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Review Paper

Human Health and Environment Friendly Applications Used in Grape Storage

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Abstract

Grape is nonclimacteric and has low physiological mechanism. Although, in addition to these positive features, decay induced by gray mold (*Botrytis cinerea*) after harvest, drying of the bunch rachis and water loss from berries are important factors limiting the storage period. Grapes are often treated with SO_2 to protect post-harvest spoilage during storage and transport. However, the application of SO_2 can cause damages to the grapes and the sulphide residues are unacceptable for consumer health. Especially in recent years, for the storage of grapes in the cold; studies focus on methods and chemicals that are more effective and harmless to human health.

Introduction

Grape varieties have been grown since ancient times, and various studies are carried out to develop their quality parameters. Moreover, with the worldwide expanding table grape market, these grapes need to be transported, stored and marketed without spoiling their appearance and taste (Droby and Lichter, 2007). Storage at low temperatures and the usage of sulfur dioxide (SO_2) are carried out either in the form of frequent fumigation to the store or in the form of storage between sulfur dioxide pads in polyethylene bags; it is widely used around the world to both reduce fungal spoilage and prolong the storage period of table grapes (Crisosto et al., 1994). Although sulfur dioxide applications have a significant effect on controlling fungal spoilage in grapes, this is known to cause phytotoxicity such as bleaching of the grape, discoloration, post-harvest cracking, sulfur taste and browning of the bunch rachis (Zoffoli et al., 2008). These negative perceptions and consumer demands can control the post-harvest decay of grapes instead of using synthetic preservatives; It has focused the search for alternative strategies that will not cause human, environmental and plant toxicity (Abdolahi et al., 2010). Storing grapes in moist and warm climates is very hard due to fungal diseases such as mold, anthracnose and soft decay, *Botrytis cinerea* and *Fusarium* decays (Barkai-Golan, 2001). Due to the high sugar and water content in ripe grapes, deterioration is also rapid (Sonker et al., 2016). *Botrytis cinerea* is commonly widespread worlwide for late ripening grapes because its subject to more rain and higher humidity (Sholberg et al., 1996). Fungal decay not only reduces the nutritional value of the fruit, but also threat to human health due to mycotoxins. Raisins, bruised berries, also and wines are often infected from mycotoxins, but due to the low concentration they do not pose a danger to consumers. The most important mycotoxins in table grapes and wines are "Ochratoxin A" caused by *Penicillium verucosum* and *Aspergillus ochraceous*, and it is a "aflatoxin" produced by *Aspergillus flavus parasiticus* and *Aspergillus flavus* (Abrunhosa et al., 2002; Sonker, 2016).

In order to keep safe, the grapes from postharvest decays, extend shelf life and increase their marketing value, consider it necessary to reduce postharvest diseases. Traditionally, postharvest fungal pathogens have been tried to be kept under control using synthetic fumigants (Eckert and Ogawa, 1988; Wurms et al., 1999; Sonker, 2016). Hot water application, hot application, chemical fungicides, biological and herbal products can be used frequently in order to successfully control these diseases (Kataoka et al., 1982; Karabulut et al., 2003; Sukatta et al., 2008; Tripathi et al., 2008). But, different application methods have some restriction. Biologically active herbal products have been studied for their effectiveness in preserving easily spoilt fruits (Hassani et al., 2012). One of the herbals, essential oils have recently take attention due to their antifungal, antibacterial, antioxidant, and bioregulatory features (Burt and Rienders, 2003; Pandey et al., 2012; Singh et al., 2012).

Essential Oils

Since there is a restriction in the use of fungicides applied to prevent decays in grapes, it is possible to prevent decays by means of natural compounds like essential oils (Valverde et al., 2005; Martínez-Romero et al., 2007). Attention in application of essential oils to food storage has increased in recent years with the negative perspective of synthetic protections (Sonker et al., 2016). These oils are formed multi-component mixtures of aromatic compounds, sesquiterpenes, monoterpenes, and their derivative, and they are substances that provide antibacterial, antiviral and antifungal effects that plants generally produced to handle stress situations (Lovkova et al., 2001). They are also in the GRAS (Generally Recognize As Safe) status. One of the positive aspects of essential oils is that their biological activity in vapor form is as high as fumigants (Palou et al., 2010). As in SO_2 applications, the applications of essential oils in the form of vapor is more effective in reducing gray mold as it comes into contact with the epidermis of the grape (Palou et al., 2002). Palou et al. (2002) reported that the essential oil vapor given in the package disappeared quickly when the package was opened, and without any side effect on the sensorial characteristics of the grape. In addition, when essential oils are used in combination with active MAP (Modified Atmosphere Package), they can reduce berry softening, delay color change and preserve organoleptic properties, as well as control decay and reduce microbial spoilage (Martínez-Romero et al., 2003). Studies on use of essential oils in grape preservation are shown in Table 1.

Polyamines

Polyamines are positive charged aliphatic amines, and there are in nearly all living organism, and are declared to affect diverse biological activities such as flowering, growth, ripening, senescence and reaction to stress situations in fruits under cold storage (Malik and Singh, 2004; Khan and Ali, 2018). These cationic aliphatic amines have been used for their possible antagonistic effects against ethylene release. Therefore, it is known that the three main polyamines found in plants (putresin, spermine and spermidine) have an effect on fruit ripening (Khan and Ali, 2018). The results of many studies show that polyamines in their free form reduce respiration rate, act as anti-aging agents, delay ethylene production and color transformations; induce mechanical resistance, increase fruit firmness, and reduce chilling damages (Valero et al., 2002). With this, delay ripening, preservation, and extending shelf life depend on the concentrations of polyamines applied (Malik and Singh, 2004).

In addition to extending the storage period and shelf life of fruits, pre-harvest polyamine applications affect some quality properties of different fruits positively or negatively. For example, pre-harvest spermine application increased the ascorbic acid content in mango, while putresin and spermidine applications decreased it. The effects of pre-harvest use of polyamines include increasing fruit firmness, delay color change, and thus extending storage period and shelf life (Malik and Singh, 2004). Studies on use of polyamines oils in grape are presented in Table 2.

Polyamines are naturally found in many fruits and vegetables, except broccoli, cauliflower, and citrus fruits (Eliassen et al., 2002). It is reported that the predominant polyamine in grapes is putresin, followed by spermidine and spermine (Reddy et al., 2008).

Edible Coatings

Edible coatings have been used since the 12th century to delay food spoilage, reduce water loss, suppress respiration, preserve volatile aromatic compounds, and reduce microbiological activity (Debeaufort et al., 1998). Edible coatings are widely used to preserve post-harvest fruit quality and extend storage life (Modesti et al., 2019). The coating materials used for this purpose do not have any danger in terms of food safety (Alvarez et al., 2018; Modesti et al., 2019). The fact that they are biodegradable, healthy and environmentally friendly has encouraged their usage (Chauhan et al., 2014).

Studies on edible coating materials used in grapes are shown in Table 3. As can be seen from the table, the most commonly used coating material in grapes is chitosan. It can be applied directly to the fruit surface as a single or double layer, thin and transparent. In this way, it provides a good barrier to control the atmosphere content, delays metabolic senescence and slows down microbial growth (Gutiérrez and Álvarez, 2017). The fact that the semi-permeable chitosan film is strrong, durable, flexible and does not tear easily is evaluated as its important advantages, and these

Table 1. Studies using essential oils in grape preservation

Source of Essential Oil	Concentration	Cultivar	Reference
Thymol, mentol	0.5 mL	Crimson	Martínez-Romero et al., 2004
Eugenol, mentol, thymol	0.5 mL	Crimson Seedless	Valverde et al., 2005
Eugenol, thymol	75, 150 µl	Autumn Royal	Valero et al., 2006
Eugenol, thymol, carvacrol	25 µl	Aledo	Guillén et al., 2007
Carvacrol vapor	0, 0.1, 0.4, 1, 2 mL	Autumn Royal	Martínez-Romero et al., 2007
Peach leaf, basil leaf, ginger	100, 200 ppm	-	Tripathi et al., 2008
Fennel seed, thyme, sater, basil	0, 200, 400, 600 µl/L	Tabarzeh	Abdolahi et al., 2010
Ginger leaf oil	0.5, 2.5 ve 5 g/L	Red Globe	Melgarejo-Flores et al., 2013
NaAlg + Grapefruit oil	1% ve 2% NaAlg + 1% GFEY	Italia	Aloui et al., 2014
Chitosan + *Mentha piperita* and *Mentha villosa*	4 ve 8 mg/ml chitosan + 1.25, 2.5 ve 5 µl/ml *M.piperita-M. villosa*	Isabella	Guerra et al., 2016
Chitosan + lemon grass essential oil	1% +1%	*Vitis vinifera* x *Vitis labruscana*	Oh et al., 2017

NaAlg: Sodium alginate
GFEY: Grapefruit essential oil

Table 2. Studies using polyamines in grape preservation

Polyamine	Concentration	Cultivar	Reference
Putresin - Salicylic Acid	8 mM and 100 mg/L	Thompson Seedless	Marzouk and Kassem, 2011
Putresin	1 and 2 mM	Shahroudi	Shiri et al., 2012
Putresin and Spermidine	2 mM and 2 mM	-	Mirdehghan et al., 2013
Putresin and Spermidine	0.5, 1 and 1.5 mmol/L	Flame Seedles	Harinda Champa et al., 2014
Spermine	0.5, 1 and 1.5 mmol/l	Flame Seedless	Harinda Champa et al., 2015
Putresin and Spermidine	1 and 2 mM	Olhoghi and Rishbaba	Mirdehghan and Rahimi, 2016

Table 3. Studies using edible coatings in grape preservation

Coatings	Concentration	Cultivar	Reference
Chitosan + GFSE	1% + 1%	Red Globe	Xu et al., 2007
Propolis + HPMS	5% HPMC + 0.5, 1, 1.5 % Propolis	Muscatel	Pastor et al., 2011
Chitosan + Bergamot essential oil	1% + 2%	Muscatel	Sánchez-González et al., 2011
Chitosan	1%	Muscat of Hamburg	Gao et al., 2013
Pectin + Cinnamon Leaf Oil	-	Red Globe	Melgarejo-Flores et al., 2013
NaAlg + GFSE	1% ve 2% NaAlg + 1% GFSE	Italia	Aloui et al., 2014
Aloe vera gel	1%, 5%, 10%	Thompson, Sharad and Seedless	Chauhan et al., 2014
Chitosan	15, 7.5, 3.75, 1.88, 0.94, 0.045 and 0.022 mg/ml	Isabella	de Oliveira et al., 2014
Aloe vera extract	-	Sugar One, Victoria and Black Magic	Alberio et al., 2015
Maize Starch + Gelatine	-	Red Crimson	Fakhouri et al., 2015
Aloe vera gel : Distilled water	0:1, 1:1, 2:1, 3:1 v/v	Askari	Farahi, 2015
Chitosan	0.5% and 1%	Crimson	Freitas et al., 2015
Chitosan + *Mentha piperita* ve *Mentha villosa*	4 and 8 mg/ml Chitosna + 1.25, 2.5 and 5 µl/ml *M.piperita-M. villosa*	Isabella	Guerra et al., 2016
Chitosan + *Salvia fruticosa* extract	1% + 500 mg/L	Thompson Seedless	Kanetis et al., 2016
HPMS + *Candida sake*	2% w/v + $5x10^7$ m/L	Red Globe	Marín et al., 2016
Chitosan + Lemon grass essential oil	1% + 1%	*Vitis vinifera* x *Vitis labruscana*	Oh et al., 2017
Chitosan-g- Salicylic Acid	1% Chitosan + 2mM SA	Yongyou 1	Shen and Yang, 2017
Gelatin extracted from Cod fish + Indian rosewood essential oil + Pine needle extract	5% + 1% + 1%	Kyoho	Yang et al., 2017
Chitosan	1% and 2%	Sagrantino	Petriccione et al., 2018
HPMS + *k*-carrageenan	4% w/v + 0.2%	-	Silva-Vera et al., 2018

HPMS: Hydroxypropylmethylcellulose
SA: Salicylic Acid
NaAlg: Sodium Alginate
GFSE: Grapefruit Seed Extract

properties are comparable to most commercial polymers (Taştan and Baysal, 2013).

Conclusion

Grape is a nonclimacteric fruit cultivar and has low physiological activity. In addition to these positive features, post-harvest decays caused by gray mold (*Botrytis cinerea*), rachis drying and water loss are important factors limiting the storage. Because of that grapes are often treated with SO_2 to prevent post-harvest decay during storage and transportation. On the other hand, SO_2 treatment may harm the grapes and cause sulfide residual effects, which is an inadmissible situation in terms of consumer health. Recent studies have shown that essential oil applications such as eugenol, thymol, menthol or carvacrol, highly reduce the growth of *Botrytis cinerea*. They are also reported to delay fruit softening and color change and preserve their sensorial properties. In future studies, it should be appropriate to apply these essential oils and edible coatings combine with different packaging and technologies, individually or in combination, and thus determine their effects on grapes. Also, due to the high differences among cultivars, the application material, application methods (pre or post-harvest, spraying, vapor etc.), and conditions should be investigated and optimized sensitively for each table grape cultivar.

REFERENCES

Abdolahi, A., Hassani, A., Ghosta, Y., Bernousi, I., Meshkatalsadat, M. H. (2010). Study on the potential use of essential oils for decay control and quality preservation of Tabarzeh table grape. Journal of Plant Protection Research, 50 (1), 45-52.

Abrunhosa, L., Serra, R., Venaoncio, O. (2002). Biodegradable of ochratoxin a by fungi isolated from grapes. Journal of Agricultural and Food Chemistry, 50, 7493–7496. https://doi.org/10.1021/jf025747i

Alberio, G. R. A., Muratore, G., Licciardello, F., Giardina, G., Spagna, G. (2015). *Aloe vera* extract as a promising treatment for the quality maintenance of minimally-processed table grapes. Food Sci. Technol, Campinas, 35 (2), 299-306. https://doi.org/10.1590/1678-457X.6471

Aloui, H., Khwaldia, K., Sánchez-González, L., Muneret, L., Jeandel, C., Hamdi, M., Desobry, S. (2014). Alginate coatings containing grapefruit essential oil or grapefruit seed extract for grapes preservation. Int J Food Sci Technol, 49 (4), 952–959.

Álvarez, K., Alvarez, V. A., Gutiérrez, T. J. (2018). Biopolymer composite materials with antimicrobial effects applied to the food industry. In V. K. Thakur & M. K. Thakur (Eds.), Functional Biopolymers (pp. 57–96). Editorial Springer International Publishing. Zug, Switzerland. https://doi.org/10.1007/978-3-319-66417-0_3

Barkai-Golan, R. (2001). Soft fruits and berries: Grapes. In R. Barkai-Golan (Ed.), Postharvest diseases of fruits and vegetables development and control (pp. 315–316). Elsevier. eBook ISBN: 9780080539294.

Burt, S. A., & Rienders, R. D. (2003). Antibacterial activity of selected plant essential oils against *Escherichia coli* O157:H7. Letters in Applied Microbiology, 36, 162–167. https://doi.org/10.1046/j.1472-765x.2003.01285.x

Chauhan, S., Gupta, K. C., Agrawal, M. (2014). Application of Biodegradable *Aloe vera* gel to control post harvest decay and longer the shelf life of grapes. Int. J. Curr. Microbiol. App. Sci., 3 (3), 632-642.

Crisosto C. H., Smilanick J. L., Dokoozlian N. K., Luvisi D. A. (1994). Maintaining table grape post-harvest quality for long distance markets. Proc. Int. Sym. on Table Grape Production, 195–199. Debeaufort, F., Quezada-Gallo, J. A., Voilley, A. (1998). Edible films and coatings: tommorrow's packaging: a review. Crit. Rev. Food Sci. 38, 299- 313. http://dx.doi.org/10.1080/10408699891274219

de Oliveira, C. E. V., Magnani, M., de Sales, C. V., de Souza Pontes, A. L., Campos-Takaki, G. M., Stamford, T. C. M., de Souza, E. L. (2014). Effects of chitosan from *Cunninghamella elegans* on virulence of post-harvest pathogenic fungi in table grapes (*Vitis labrusca* L.). International Journal of Food Microbiology, 171, 54–61. https://doi.org/10.1016/j.ijfoodmicro.2013.11.006

Droby S., & Lichter A. (2007). Post-harvest Botrytis infection: Etiology, development and management. In: "*Botrytis*: Biology, Pathology and Control" (Y. Elad, B. Williamson, P. Tudzynski, N. Delen, eds.), (pp. 349–367). Kluwer Academic Publishers, London.

Eckert, J. W., & Ogawa, J. M. (1988). The chemical control of postharvest diseases: Deciduous fruits, berries, vegetables and root tuber crops. Annual Review of Phytopathology, 26, 433–469. http://dx.doi.org/10.1146/annurev.py.26.090188.002245

Eliassen, K. A., Reistadb, R., Risøena, U., Rønninga, H. F. (2002). Dietary polyamines. Food Chemistry, 78, 273 – 280. http://dx.doi.org/10.1016/S0308-8146(01)00405-8

Fakhouri, F. M., Martelli, S. M., Caon, T., Velasco, J. I., Mei, L. H. I. (2015). Edible films and coatings based on starch/gelatin: Film properties and effect of coatings on quality of refrigerated Red Crimson grapes. Postharvest Biol. Technol, 109, 57–64. http://dx.doi.org/10.1016/j.postharvbio.2015.05.015

Farahi, M. H. (2015). The Impact of *Aloe vera* Gel as Postharvest Treatment on the Quality and Shelf Life of Table Grape cv. 'Askari'. Agricultural Communications, 1 (1), 30-36. https://www.researchgate.net/publication/273955167

Freitas, P. M., López-Gálvez, F., Tudela, J. A., Gil, M. I., Allende, A. (2015). Postharvest treatment of table grapes with ultraviolet-C and chitosan coating preserves quality and increases stilbene content.

Gao, P., Zhu, Z., Zhang, P. (2013). Effects of chitosan-glucose complex coating on postharvest quality and shelf life of table grapes. Carbohydrate Polymers, 95 (1), 371-378. http://dx.doi.org/10.1016/j.carbpol.2013.03.029

Guerra, I. C. D., de Oliveira, P. D. L., Santos, M. M. F., Lúcio, A. S. S. C., Tavares, J. F., Barbosa-Filho, J. M., Madruga, M. S., de Souza, E. L. (2016). The effects of composite coatings containing chitosan and Mentha (*piperita* L. Or x *villosa* huds) essential oil on postharvest mold occurrence and quality of table grape cv. Isabella. Innovative Food Science and Emerging Technologies, 34, 112-121. http://dx.doi.org/10.1016/j.ifset.2016.01.008

Guillén F., Zapata J., Martínez-Romero D., Castillo S., Serrano M., Valero D. (2007). Improvement of the overall quality of table grapes stored under modified atmosphere packaging in combination with natural antimicrobial compounds. Journal Food Science, 72, 185–190. http://dx.doi.org/10.1111/j.1750-3841.2007.00305.x

Gutiérrez, T. J., & Álvarez, K. (2017). Transport phenomena in biodegradable and edible films. In M. A. Masuelli (Ed.), (pp. 58–88), Biopackaging Miami. Editorial CRC Press Taylor & Francis Group. EE.UU. ISBN: 978-1-4987-4968-8.

Harinda Champa, H. W. A., Gill, M. I. S., Mahajan, B. V. C., Arora, N. K. (2014). Postharvest treatment of polyamines maintains quality and extends shelf-life of table grapes (*Vitis vinifera* L.) cv. Flame Seedless. Postharvest Biology and Technology, 91, 57–63. http://dx.doi.org/10.1016/j.postharvbio.2013.12.014

Harinda Champa, H. W. A., Gill, M. I. S., Mahajan, B. V. C., Bedi, S., 2015. Exogenous treatment of spermine to maintain quality and extend postharvest life of table grapes (*Vitis vinifera* L.) cv. Flame Seedless under low temperature storage. Food Science and Technology 60, 412-419.

Hassani, A., Fathi, Z., Ghosta, Y., Abdollahi, A., Meshkatalsasat, M. H., Marandi, R. J. (2012). Evaluation of plant essential oils for control of postharvest brown and gray mold rots on apricot. Journal of Food Safety, 32, 94–101. https://doi.org/10.1111/j.1745-4565.2011.00353.x

Kanetis, L., Exarchou, V., Charalambous, Z., Goulas, V. (2017). Edible coating composed of chitosan and *Salvia fruticosa* Mill. extract for the control of grey mould of table grapes. J Sci Food Agric, 97 (2), 452–460. https://doi.org/10.1002/jsfa.7745

Karabulut, O. A., Smilalanick, J. L., Gabler, F. M., Mansour, M., Droby, S. (2003). Near harvest application of *Metschnikowia fructicola*, ethanol and sodium bicarbonate to control post-harvest diseases of grape in central California. Plant Disease, 87, 1384–1389. https://doi.org/10.1094/PDIS.2003.87.11.1384

Khan, A. S., & Ali, S. (2018). Preharvest Sprays Affecting Shelf Life and Storage Potential of Fruits. Preharvest Modulation of Postharvest Fruit and Vegetable Quality, Chapter 9, 209-255. http://dx.doi.org/10.1016/B978-0-12-809807-3.00009-3

Kataoka, I., Sugiura, A., Utsunomiya, N., Tomata, T. (1982). Effect of abscissic acid and defoliation on anthocyanin accumulation in Kyoho grapes (*Vitis vinifera* L. x *Vitis Labruscana* Bailey). Vitis, 21, 325– 332. https://doi.org/10.5073/vitis.1982.21.325-332

Lovkova, M. Y. A., Buzuk, G. N., Sokolova, S. M., Kliment'eva, N. I. (2001). Chemical features of medicinal plants. Applied Biochemistry and Microbiology, 37, 229–237. https://doi.org/10.1023/A:1010254131166

Malik, A. U., & Singh, Z. (2004). Endogenous free polyamines of mangos in relation to development and ripening. J. Am. Soc. Hortic. Sci., 129, 280–286. https://doi.org/10.21273/JASHS.129.3.0280

Marín, A., Cháfer, M., Atarés, L., Chiralt, A., Torres, R., Usall, J., Teixidó, N. (2016). Effect of different coating-forming agents on the efficacy of the biocontrol agent *Candida sake* CPA-1 for control of *Botrytis cinerea* on grapes. Biological Control, 96, 108–119. https://doi.org/10.1016/j.biocontrol.2016.02.012

Martínez-Romero D., Castillo S., Serrano M., Valverde J.M., Guillén F., Valero D. 2004. The use of natural aromatic essential oils helps to maintain postharvest quality of 'Crimson' table grapes. p. 1723–1727. In: Proc. 5th Int. Postharvest Symp. 6–11 June 2004, Verona, Italy. https://www.academia.edu/84919937/The_Use_of_Natural_Aromatic_Essential_Oils_Helps_to_Maintain_Post_Harvest_Quality_of_crimson_Table_Grapes?f_ri=39718

Martínez-Romero, D., Guillén, F., Castillo, S., Valero, D., Serrano, M. (2003). Modified Atmosphere Packaging Maintains Quality of Table Grapes. Journal of Food Science, 68, 1838-1843. https://doi.org/10.1111/j.1365-2621.2003.tb12339.x

Martinez-Romero, D., Guillén, F., Valverde, J. M., Bailén, G., Zapata, P. J., Serrano, M., Castillo, S., Valero, D. (2007). Influence of Carvacrol on Survival of *Botrytis cinerea* Inoculated in Table Grapes. International Journal Food Microbial., 115, 144-148. https://doi.org/10.1016/j.ijfoodmicro.2006.10.015

Marzouk, H. A., & Kassem, H. A. (2011). Improving yield, quality, and shelf life of Thompson Seedless grapevine by preharvest foliar applications. Sci. Hortic., 130, 425–430. https://doi.org/10.1016/j.scienta.2011.07.013

Melgarejo-Flores, B. G., Ortega-Ramírez, L. A., Silva-Espinoza, B. A., González-Aguilar, G. A., Miranda, M. R. A., Ayala-Zavala, J. F. (2013). Antifungal protection and antioxidant enhancement of table grapes treated with emulsions, vapors, and coatings of cinnamon leaf oil. Postharvest Biology and Technology, 86, 321–328. https://doi.org/10.1016/j.postharvbio.2013.07.027

Mirdehghan S. H., & Rahimi, S. (2016). Pre-harvest application of polyamines enhances antioxidants and table grape (*Vitis vinifera* L.) quality during postharvest period. Food Chemistry, 196, 1040–1047. https://doi.org/10.1016/j.foodchem.2015.10.038

Mirdehghan, S. H., Rahimi, S., Esmaeilizadeh, M. (2013). Improving the postharvest characteristics of table grape by preharvest application of polyamines. Acta Hortic., 1012, 293–298. https://doi.org/10.17660/ActaHortic.2013.1012.36

Modesti, M., Zampella, L., Petriccione, M. (2019). Chitosan Mono- and Bilayer Edible Coatings for Preserving Postharvest Quality of Fresh Fruit. T. J. Gutiérrez (ed.), Polymers for Agri-Food Applications (pp. 465-486), Springer, Cham. https://doi.org/10.1007/978-3-030-19416-1_23

Oh, Y. A., Oh, Y. J., Song, A. Y., Won, J. S., Song, K. B., Min, S. C. (2017). Comparison of effectiveness of edible coatings using emulsions containing lemongrass oil of different size droplets on grape berry safety and preservation. LWT Food Sci Technol, 75, 742–750. https://doi.org/10.1016/j.lwt.2016.10.033

Palou, L., Crisosto, C. H., Garner, D., Basinal, L. M., Smilanick, J. L., Zoffoli, J. P. (2002). Minimum Constant Sulfur Dioxide Emission Rates to Control Gray Mold of Cold-Stored Table Grapes. American Journal of Enology and Viticulture, 53, 110-115. https://doi.org/10.5344/ajev.2002.53.2.110

Palou, L., Serrano, M., Martínez-Romero D., Valero, D. (2010). New Approaches for Postharvest Quality Retention of Table Grapes. Fresh Produce, (Special Issue 1): 103-110. http://www.globalsciencebooks.info/Online/GSBOnline/images/2010/FP_4(SI1)/FP_4(SI1)103-110o.pdf

Pandey, A. K., Singh, P., Palni, U. T., Tripathi, N. N. (2012). *In-vitro* antibacterial activity of essential oils of aromatic plants against *Erwinia herbicola* (Lohnis) and *Pseudomonas putida*. Journal of the Serbian Chemical Society, 77, 313–323. https://doi.org/10.2298/JSC110524192P

Pastor, C., Sánchez-González, L., Marcilla, A., Chiralt, A., Cháfer, M., González-Martínez, C. (2011). Quality and safety of table grapes coated with hydroxypropylmethylcellulose edible coatings containing propolis extract. Postharvest Biology and Technology, 60 (1), 64–70. https://doi.org/10.1016/j.postharvbio.2010.11.003

Petriccione, M., Pagano, L., Forniti, T., Zampella, L., Mastrobuoni, F., Scortichini, M., Mencarelli, F. (2018). Postharvest treatment with chitosan affects the antioxidant metabolism and quality of wine grape during partial dehydration. Postharvest Biology and Technology, 137, 38–45. https://doi.org/10.1016/j.postharvbio.2017.11.010

Reddy, N. Y., Shankar, B. V., Padmalatha, V. (2008). Studies on the possible involvement of polyamines in the shelf life of grapes (*Vitis vinifera* L.). Acta Horticulturae, 785, 457-463. https://doi.org/10.17660/ActaHortic.2008.785.60

Sánchez-González, L., Pastor, C., Vargas, M., Chiralt, A., Gonzáles-Martínez, C., Cháfer, M. (2011). Effect of hydroxypropylmethylcellulose and chitosan coatings with and without bergamot essential oil on quality and safety of cold-stored grapes. Postharvest Biology and Technology, 60, 57–63. https://doi.org/10.1016/j.postharvbio.2010.11.004

Shen, Y., & Yang, H. (2017). Effect of preharvest chitosan-g-salicylic acid treatment on postharvest table grape quality, shelf life, and resistance to *Botrytis cinerea*-induced spoilage. Scientia Horticulturae, 224, 367–373. https://doi.org/10.1016/j.scienta.2017.06.046

Shiri, M. A., Ghasemnezhad, M., Bakhshi, D., Sarıkhanı , H. (2012). Effect of Postharvest Putrescine Application and Chitosan Coating on Maintaining Quality of Table Grape cv. "Shahroudi" During Long Term Storage. Journal of Food Processing and Preservation, 1-9. https://doi.org/10.1111/j.1745-4549.2012.00735.x

Sholberg, P. L., Reynolds, A. G., Gaunce, A. P. (1996). Fumigation of table grapes with acetic acid to prevent post-harvest decay. Plant Disease, 80, 1425–1428. https://doi.org/10.1094/PD-80-1425

Silva-Vera, W., Zamorano-Riquelme, M., Rocco-Orellana, C., Vega-Viveros, R., Gimenez Castillo, B., Silva-Weiss, A., Osorio-Lira, F. (2018). Study of spray system spplications of edible coating suspensions based on hydrocolloids containing cellulose nanofibers on grape surface (*Vitis vinifera* L.). Food and Bioprocess Technology, 11 (8), 1575–1585. https://doi.org/10.1007/s11947-018-2126-1

Singh, P., Pandey, A. K., Tripathi, N. N. (2012). Essential oils: A renewable source for the management of stored product insects – A review. Agricultural Review, 33, 226–236. https://www.researchgate.net/publication/232322257_Essential_oils_A_renewable_source_for_the_management_of_stored_product_insects_-_A_review

Sonker, N., Pandey, A. K., Singh, P. (2016). Strategies to control post-harvest diseases of table grape: a review. Journal of Wine Research, https://doi.org/10.1080/09571264.2016.1151407

Sukatta, U., Haruthaithanasan, V., Chantarapanont, D., Suppakul, P. (2008). Antifungal activity of clove and cinnamon oil and their synergistic against postharvest decay fungi of grape *in vitro*. Kasetsart Journal (Natural Science), 42, 169–174. https://li01.tci-thaijo.org/index.php/anres/article/view/244586

Taştan, Ö., & Baysal, T. (2013). Meyve-Sebze İşleme Endüstrisinde Kitosan Kullanımı. GIDA, 38 (3), 175-182. https://dergipark.org.tr/tr/pub/gida/issue/6951/92720

Tripathi, P., Dubey, N. K., Shukla, A. K. (2008). Use of essential oils as postharvest botanical fungicides in the management of grey mould of grapes caused by *Botrytis cinerea*. World Journal of Microbiology and Biotechnology, 24, 39–46. https://doi.org/10.1007/s11274-007-9435-2

Valero, D., Martinez-Romero, D., Serrano, M. (2002). The role of polyamines in the improvement of the shelf life of fruit. Trends Food Sci. Technol., 13, 228–234. https://doi.org/10.1016/S0924-2244(02)00134-6

Valero, D., Valverde, J. M., Martínez-Romero, D., Guillén, F., Castillo, S., Serrano, M. (2006). The combination of modified atmosphere packaging with eugenol or thymol to maintain quality, safety and functional properties of table grapes. Postharvest Biology and Technology, 41, 317–327. https://doi.org/10.1016/j.postharvbio.2006.04.011

Valverde J. M., Guillén F., Martínez-Romero D., Castillo S., Serrano M., Valero D. (2005). Improvement of table grapes quality and safety by the combination of modified atmosphere packaging (MAP) and eugenol, menthol, or thymol. J. Agric. Food Chem., 53, 7458–7464. https://doi.org/10.1021/jf050913i

Wurms, K. V., Long, P. G., Sharrock, K. R., Greenwood, D. R. (1999). Review: The potential for resistance to *Botrytis cinerea* by Kiwifruit. Crop Protection, 18, 427–435. https://doi.org/10.1016/S0261-2194(99)00047-2

Xu, W. T., Huang, K. L., Guo, F., Qu, W., Yang, J. J., Liang, Z. H., Luo, Y. B. (2007). Post-harvest grape fruit seed extract and chitosan treatment of table grapes to control *Botrytis cineria*. Postharvest Biology and Technology, 46, 86–94. https://doi.org/10.1016/j.postharvbio.2007.03.019

Yang, H. J., Lee, J. H., Lee, K. Y., Bin Song, K. (2017). Application of gelatin film and coating prepared from dried Alaska Pollock by-product in quality maintanance of grape berries. J Food Process Preserv., 41 (6), https://doi.org/10.1111/jfpp.13228

Zoffoli J. P., Latorre B. A., Naranjo P. (2008). Hairline, a postharvest cracking disorder in table grapes induced by sulfur dioxide. Postharvest Biol. Technol., 47, 90–97. https://doi.org/10.1016/j.postharvbio.2007.06.013