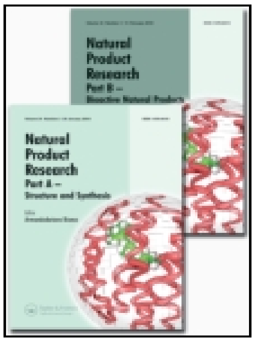

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SHORT COMMUNICATION

Evaluation of essential oils for maintaining postharvest quality of Thompson seedless table grape

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The effects of postharvest spraying of essential oils from sweet basil (*Ocimum basilicum*), fennel (*Foeniculum vulgare*), summer savory (*Satureja hortensis*) and thyme (*Thymus vulgaris*) on fungal decay and quality parameters of the 'Thompson seedless' table grape stored at $0 \pm 1^{\circ}C$ for 60 days were evaluated. Results showed that the essential oils, especially of thyme and fennel, have a good inhibitory effect on the development of fungal decay in Thompson table grapes. In addition, essential oils reduced weight loss, berry and rachis browning and had no considerable adverse effect on the flavour of the fruits. GC-MS analysis showed that the main compounds identified in sweet basil, fennel, summer savory and thyme oils are linalool (65.25%), trans-anethole (64.72%), carvacrol (54.14%) and β-ocimene (12.62%), respectively. Therefore, these essential oils have good potential for use as an alternative to synthetic fungicides for the preservation and storage of table grapes.

Keywords: essential oil; table grape; storage; fungal decay; quality parameters

1. Introduction

Table grape is a non-climacteric fruit with low physiological activity and susceptible to fungal decay during postharvest handling, storage and marketing. Several fungi such as *Alternaria alternata* (Fr.: Fr.) Keissler., *Aspergillus niger* Tiegh., *Botrytis cinerea* Pers.: Fr., *Mucor piriformis* A. Fischer., *Penicillium* spp. and *Rhizopus stolonifer* (Ehrenb: Fr) Vuill. are common postharvest pathogens causing high losses of grapes in most regions of world (Snowdon, 1990). Storage in low temperature and frequent SO_2 fumigation during storage or use of SO_2 generator pads are the main

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methods to control postharvest diseases of table grapes (Crisosto, Smilanick, Dokoozlian, & Luvisi, 1994).

Although SO_2 treatment is a feasible option in controlling fungal decay, its application is faced with restrictions in many countries. SO_2 residues have a harmful effect on the environment and people. Moreover, the use of SO_2 may cause damage in grape berries such as bleaching of berries, browning of rachis and off-flavour of grapes (Taylor, 1993). Therefore, it is necessary to develop alternative control methods which are able to reduce postharvest decay of table grapes with no residues for consumers and environment.

Natural products such as plant essential oils are research areas for the development of new strategies for postharvest fungal decay control. Essential oils are secondary metabolites that plants usually synthesised in response to stress conditions, as well as, they play an important role in the protection of plants as antibacterial, antiviral, antifungal, insecticide and also against herbivores by reducing their appetite for such plant (Bakkali, Averbeck, Averbeck, Zhiri, & Idaomar, 2008; Rauha et al., 2000). Recently, many studies have been carried out on plant essential oils and their constituents for screening antifungal activity and potential use to postharvest pathogens control on fruit and vegetables (Abdolahi, Hassani, Ghosta, Javadi, & Meshkatalsadat, 2010b; R.K. Dubey, Kumar, & N.K. Dubey, 2007; Martínez-Romero et al., 2008; Serrano, Martínez-Romero, Castillo, Guillén, & Valero, 2005; Tripathi, Dubey, & Shukla, 2008; Valero et al., 2006).

Although several studies on the antimicrobial activity of sweet basil, fennel, summer savory and thyme oils have been performed (Abdolahi, Hassani, Ghousta, Bernousi, & Meshkatalsadat, 2010a; Daferera, Ziogas, & Polissio, 2003; Dikbas, Kotan, Dadasoglu, & Sahin, 2008; Reddy, Angers, Gosselin, & Arul, 1998), data on the effect of plant essential oils on postharvest quality of table grape are scarce. Therefore, the aim of this study was to assay the potential use of essential oils from sweet basil, fennel, summer savory and thyme in controlling postharvest fungal decay and enhancing fruit quality and marketability of table grapes.

2. Results and discussion

2.1. *GC-MS analysis*

The chemical composition of essential oils applied in this study is listed in Supplementary Table S1 (online only). The major compounds found in essential oils of sweet basil, fennel, summer savory and thyme were linalool (65.25%), trans-anethole (64.42%), carvacrol (54.14%) and thymol (10.56%), respectively.

2.2. *Fruit decay*

Spraying of essential oils performed a good inhibitory effect on disease severity (Supplementary Table S2 – online only). The effectiveness of essential oils on the control of fungal decay was dependent on the type and concentration of essential oil. The antifungal activity of oils enhanced as essential oil concentration increased (Supplementary Figure S1 – online only). Thyme oil had the greatest antifungal activity and fennel, summer savory and sweet basil oils showed less antifungal activity (Supplementary Figure S2 – online only). In addition, the antifungal activity of essential oils was dependent on the storage period, as with the passage of storage time fruit decay increases (Supplementary Figure S3 – online only).

For many years plant extracts and essential oils have been used in folk medicine and in food preservation. The antimicrobial activity of essential oils has been acknowledged in several studies (Abdolahi et al., 2010b; Lee et al., 2007; Tripathi et al., 2008). Novel treatment using essential oils may have relatively high acceptance, because of consumer preference for the use of natural plant products rather than synthetic fungicides to control decay. Essential oils are biodegradable in native, non-pollutants and posses no residual or phytotoxic properties, they are active in vapour phase and they have minimum effect on the organoleptic properties of food (Serrano et al., 2005; Sharma & Tripathi, 2008).

The results of this study are in accordance with the reports of Özcan, Chalchat, Arslan, Ates, and Ünver (2006), Klarić, Kosalec, Mastelić, Pieckozá, and Pepeljnak (2007) and Dikbas et al. (2008) who have mentioned that fennel, thyme and summer savory oils show high antifungal activity against *Alternaria alternata*, *Mucor* spp. and *Aspergillus flavus*.

Reddy et al. (1998) states that *Thymus vulgaris* essential oil contains phenolic compounds such as thymol (18.1%) and carvacrol (8.9%) and has high efficacy in the reduction of gray mould and soft rots in strawberries, caused by *B. cinerea* and *R. stolonifer*, respectively. Tripathi et al. (2008) mentioned that the essential oils extracted from *Prunus persica*, *Ocimium cannum* and *Zingiber officinable* show high fungitoxic effect on *B. cinerea* in grapes and enhanced shelf-life of grape berries. The effectiveness of some constituents of essential oils such as thymol, eugenol, menthol and carvacrol in MAP packaging in reducing funal decay in table grapes and sweet cherries has been well documented (Guillén et al., 2007; Serrano et al., 2005; Valero et al., 2006; Valverde et al., 2005).

The action of essential oils from several plants against microorganisms has been previously discussed by several authors (Cox & Markham, 2007; Farag, Daw, & Abo-Raya, 1989; Lambert, Skandamis, Coote, & Nycs, 2001; Nychas, 1995; Rasooli & Owlia, 2005). It is known that the antimicrobial property of essential oils is related to their chemical composition. Additionally, it is well documented that the chemical composition of essential oil is affected by the plant genotype, geographical origin, season, environmental and agronomic condition (Marotti, Dellacecca, Piccaglia, & Giovanelli, 1993; Özcan et al., 2006). Several researchers reported that there is a relationship between the chemical structures of most dominant compounds in the assayed essential oil and antifungal activity although the exact action mechanism(s) of the essential oils against fungi has not been completely clarified (Farag et al., 1989). Nychas (1995) claimed that the phenolic compounds available in essential oils such as thymol, carvacrol and γ-terpinene are the main components that can be responsible for antimicrobial activity of essential oils. Rasooli and Owlia (2005) noted that essential oils of *Thymus eriocalycx* and *Thymus xporlock*, which contain thymol as a major component (63.8 and 31.7%), showed fungistatic activity against *Aspergillus parasiticus*. Additionally, they described that the main targets of essential oils are cell wall and cell membrane of fungus. Arras and Usai (2001) demonstrated that the antifungal activity of thyme oil can be related to carvacrol as a phenolic compound in the essential oil that causes morphological alternations of hyphae and conidia of *P. digitatum*. Cox and Markham (2007) described that hydrophobicity of essential oil and accumulation of these hydrophobic compounds in the lipid-rich environments of cell membrane structures and damage to cell membrane is one of the factors that affect the antimicrobial property of essential oil. Some essential oils may affect the production energy and structural components in microorganism (Lambert et al., 2001). Lee et al. (2007) stated that the inhibitory effect of plant extracts on fungal growth is due to the inhibition of mycelia growth or spore germination. Dubey et al. (2007) reported that the essential oil of *Euputorium cannabinum* shows fungitoxic effect on *Botryodiplodia theobromae* and *Colletotrichum gloesporioides* causing stem end rot and anthracnose diseases, respectively, in mango. Also they described that these oils show inhibitory effect on pectinase and cellulase enzymes produced by fruit-rotting fungi and play a prominent role in disease development. Some authors have said that the antimicrobial activity of essential oils can be related to the total composition of essential oil and being synergistic relationship between major and minor components of essential oil (Daferera et al., 2003). Therefore, according to the results of this study and previous studies, it can be concluded that the effect of thyme and summer savory oils in the control of postharvest fungal decay can be related to the existence of phenolic components (thymol and carvacrol) in essential oil.

2.3. *Quality sensors*

The weight loss of fruits increased during storage period which was significantly higher in control than treated clusters. The weight loss in clusters treated with sweet basil oil was lower than other treatments. The percentage of weight loss decreased as essential oil concentration increased (Supplementary Table S3 – online only).

The cluster appearance was significantly affected by treatments (Table S2). Thyme oil at $\geq 200\,\mu L\,L^{-1}$ concentrations and fennel oil at $\geq 400\,\mu L\,L^{-1}$ concentrations were the most effective treatments and sweet basil oil showed the lowest effect on keeping cluster appearance (Table S3). Sensory analysis shows that oil-treated grapes were slightly less acceptable than controls. The effect of sweet basil oil on fruit taste was less than that of other treatments (Table S3).

Berry shrinkage levels of fruits were affected by essential oils treatment. As the essential oil concentration increased the level of berry shrinkage decreased. Fennel and thyme oils at $600\,\mu L\,L^{-1}$ concentration were more effective than other treatments (Table S3). Likewise, essential oil treatments show inhibitory effects on the berry browning. Fennel and summer savory oils at $600\,\mu L\,L^{-1}$ concentration were more effective than other treatments. On the other hand, sweet basil oil increased berry browning in all concentrations (Table S3). All treatments significantly reduced rachis browning in compare with the control. On the contrary, sweet basil oil was more effective in inhibition of rachis browning than other oils (Table S3).

The fruits treated with sweet basil oil showed lower levels of TSS than other oils and differences between fennel, summer savory and thyme oil were not significant (Supplementary Figure S4 – online only). On the other hand, an increase in essential oil concentration enhanced the levels of TA and treated fruits with summer savory oil showed the lowest TA (Supplementary Figures S5 and S6 – online only). MI was significantly higher in control than in treated berries. The MI decreased as the essential oil concentration increased. The highest reduction in MI was observed in berries treated with summer savory oil (Table S3).

A few reports on the essential oil effect on quality sensors of fruits have been published. Thanassoulopoulos and Yanna (1997) reported that origanum, sweet basil and thyme oils have adverse effect on quality of kiwi fruits.

Results of this study showed that essential oils can have positive effects on quality sensors. Weight loss of clusters, browning of berry and rachis and fungal decay are the most important factors that affect the shelf-life of table grape (Crisosto, Smilanick, & Dokoozlian, 2001). It is observed that the reduction of weight loss by essential oil components occurs in cherry (Serrano et al., 2005) and table grape (Valero et al., 2006) indicating that essential oil forms a hydrophobic cover on fruits and lowers the dehydration process. Also in treated fruits, level of berry and rachis browning were lower than controls. It seems that essential oils could reduce the activity of poly phenoloxidase enzyme and reduce berry and rachis browning. Additionally, the rachis and berry browning is affected by weight loss (Crisosto et al., 2001). On the basis of this study, we can speculate that the effectiveness of essential oils in reducing weight loss (%) could result in an increase in rachis and berry browning in oil-treated fruits.

3. Conclusion

On the basis of our results and previous studies, it can be emphasised that some essential oils show promising antifungal properties and can be used as suitable alternatives to synthetic preservative agents for the treatment of table grapes. However, further *in vitro* and *in vivo* studies are required to improve our knowledge of the action mechanism(s) of essential oils on fungi and quality sensors of fruits.

Supplementary material

Experimental details are available online, alongside Tables S1–S3 and Figures S1–S6.

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