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Use of natural and safe alternatives methods to control postharvest diseases of grapes: A review

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ABSTRACT

Table grapes are subject to mycobial decay during postharvest handling worldwide. Grape berries are rich in water and nutrients; during storage of fruit high sugar content of grapes are ideal substrates for the development of pathogenic microorganisms, establishing processes of rot with consequent losses of product ranging from a minimum of 30 - 40 % in countries with advance technologies, to over 50% in developing countries. Rotting caused by the fungi such as *Aspergillus, Botrytis, Cladosporium, Fusarium, Penicilium, Mucor, Rhizopus,* is the main factor reducing the post harvest quality of table grapes. The standard practices to control the postharvest decay of table grapes worldwide are the physical control like hot water treatment, variations in temperature, UV-C irradiation, pressure or changing atmospheric composition, to fumigate the grapes with chemicals or botanicals, coating the grapes by chitosans or salts and their synergistic applications. The purpose of this review is to provide an overview of past and current knowledge about the postharvest management of grapes with physical, chemical, biological and botanical means and to identify research avenues that can facilitate the implementation of these technologies as preservatives of table grapes. Such knowledge could contribute to design of new and more potent technology for the management of postharvest decay of table grapes because alternative and integrative strategies like use of biological antagonists, natural compounds, controlled atmosphere storages are need of the day.

Keywords : Grapes, Post harvest diseases, Biological, Botanical.

Grape *(Vitis vinifera*) belong to family Vitaceae is one of the important temperate fruits, broadly distributed between 25 ° and 50° latitude in Eastern Asia, Europe, Middle East, and North America. Grapes are cultivated in many countries of the world. During 2008, grape was grown in an area of 7423.72 thousand ha with the production of 67909.28 thousand tonnes in the world. Italy (11.48), China (10.73), USA (9.93), Spain (8.91) and France (8.34%) together accounted for about 49.39 % of total world production. India produces only about 2.77 % of the total world production. However, in productivity India stood first with 23.50 tonnes /Ha followed by USA (17.80 tonnes/Ha), China (16.60 tonnes/Ha), South Africa (13.80 tonnes/Ha), Argentina (13.20 tonnes/Ha), Chile (12.90 tonnes/Ha) and Italy (10.10 tonnes/Ha).

Grape is an important fruit crop of India in which Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh and Punjab are the major grapes growing states. Maharashtra was the largest grapes producing state accounting for 75.33% of total country's production followed by Karnataka (14.32), Tamil Nadu (4.84), Andhra Pradesh (3.31) and Punjab (1.18 %) of total production. Maharashtra and Karnataka together contributes about 89.65% of total national grapes production. In structure, berries are semi translucent, flesh enclosed by a smooth skin; some contain edible seeds while other is seedless. The color of fruit is due to the presence of poly phenolic pigments in them. Red or purple berries are rich in anthocyanines while white green berries contain more of tannins especially Catechin, these antioxidant compounds are densely concentrated in the skin and seeds.

A grape is a complete diet in itself with 75 cal/100g of fruit. Grapes possess about 80% water, low level of cholesterol, fat, sodium, protein, dietary fiber, vitamin and minerals (phosphorus, potassium). The fruit is also rich source of carbohydrate, vitamin C (ascorbic acid), vitamin B and vitamin K. It also contain high amount of caffiec acid, which is a strong cancer-fighting substance. Fruit also contain flavonoids which are powerful antioxidants. These are compounds help minimize the risk of heart attack because they increase the level of nitric acid in the blood which prevent blood clot. They are used to help cure asthma, indigestion, migrane, kidney disease and fatigue. Most of the productive species are used to make juice, jelly, fermented to wine, brandy, and dried into raisins.

The storage of grape in humid and warmer climate is difficult due to the occurrence of fungi which causes various postharvest diseases like gray mold rot, blue rot, anthracnose and soft rot, botrytis rot, *Fusarium* rot. Due to high carbohydrate and moisture content the fruit ripens and deteriorate quickly. Fungal species that are conscientious for grapes diseases are *Aspergillus niger, A. flavus, A. terreus, A. ochraceus, Alternaria alternata, Botrytis cinerea, Colletotrichum gloeosporiodes, Cladosporium* sp., *Mucor* sp., *Penicillium expansum, P funiculosum, Phomopsis viticola, Lasioplodia theobromae* and *Rhizopus stolonifer* (Nelson 1979, Barkai-golon 2001, Lichter *et al.* 2002). *Botrytis cinerea* is the main fungus worldwide in late harvested table grapes that have been exposed in the field of high humidity, dews and rainfall (Sholberg 1996). Fungal infestations not only decrease the fruit nutritive value but also produce additional health hazards in the form of mycotoxin. Mycotoxins are more dangerous than mycosis. Raisins, decayed grapes and wine are generally contaminated, but due to low concentration, it is not dangerous for the consumer. The risks are not only for the consumers but also for the workers, which take up the fungal spores with the respiration. The aflatoxins are caused by the fungus *Aspergillus flavus* and *A. parasiticus*. In table grapes and in wine, the most important mycotoxin is ochratoxin A, which is produced by *Aspergillus ochraceous* and *Pennicillium verucosum* (Abrunhosa *et al*. 2002). The colonisation occurs in the field after the colour turning stage of the berries (Chulze *et al.* 2006).

In order to protect the postharvest deterioration of grape fruits and to increase its shelf life and market value it becomes essential to control postharvest diseases for the maintenance of produced quality. Postharvest fungal pathogens are controlled traditionally by using synthetic fungicides (Eckert & Ogawa 1988, Wurms *et al.* 1999). Control of these diseases is usually achieved by hot water treatment, heat treatment, chemical fungicide, biological and plant products (Kutaoka *et al.* 1982, Karabulet *et al.* 2003, Sukata *et al.* 2008, Tripathi *et al.* 2008). However, physical and chemical methods have their own limitations. Biologically active plant based products are, therefore, studied for their efficacy to protection of horticulture crops (Hassani *et al.* 2012). Among these materials, essential oils have recently attracted a great deal of their antibacterial, antifungal, antioxidant and bio-regulatory properties (Burt & Rienders 2003, Pandey *et al.* 2012, Singh *et al.* 2012, Pandey *et al.* 2013).The use of natural products such as plant extracts, essential oils, salicylic acid and chitosan or integrated use of these products with other methods such as controlled atmosphere and modified storage atmosphere was investigated (Shahi *et al.* 2003 Valero *et al.* 2006). Recently, Romanazzi *et al.* (2012) published a review on postharvest control of gray mould of table grapes by the natural and alternative means. They concentrated their deliberation only on the gray mould not on other diseases and also did not illustrate the control of postharvest diseases of table grapes by other means like physical and chemical. So far, in this review we have focused our attention as integrated approach for the control of various postharvest diseases of table grapes by physical, chemical, biological and botanical way to control mycobial decay of fruits during transit and storage. This may lead to the occurrence of new effective technology that will be more useful for scientists and scholars to convey it before retailers to store their perishables.

Botanical control—The documented use of botanicals extends back more than 150 years, dramatically predating discoveries of the major classes of synthetic chemical insecticides in the mid-1930s to 1950. At present there are five major types of botanical products viz., plant extract, pyrethrum, rotenone, neem, and essential oils. An essential oil is a concentrated hydrophobic liquid containing volatile aroma compounds from plants. Essential oils are also known as volatile oils, ethereal oils or aetherolea, or simply as the "oil of" the plant from which they were extracted, such as oil of clove. The volatile components of essential oils can be classified into four main groups: terpenes, benzene derivatives, hydrocarbons and other miscellaneous compounds. Terpenes form structurally and functionally different classes. They are made from combinations of several 5-carbon-base (C_5) units called isoprene. The main terpenes are the monoterpenes (C_{10}) and sesquiterpenes (C_{15}) (Figure 2). Essential oils and plant extract produced by different plants have been also reported to be biologically active and are endowed with insecticidal, antimicrobial, antioxidant and bio-regulatory properties (French 1985, Gulluce *et al*. 2003, Kordali *et al*. 2008). At present, approximately 3000 essential oils are known, 300 of which are commercially important especially for the pharmaceutical, agronomic, food, sanitary, cosmetic and perfume industries. d-Limonene, geranyl acetate or d-carvone are employed in perfumes, creams, soaps, as flavour additives for food, as fragrances for household cleaning products and as industrial solvents.

1. Extracts—There is little literature available on plant extracts which showed their application in the disease control of table grapes. In this context Serrano *et al.* (2006) maintained total phenol, ascorbic acid and high retention of total antioxidant activity in table grapes coated with *Aloe vera* gel. *Aloe vera* gel is a tropical and subtropical plant that has been used for centuries for its medicinal and therapeutic properties (Eshun & He 2004). Earlier scholars (Martinez-Romero *et al.* 2003, Rodriguez *et al.* 2005) have proposed the use of *Aloe vera* gel as antimicrobial coatings for fruits and vegetables, because of their proven antifungal activity *Aloe vera* gel based edible coatings for preventing moisture loss, reducing texture decay and controlling respiratory rate of table grape and sweet cherries (Martinez-Romero *et al.* 2006). The effect of Isabella (*Vitis labrusca)* on the growth of *B. cinerea* was tested *in-vitro* on 'Roditis' grape at various temperatures. Valverde (2005) reported that those clusters treated with *Aloe vera* gel significantly delayed postharvest quality losses, and storability could be extended up to 35 day at 1°C. Edible coatings are traditionally used to improve food appearance and conservation due to their environmental friendly nature, because they are obtained from animal and agricultural products (Valverde 2005). Different investigators have reported antifungal activity in plant parts extract from time to time. The plant extracts are generally assumed to be more acceptable and less hazardous than synthetic compounds. Grape fruit seed extract and chitosan have a synergistic effect in reducing *B. cinerea* fungal rot and maintaining the keeping quality (color change, ripening sensory quality and microorganism index) of 'Red globe' grapes when stored at 1°C (Xu *et al.* 2007). Moreover, some plant extract base compounds such as resveratrol and laminarin have shown their efficacy in control of gray mold decay of table grapes (Adrian *et al*. 1997, Aziz *et al*. 2003). Romanazzi *et al.* (2007) found that potency of grape seed extracts was enhanced when it was combined with biopolymer chitosan or ethanol. Boyraz & Ozcan (2006) observed with the aim of extract of *Saturaja hortensis* to be effective against *Alternaria mali* and *Botrytis cinerea.* Ribera *et al.* (2008) reported effectiveness of ethanol and methanol extract of *Quillaza saponaria* against *B. cinerea* causing rot in several fruits. The effectiveness of hot water extract of *Xylopia aethiopica* seeds and *Zingier officinale* against *Aspergillus flavus* and *A niger* isolated from yam was reported by Okigbo & Nmeka (2005). The extracts were also effective in preservation of yam during storage. Soytong *et al.* (2005) found that antifungal substances extracted from *Chetomium cupreum, C. globosum*, *Trichoderma harzianum*, *Penicillium chrysogenum* KMITL44 and Trichotoxin A50 could inhibit the growth of *Colletotrichum gloeosporioides*.

2. Essential oils—The interest in essential oils and their application in food preservation have been amplified in recent years by an increasingly negative consumer perception of synthetic preservatives. Furthermore, food borne diseases are a growing public health problem worldwide as descried understory, calling more effective preservation strategies (Hyldgaard *et al.* 2012.). There is plenty of literature available which showed that most of the essential oils have potency to inhibit the postharvest fungi in in-vitro conditions (Bishop & Reagan 1998, Singh & Tripathi 1999, Hildalgo *et al.* 2002). Sukatta *et al.* (2008) reported the potentiality of clove and cinnamon oils in controlling postharvest decay of grapes caused by six fungi *Aspergillus, Alternaria, Colletotrichum, Lasiodiplodia, Phomopsis* and *Rhizopus* and concluded that both the oils were effective

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in the management of diseases in table grapes caused by these fungi. Cinnamon and clove oils were also found as ideal antifungal agent for the control of several diseases of table grapes in other investigations conducted by the researchers (Azzouz & Bullerman 2003, Singh *et al.* 2007, Feng & Zheng 2007, Lopez –Malo *et al,* 2007).

Martinez-Romero *et al*. (2007) found that during fumigation carvacol essential oil components reduced the incidence of *B. cinerea* on table grapes. Tripathi *et al.* (2008) implemented that treatment with essential oils of *Ocimum sanctum, Prunus persica* or *Zingiber officinale* resulted in appearance of decay after 8, 9 and 10 d, respectively, while they appeared in the control after 4 d. Similarly, Valero *et al*. (2006) observed that table grape clusters treated with eugenol or thymol reduced the number of decayed berries after 56 d storage at 1 ºC and 3 days shelf-life from 50% in the control to 10–22%. Abdolahi *et al.* (2010) investigated that grape bunch sprayed with *Thymus vulgaris* and *Satureja hortensis* oils were able to reduce gray mold disease severity to 4.1 and 4.2, respectively, compared to 4.9 units (based on a 0–6 empirical scale) in the control, on table grapes after 60 d storage at 0 ºC. During *in vitro* conditions, both oils showed a different degree of inhibition against the mycobial growth of *B. cinerea*. In addition, exposure of Carvacrol vapor at 0.05, 0.2, 0.5 and 1.0 ml/l completely inhibited the growth of *B. cinerea* isolated from Table grapes and also reduced the spoilage of berries when it was stored at 25 ºC for 4 day (Martínez-Romero *et al*. 2007). Carvacrol, eugenol and thymol were also reported to be effective against several pathogens of table grapes and significantly reduced weight loss, colour changes, MI and fruit firmness as compared to control fruits (Guillén *et al.* 2007). Marandi *et al.* (2010) found that use of *Thymus kotschyanus* and *Carum copticum* oils control the fungal decay in Thompson seedless table grape. De Sousa *et al.* (2013) examined that application of the essential oils of *Origanum vulgare* (OVEO) and *Rosmarinus officinalis* (ROEO) alone and in combination inhibited the mycobial biomass of two strains of fungi *Aspergillus flavus* URM 4540 and *A. niger* decaying table grapes. Recently, Sonker *et al.* (2014) reported that application of 200 and 300 µl of *Cymbopogon citratus* oil on 1 kg of stored grapes enhance the shelf life for up to 10 d and preserve it from microbial spoilage.

Regarding integrated approach such as combine application of physical, chemical, botanicals and biological has also been studied. In this context, Antonov *et al.* (1997) used 21 oil extracts (19 plant oil extracts and two microbial metabolites) and assessed at 0.1, 1.0 and 10 % concentration for effects on conidium germination, germ tube elongation and mycecilial growth in *Botrytis cinerea* and observed that *Thyme* oil and *Trichoderma harzianum,* metabolites 6-Penta-alpha-pyrone (6-PAP) and a 6-PAP derivative in combination, gave the greatest inhibition of mycelial growth of the extracts tested at 10% concentration. Combine application of modified atmosphere packaging (MAP) with the use of eugenol–thymol–carvacrol essential oils, reduced decay incidence from 37% in the control to 7% in treated bunches after 56 d cold storage at 1 ºC (Guillén *et al.* 2007).

Biological control—Biological control of postharvest disease (BCPD) has emerged as an effective alternative. Several postharvest pathogens are being controlled by a number of antagonistic microorganisms such as, fungal, yeast and bacteria. Lichter *et al.* (2006) controlled the postharvest decay of table grapes by biological fumigation with the fungus *Muscodor albus*. The volatile produced by *M. albus* is a mixture of low molecular weight compounds that are biocidal or biostatic to a broad variety of microorganism including *B. cinerea* (Gabler *et al.* 2006). Gabler *et al.* (2006) developed continuous bio-fumigation of table grape with a rye grain formulation of *M. albus* against the postharvest gray mold. Strain of *Candida, Cryptococcus, Debaryomyces, Metschnikowia*, *Pichia, Rhodotorula, Sporobolomyces* and *Trichosporon* all have been reported to inhibit postharvest decay of fruits due to their antifungal effect (Sipiczki 2006). De Curtis *et al.* (1996) reported that fruit borne strains of *Metschnikowia pulcherrima* can be effective in protective grapes against postharvest rot caused by *B. cinerea* and other postharvest pathogens. Another bio-agent *Metschnikowia fructicola* is an effective biocontrol agent for postharvest diseases of grapes followed by Karabulet *et al.* (2003). Two strains of *Cryptococcus laurentii* and *Aureobasidium pullulans*, were found to control ochratoxin accumulation by black aspergilli in table grapes (Dimakopoulou *et al.* 2005). Another bio-control agent *Hanseniaspora uvarum,* has shown better effectiveness than conventional methods to control gray mold of table grapes in laboratory scale experiments (Liu *et al,* 2010). Additionally, combine application of Chitosan and *Cryptococcus laurentii* also keep away the table grapes from fungal spoilage (Meng & Tian 2009, Meng *et al*. 2010). Another species of *Cryptococcus* i.e. *C. humicolus* was found as effective bio-agent in the postharvest decay of table grapes when it was mix with *Pichia anomala,* bentonite, potassium, caseinate and calcium chloride (Ligorio *et al.,* 2008).

CONCLUSION

Horticultural techniques are thought to play a complex role in our daily life. Appropriate production, harvesting, packaging, handling and transportation all these contribute to the good product quality but also postharvest treatment are required. In order to reduce postharvest losses of grapes, there is a need for better handling, packing and grading. The major postharvest losses in grapes reported by producers, contractors and retailers during early maturity, before and after harvesting were mainly occurred due to wind velocity, poor packing, handling and transportation. Per year loss in grapes production is estimated to be 50% which result in the less supply of fruits and ultimately causes to increase the cost of commodity. Thus today's fruit are withdrawing from our balance diet. Postharvest losses of perishables commodity caused great effect of agro- based economy. In this time several strategies are forms for the maintenance of good quality and production of fruit. Physiological, chemical, biological and botanical treatments relatively show good result and might be useful in particular circumstances for common postharvest treatment. The physiological control of grapes ripening and how the different processes ultimately affect the fruit quality is far from being understood now. Low temperature storage at 0ºC is recommended to delay ripening and maintain fruit quality. The benefits of modified and controlled atmosphere and packaging are not so pronounced as in other fruit commodities and consequently this technology are not widely used commercially. Botanical and Biological control is alternative method of chemical control of postharvest disease of fruits because use of synthetic fungicide and of sulfur dioxide is not allowed on organic grapes and study of alternative method to control postharvest decay has developed over several decades, along with the demand for safer storage methods.

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