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Cold plasma slowed grape spoilage but left an off-odor

A study found the in-package treatment cut microbes during cold storage, but lower aroma and flavor scores clouded its commercial promise.

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Researchers have reported that a form of in-package cold plasma may help slow microbial spoilage in table grapes during refrigerated storage, though the treatment also created an off-odor that hurt aroma and flavor scores.

The study, published in Frontiers in Food Science and Technology, tested indirect surface dielectric barrier discharge cold plasma on Crimson Seedless table grapes packed in low-density polyethylene bags under passive modified atmosphere

conditions. The work was carried out by researchers using grapes sourced from a farm in Noicattaro, in the Bari area of southern Italy, and analyzed at the University of Foggia.

The goal was to address a common post-harvest problem. Table grapes are highly vulnerable to weight loss, browning of the stalk and spoilage caused by microorganisms, especially molds. Those issues limit shelf life and marketability even when grapes are stored in modified atmosphere packaging. The researchers examined whether a very short plasma treatment applied after sealing could improve microbial control without damaging fruit quality.

In the experiment, about 200 grams of grape clusters were placed in PET trays and sealed in bags with an internal volume of about 2.5 liters. The packages then received cold plasma treatments lasting 3, 7 or 10 seconds. Untreated grapes served as controls. All samples were stored at 0°C for 18 days and evaluated at day 0, day 3, day 12 and day 18.

According to the paper’s abstract and methods, the plasma system generated ozone inside the sealed package headspace. Initial ozone concentrations rose with treatment time, reaching about 420ppm after 3 seconds, about 811ppm after 7 seconds and as much as roughly 1,050ppm after 10 seconds. The ozone then broke down quickly. The researchers found that concentrations fell to low levels within less than an hour, with estimated exposure times to reach 0.1ppm ranging from about 39.8 minutes for the shortest treatment to about 57.9 minutes for the longest one.

That rapid decay is central to the appeal of the technology. Unlike some conventional sanitizing approaches, in-package cold plasma is designed to act quickly and leave no chemical residue because ozone decomposes into oxygen. It also treats fruit after sealing, which may reduce the risk of recontamination during handling and may sanitize the inner surface of the package at the same time.

The main benefit observed in the study was microbial reduction during early storage. Treated grapes showed significantly lower counts of yeasts and psychrotrophic bacteria than untreated controls through day 12. The paper describes this as evidence that indirect in-package cold plasma can improve microbial control in packaged grapes

under cold storage.

At the same time, the treatment did not appear to change several core quality measures in a major way. The researchers reported that oxygen and carbon dioxide levels inside the packages remained stable across treatments. They also found no significant alteration in the berries' internal quality or metabolism. The study tracked weight loss, berry and stalk color, texture, resistance to detachment, soluble solids, pH and titratable acidity over the storage period.

That balance matters because direct plasma exposure has raised concerns in earlier research on delicate fruit tissues. In this case, the system used an indirect configuration, meaning the fruit was exposed to reactive species diffusing through the package headspace rather than sitting directly in the discharge zone. The authors said this approach may reduce the risk of surface damage compared with more aggressive plasma setups.

But the sensory results were a clear limitation. Despite gains in microbial control, treated samples received lower scores for aroma and flavor because panelists detected a pungent off-odor that persisted during consumption. In practical terms, that means a treatment that improves sanitation may still fail if it changes how consumers perceive the fruit.

The researchers suggested that the sensory problem may be linked not only to ozone itself but also to interactions between plasma and the plastic packaging material. Their conclusion points to a need for further work on how plasma affects packaging properties and whether those changes contribute to unwanted odors or flavors.

The findings are relevant beyond fresh produce retail because table grapes are also part of the supply chain for beverages. If post-harvest technologies can extend grape life and reduce losses while preserving raw material quality, they could eventually matter for wineries and other grape-based beverage producers. This study does not show that outcome directly, and it focused on fresh table grapes rather than wine grapes, but it highlights a possible route for reducing waste before processing if sensory and packaging issues can be solved.

The paper places the work within a broader push for preservation methods that fit demand for cleaner food systems with fewer chemical residues. Ozone has long been valued for its antimicrobial power against bacteria, fungi, viruses and spores, but traditional ozone treatments can require longer exposure times or create safety concerns if not tightly controlled. Generating reactive species inside sealed packaging through cold plasma is being explored as a way to make treatment faster and more compatible with commercial packing lines.

For now, the study presents a mixed result. The technology worked as a fast sanitizing tool and reduced some microbial populations during storage, but it did not overcome one of the most important barriers to adoption: maintaining acceptable sensory quality. That leaves packaging compatibility as a key issue for future research before indirect in-package cold plasma could move closer to commercial use on grapes.