Introduction

Fresh grapes arrive daily on our tables. An habit we usually take for granted and think easy to achieve is indeed the last step of complex harvest and storage procedure, involving more than meets the eye. The major issue that threatens products quality is gray mold, (aka Botrys Cinerea), the most economically important postharvest disease of table grapes. Gray mold can be especially troublesome for its vigorous growth rate and ability to spread among berries even at low temperatures (–0.5°C).

A single infected berry, escaped from removal during packaging, can affect the majority of the product almost simultaneously, but sometimes the infection can originate simply from spores on the berries surface or from latent infections that occurred before harvest, during the growing season. Whatever the reason, control of postharvest decay and prevention of quality losses actually represents one of the most challenging goal for table grapes large-scale retail trade, essentially to achieve to satisfy customer needs.

The control of decay and preservation of the quality of table grapes during storage are complex issues because of the interplay among effectiveness, phytotoxicity, physiological compatibility, acceptability, simplicity of use and cost. The huge amount of research papers published so far, each of them presenting many different solutions, are solid proof of the actual interest in developing an effective method for grey mold control. While practically all researches point to the same “what”, suppression of B. Cinerea growth, what characterizes one method from the other, is “how”.

Table grapes postharvest decay control with CA/MAP/Fumigation
 Controlled Atmosphere

Controlled atmosphere (CA) storage is a well-established technology that is used to preserve the quality of fruit by active manipulation of atmosphere composition in the storage rooms, transport containers or retail food packages. CA are created altering oxygen (O₂) and carbon dioxide (CO₂) relative amount, thus creating a less suitable atmosphere for molds and fungi to grow in.

- **Advantages: Versatility**
  Any desired combination of O₂ and CO₂ can be used to protect the product from physiological or pathological disorders.

- **Disadvantages: Flavor**
  Table grapes taste can be compromised after many days of storage in CO₂ enriched atmospheres.

 Modified Atmosphere Packaging

Modified Atmosphere Packaging (MAP) shares the same growth suppression principle of CA, using altered atmospheres usually rich of CO₂ and poor of O₂ for postharvest decay control. MAP focus on closed packaging, putting food in contact with atmospheres radically different from breathable air, often using hazardous gases as carbon monoxide (CO) as main infection suppressor.

- **Advantages: Versatility**
  A large spectrum of commercial gases can be used as component of the MAP, allowing this technology to produce satisfactory results for a great variety of products.

- **Disadvantages: Sealed packaging**
  The strong point of MAP its also its main weakness. Since the products are completely sealed from outside, accumulation of condensation and respiratory water can occur during storage, which in turn can increase decay caused by B. cinerea. For table grapes MAP represent a viable option only when combined with other method of active protection against decay before or during storage. One of them is the sulfur dioxide fumigation.

Grey Mold Infection

B. Cinerea must have nutrients or some food source to invades the plant. Nutrients leaking from wounded plant parts or from dying tissue such as old flower petals can provide the required nutrients. Once infected, a dark to light brown rot forms in the diseased grape.

MAP applied to grapes

Packaging with modified atmosphere can be successfully applied to table grapes. Packaging atmosphere usually works with high values of CO₂ (around 8%) combined with a low oxygen content (around 5%). This method however grants protection against B. Cinerea for short period of time only.
SO₂ fumigation

Fumigation with sulfur dioxide (SO₂) is probably the most practical, economically viable and efficient method to preserve fruits quality. Grapes are usually fumigated (i.e. put in contact with a modified atmosphere for a certain period of time) with SO₂ immediately before or after packing and are re-fumigated at weekly intervals, monitoring the total amount of sulfur dioxide dosed. It has been demonstrated that the amount of SO₂ gas needed to kill Botrytis spores is dependent on the concentration and the length of time the fungus is exposed to the fumigant. In addition to direct exposure, SO₂ can be locally generated with sulfur dioxide generator sheets. The sheets, which contain sodium metabisulphite, are placed within grape packages. Later, when hydrated by water vapor, they continuously emit a low concentration of SO₂ during storage. Low temperature (-0,5°C) and SO₂ fumigation combined can protect the grapes from decay for months.

- **Advantages: Handling & high effectiveness/cost ratio**
  The ease of handling and the good results obtained with relatively low SO2 concentration make this technique extremely common among table grapes large-scale producers. Many kind of berries show a tolerance towards sulfur dioxide in concentrations that would damage other fruits, vegetables, eggs, meat, or poultry.

- **Disadvantages: SO2 poisoning**
  Sulfur dioxide tends to react with water to produce sulphites, which accumulate inside the grapes. Ingestion fruits with high quantity of sulphates can cause hypersensitive reactions in some people, which lead the United States Environmental Protection Agency to declare SO2 as pesticide when in concentration above 10 ppm. Moreover, even if the fumigation is properly controlled, excessive residues of SO2 can still be found in wounded or detached berries, compromising the taste as well.

O₃ fumigation

Ozone is a natural substance in the atmosphere and one of the most potent sanitizers known against a wide spectrum of micro-organisms at relatively low concentration. Ozone strongly interact with other molecules due to its decomposition
products (radicals) which are highly reactive and tend to crack and/or oxidize other substances and micro-organisms as well. Its reactivity lead ozone to be tested as alternative fumigant for postharvest decay control, and many studies proved O3 capable of good performance in certain kind of fungi and molds suppression.

- **Advantages: Low concentration & No byproducts**
  Ozone is chemically less troublesome than SO2 (there is no accumulation of potentially dangerous byproducts) and the optimal working concentration of O3 is extremely low, with concentration that usually goes from 0,1 up to 500 ppm.

- **Disadvantages: Handling & Selectivity**
  The use of ozone can be less appealing, mostly due to its complicated handling. Ozone is so reactive that cannot practically be store for a long period of time, making necessary to produce O3 in situ, with ozone generators. Moreover O3 shows a high degree of selectivity towards molds and fungi, making it a perfect killers for some species while totally ineffective for others.

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O_3 + SO_2
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Postharvest decay control methods presented so far showed both their strong points as well as their weaknesses. No technology available today is flawless. Nonetheless the solution could be at hand: combining two (or more) of this techniques to enhance the results and lessen the intrinsic downsides. Among all the new experimentation undertaken, the combine used of SO2 and O3 as fumigant looks one of the more promising. Recent studies showed how ozone can effectively team-up with SO2, partially replacing it. When combined with ozone, sulfur dioxide needed to prevent quality losses is reduced (thus lower byproducts that can spoilage fruits). Moreover, SO2 interact with a wider spectrum of micro-organisms, suppressing molds and fungi growth where O3 can not.

**Lab Standard Equipment**

Experimentation involving CA/MAP/fumigants required versatility. Creating proper atmospheres or selecting the desired concentration of fumigant is crucial. Standard
laboratory equipment is frequently an array of mass flow controller, single channeled, connected with an external control unit usually unprovided of any software interface for the gas mixture management. These hardware configurations can be troublesome and may present mixture composition issue (instrument precision tends to lower especially when working with low flow rate). Moreover this kind of configuration doesn’t allow a fast modification of the gas mixture parameters and usually require a lot of lab room.

MCQ Solution

For lab applications requiring versatility, high precision gas mixtures generation and quick and easy mixture management methods, MCQ suggests the Gas Blender 100. This top-notch product is appositely designed for in lab experimentation. Gas Blender 100 allow the user to create multi-component dynamic gas mixtures, extremely precise and ideal to handle microflows with low concentration components, all of them easily manageable with bundled software MCQ Gas Mixer Manager.

GAS Blender 100 & Gas Mixer Manager

The Gas Blender 100 Series is the improved solution proposed by MCQ. Designed following the Lab in Box concept, the MCQ Gas Blender 100 is a high precision instrument, easy to configure and adaptable to many different lab-applications, that offers more efficiency and an innovative quick and easy way for mixtures management, all in a compact case. The Gas Blender 100 works with 3 components gas mixtures, each gas media connected to a dedicated instrument channel for which MCQ guarantees high accuracy (1.0% of set point), high repeatability (0.16% of reading value) and the fastest response time for set point value change (50ms) now available in the market. The instrument works with dry, non-aggressive gases and the channels are always calibrated with native gases following customer’s request. For the gas mixture management the MCQ Gas Mixer Manager is also provided. Easy to use, compatible with any common desktop or laptop PC, MCQ Gas Mixer Manager allow taking a complete control over the instrument and its functions, letting the user to start working with dynamic gas mixtures immediately.
Hardware Configuration

An example of MCQ Gas Blender 100 Series hardware configuration is represented on the right. The gas in use are:

- **Channel 1: Compressed Air**
- **Channel 2: Compressed Air**
- **Channel 3: Air + 1ppm SO₂**

Gasses must be dry, but for compressed air, which will be used for ozone production, an additional installation of a lab dryer is recommended. The gas cylinders are connected to the instrument through 6 mm diameter tubes and a check valve is installed along each line as backflow prevention device. Each gas is connected and controlled by a dedicated channel of the Gas Blender 100. Another 6 mm tube finally connects the instrument to the working system (a packaging box suited to maintain a modified atmosphere) in which the experiment takes place.

The three channels work together to produce a flow with proper SO₂ and O₃ levels. In case higher concentration of fumigants are needed, the channel 2 can be temporary stopped. If the amount of fumigant is still not enough, another can with air + SO₂ can be used in channel 2.

For fumigation experimentation an high value of relative air humidity is usually required, thus a lab humidifier is also suggested. Humidity and ozone concentration inside the studied system need supplement equipment to be monitored, while the relative amount of SO₂ in the coming out mixture can be adjusted with ease, monitored and modified by the user with the MCQ Gas Mixer Manager software.