ToF-MS in a non-destructive way combined with measurements of CO_2 (LI-COR, USA) and Ethylene (Sensor Sense, The Netherlands) production. In this case 20 g of leaves were sampled and left at room temperature for 3 hours and then put in a 1300 mL jar and incubated at a room temperature for 30 min. VOCs profile of baby spinach was also evaluated in a destructive way by SPME-GC-MS (Agilent, USA) and SHS-PTR-ToF-MS (Ionicon, Austria). To evaluate spinach freshness weight loss, total soluble solids, color, texture and sensory analyses were also performed. Moreover, at the end of the experiment FLW for each treatment was measured.

Results

Despite the substantial inter-shipment variation observed, notable trends in different quality parameters emerged. Figure 1 shows a significant difference for the weight loss of baby spinach between STD and BB storage conditions where the BB had a better effect in preventing dehydration than STD storage conditions.
The production of CO_2 increased during the storage especially for the second and third shipments in agreement with More et al, 2022 [2]. Moreover, the CO_2 emissions were higher for STD samples rather than BB ones. The headspace analysis on the vials for both GC-MS and PTR-ToF-MS, highlighted an evolution of the spinach volatilome during the shelf-life experiments and differences between varieties.
The higher concentration of some mass peaks such as m/z 71.049 ($C_4H_6OH^+$ - tentatively identify (t.i) as butenal) and m/z 83.085 ($C_6H_{11}^+$ - t.i hexenol) were observed for STD samples especially as the shelf life progressed.
The same effect was observed for 2-methyl butanal, 3-methyl butanal and 1-hexanol measured by GC-MS. As showed in Figure 2, also ethanol (m/z 47.049), a well-known marker of fermentation [3] increased during shelf life reaching higher levels in the STD than in the BB. The increasing trend of some biomarkers connected to spinach spoilage such as dimethyl sulfide (Figure 2) and methional was observed for STD samples[2,3].

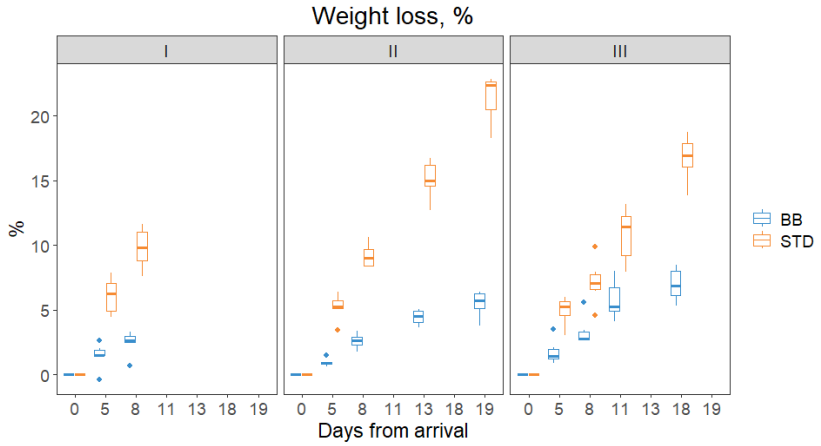

Figure1. *Weight loss of baby spinach during cold storage The plot is separated by three different transportation. The color represents the different storage conditions (BB: BulkBox, STD: Standard)*

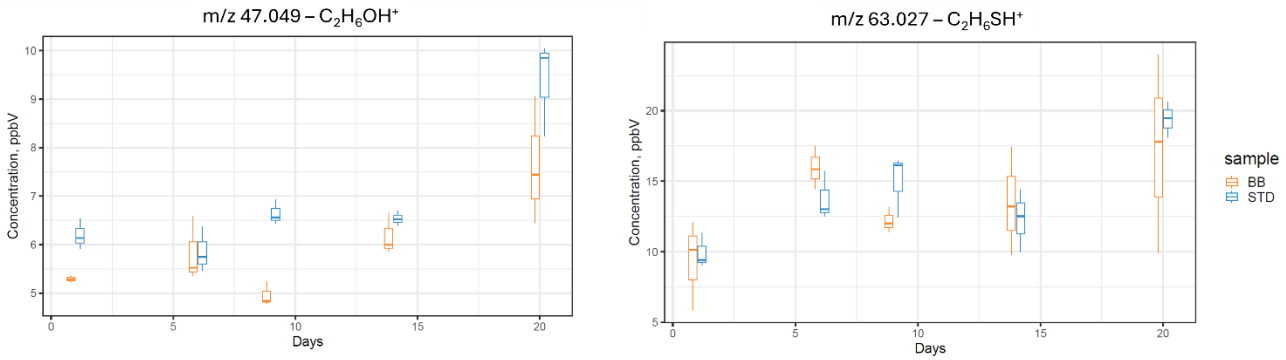

Figure 2. *Boxplot of m/z 47.049 – $C_2H_6OH^+$ (t.i. ethanol) and m/z 63.027 - $C_2H_6SH^+$ (t.i. dimethyl sulfide) during the storage of the second shipment of spinaches in BulkBox (BB) and standard (STD) conditions*

The positive impact of BB in preserving freshness during shelf life was confirmed by the sensory evaluation which highlighted better maintenance of freshness-related descriptors such as turgidity in the container.

Conclusions

The BB developed within the SISTERS project showed promising results for better preserving baby spinach quality during the post-harvest phases of transportation and storage. PTR-ToF-MS was successfully applied to monitor respiration rates and together with GC-MS VOCs emissions during the shelf life of baby spinach. While the correlation between PTR-ToF-MS VOCs profiling and other instrumental and sensory data requires further exploration, these initial findings underscore PTR-MS as a valuable tool for rapid and broad evaluation of the post-harvest quality of vegetables. The technique was also used to validate the BB performance which depends on the physiological characteristics of the fresh products, including respiration rates.

References

1. https://sistersproject.eu/
2. More, AS., Ranadheera, CS., Fang, Z., Zhang, P., Warner, R., Ajlouni, S. Using biological metabolites as biomarkers to predict safety and quality of whole and minimally processed spinach, *Food Chem J.* **375**, 131870 (2022)
3. Tudela JA., Marín A., Garrido Y., Cantwell, M., Medina-Martínez, MS, Gill, MI. Off-odour development in modified atmosphere packaged baby spinach is an unresolved problem, Postharvest Biology and Technology. 75, 75-85 (2013)
4. Dryahina, K., Som, S., Smith, D., Španěl, P. Characterization of spoilage-related volatile organic compounds in packaged leaf salads, *Flavour Fragr J*. **35**, 24–33 (2020)