

Smart bagging will also depend on embedding microclimate-responsive sensing into the bag itself. Sensor-oriented reviews propose bags capable of real-time tracking of temperature, relative humidity, ethylene, and light flux, allowing growers to adjust irrigation, canopy operations, or bag removal timing according to the fruit's actual microenvironment. More general fruit-monitoring literature reaches the same conclusion, noting that smart packaging can continuously monitor temperature, humidity, and gas composition and use wireless communication to improve freshness control and traceability. A second innovation frontier is the automation and customization of bagging operations. Recent reviews point to robotic applicators, autonomous platforms, and machine-vision-guided deployment as ways to reduce the labor bottleneck that currently limits commercial adoption, while customizable bag dimensions and materials are expected to better match cultivar-specific and market-specific requirements. This is particularly relevant because current grape studies already show that bag performance differs by material, shape, color, and closing system, so technical standardization will require adaptable rather than uniform designs.

The next step for grape bagging is to integrate it with precision viticulture, where bagging decisions are guided by sensor data rather than fixed calendars. Precision viticulture relies on reliable climatic and soil information to support site-specific actions, and grape quality is especially sensitive to local variation in temperature, humidity, and radiation at both microclimate and mesoclimate scales. Because bagging directly modifies the cluster microenvironment, its optimization should be linked to these same variables instead of being treated as an isolated practice. Sensor networks also make it possible to connect bagging with water, disease, and harvest management. IoT-focused viticulture surveys show that even relatively simple sensor sets can support disease monitoring, phenological tracking, and vineyard water-regime assessment, while more integrated systems combining humidity, radiation, soil water, and imaging data can assist irrigation management, canopy decisions, stress monitoring, and harvest timing. In practice, this creates a framework in which growers could decide when to bag, ventilate, or remove bags based on dynamic risk and ripening signals.

Non-destructive sensing is especially promising for evaluating whether bagging is improving or impairing quality development. Portable fluorescence sensing has already shown strong utility for tracking grape flavonols, estimating sugar content, and predicting optimal harvest time under different vineyard microclimates and canopy treatments. Smartphone-based thermal imaging and canopy apps also offer low-cost routes for assessing vine water status, canopy architecture, and spatial variability, which could make bagging adjustments more feasible in commercial vineyards without requiring highly specialized equipment. Bagging should therefore be viewed as one component of a broader digital decision-support system. Reviews of smart viticulture emphasize that sensing technologies, AI, and user-friendly software are valuable only when they improve decisions on canopy architecture, pests, water status, yield, and fruit composition, while climate-adaptation work similarly argues for integrated technological systems that help growers respond rapidly to variable weather and quality risks. The most useful future bagging systems will likely combine in-bag sensing, vineyard-scale monitoring, and predictive analytics to manage fruit microclimate from bagging through harvest and storage.

Acknowledgments

I extend my sincere gratitude to the anonymous reviewers for their valuable and insightful comments, which have greatly strengthened this paper.

Conflict of Interest Disclosure

The author affirms that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

- Amorim M.N., Miranda I.B., Santos Í.E.A., Turco S., Caçula B.T.S., Lourençoni D., and Guimarães M., 2020, Plastic film bags on the refrigeration of table grapes, *Revista Brasileira de Ciências Agrárias-Brazilian Journal of Agricultural Sciences*, 15(4): 1-8.
<https://doi.org/10.5039/agraria.v15i4a8415>
- Andreu-Coll L., Noguera-Artiaga L., Sendra E., and Hernández F., 2025, Impact of preharvest bagging on the volatile profile of Vinalopó table grapes, *Agronomy*, 15(5): 1066.
<https://doi.org/10.3390/agronomy15051066>