

Quality improvement under wet conditions also depends on avoiding bag materials that create heat injury or excessive enclosure. Clear plastic bags advanced ripening but caused abnormal overgrowths and sunburn, whereas brown paper bags improved fruit quality and yield while still providing strong physical protection, making breathable paper materials more suitable for humid production environments. This material effect is consistent with Mediterranean table-grape results showing that parchment bags produced larger and better-colored berries and that all tested bags substantially reduced agrochemical residues at harvest (Luca et al., 2023). Commercial rainy-region management also benefits from combining bunch protection with broader protected cultivation. In 'Niagara Rosada', both plastic cover and bunch bagging improved physical and chemical traits across two seasons and delayed maturation, indicating that dual protection can stabilize quality when climate is limiting (Guerios et al., 2021). At larger scale, rain shelter increased grape yield by 110%-176% and farmer income by 80-193% compared with fungicide-based management, suggesting that bagging under rainy conditions is most valuable when integrated with canopy-scale rainfall protection rather than used as an isolated intervention.

7.3 Integrated bagging strategies for premium grape production

Premium grape production uses bagging not only for protection but to coordinate appearance, compositional quality, and food safety. In Sicily, paper, parchment, and non-woven bags applied from BBCH 75 to harvest all reduced agrochemical residues, while parchment bags also produced bigger and better-colored berries, demonstrating how bag choice can align residue reduction with premium visual standards (Luca et al., 2023). The same study showed that bagging can be developed as a protocol added to existing table-grape management in Mediterranean climates rather than as a stand-alone replacement for vineyard practices (Pisciotta et al., 2020). Integrated premium systems also rely on matching bag design to target quality traits such as sweetness, phenolics, and aroma. In Muscat-flavored grapes, transparent polypropylene micro-perforation bags, followed by white polypropylene bags, were the most effective for sweet-sour balance, phenolics, and monoterpene accumulation, whereas pink and blue bags had the strongest negative effects (Wang et al., 2022). In 'Ruidu Kemei', bagging increased total soluble solids and sugar-acid ratio at the over-mature stage but also delayed ripening and altered hundreds of metabolites and thousands of genes, showing that premium-quality gains can come with a developmental trade-off that must be managed operationally (Yuying et al., 2023).

A further premium-production lesson is that bagging should be integrated with timing control rather than maintained continuously until harvest in every market class. In Cabernet Sauvignon, early bagging followed by sunlight re-exposure increased flavan-3-ols and flavonols, whereas bagging after véraison inhibited skin anthocyanins, showing that staged removal can improve secondary-metabolite profiles without sacrificing final color. Similarly, in 'Niagara Rosada', protected plants or bagged bunches outperformed the untreated control for all evaluated traits, but both plastic cover and bagging delayed maturation, which means harvest scheduling is part of quality optimization in commercial premium programs (Guerios et al., 2021).

8 Perspectives and Conclusions

Future grape bagging technologies will likely move beyond passive protection toward smart, sustainable, and crop-specific systems. Recent reviews identify biodegradable and sensor-enabled bags as the main innovation directions, arguing that conventional materials create environmental concerns while next-generation designs can combine fruit protection with lower ecological impact. This transition is also supported by broader packaging research, which highlights growing use of biodegradable, edible, and smart packaging platforms that can preserve fruit quality while reducing waste and environmental burden. Material innovation is especially important because future grape bagging must achieve both field durability and end-of-life sustainability. Reviews of fruit packaging emphasize bio-based films derived from cellulose and starch as practical alternatives to petroleum plastics, while recent film-engineering work shows that recyclable cellulose-containing systems can improve moisture resistance, structural integrity, and fruit freshness retention under humid conditions. For viticulture, this means that future bags should be designed not only for spectral selectivity and ventilation, but also for recyclability or biodegradability after field use.