

Chapter 1

GENERAL INTRODUCTION

Although the first orange trees (*Citrus sinensis* (L.) Osbeck) were planted in South Africa shortly after the arrival of Jan van Riebeeck in 1652, citrus was only exported from 1902 (Stanbury, 1996). Since then the South African citrus industry has grown to become the third largest exporter in the world, following Spain and the USA. The total production of citrus fruit increased from 1.26 million tonnes in the 1997/98 season to approximately 1.33 million tonnes in the 1998/99 season (Abstract of Agricultural Statistics, 2000). Due to the growing industry, exports doubled and new markets were developed which included the Far East, Eastern Europe and North America (Branders, 1996; Anonymous, 1998).

With development of new export markets and the subsequent long shipping conditions, shelf life of fruit have to be extended without compensating quality (Johnson & Sangchote, 1993). One of the major constraints to extent shelf life is postharvest diseases, and losses of up to 6% can occur on the export market (A. Heitmann, Capespan (Pty) Ltd., Cape Town, SA, personal communication). These diseases include *Alternaria* rot (*Alternaria citri* Ellis & N.Pierce), *Aspergillus* rot (*Aspergillus niger* Tiegh.), anthracnose (*Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.), stem-end rot (*Lasiodiplodia theobromae* (Pat.) Griffon & Maubl.), sour rot (*Geotrichum citri-aurantii* (Ferraris) E.E. Butler), green mould (*Penicillium digitatum* (Pers.: Fr. Sacc.), blue mould (*Penicillium italicum* Wehmer), *Rhizopus* rot (*Rhizopus stolonifer* (Ehrenb.: Fr.) Vuill), *Trichoderma* rot (*Trichoderma viride* Pers. Fr.) (Brown & Eckert, 1989; Eckert & Brown, 1989) and whisker mould (*Penicillium ulaiense* Hsieh, Su & Tzean) (Holmes *et al.*, 1994). These pathogens infect either pre- (*A. citri*, *C. gloeosporioides*, *L. theobromae*, *T. viride*) or postharvestly (*A. niger*, *G. candidum*, *P. digitatum*, *P. italicum*, *P. ulaiense*, *R. stolonifer*, *T. viride*) through wounds or natural openings (Sommer, 1982; Brown & Eckert, 1989; Eckert & Brown, 1989).

Postharvest applications of fungicides such as guazatine, imazalil and thiabendazole are the primary means of controlling postharvest diseases of citrus (Shachnai & Barash, 1982; Eckert & Ogawa, 1985; Pelsler, 1988; Smilanick *et al.*, 1997). However, widespread and intensive use of these fungicides resulted in the development of fungicide resistant strains of the postharvest

pathogens (Bancroft *et al.*, 1984; Bus *et al.*, 1991; Eckert *et al.*, 1994). Furthermore, regulatory restrictions by the US Environmental Protection Agency make registration of new fungicides increasingly difficult (Couey, 1989). This, and the increased public concern about fungicide residue on fruit (Johnson & Sangchote, 1993), created a need for development of alternative decay control strategies (Couey, 1989; Van Staden, 1994).

Several environmentally-friendly approaches are available for the control of postharvest pathogens, including a) biological control, b) natural plant products, surfactants and disinfectants, c) induced resistance and d) harvesting and handling techniques which minimise injury and infection by pathogens (Wisniewski & Wilson, 1992).

Biological control of citrus postharvest pathogens is a widely studied field, with numerous reports referring to the use of bacteria, yeasts and fungi (Table 1). Remarkable successes with biocontrol agents have been obtained on avocado (Korsten *et al.*, 1995), apple (Janisiewicz *et al.*, 1998), peach (Pusey *et al.*, 1988), mango (Koomen & Jeffries, 1993; De Villiers & Korsten, 1996), litchi (Korsten *et al.*, 1993), and pear (Janisiewicz & Criof, 1992, Benbow & Sugar, 1999). However, only a few of these antagonists have been registered and are available as commercial products for the control of postharvest diseases, e.g. Aspire (*Candida oleophila* strain I-182; Ecogen Inc., Langhorne, PA), Bio-Save 110 and 111 (*Pseudomonas syringae* strains ESC 10 and ESC 11, EcoScience Corp., Worcester, MA) (Cook *et al.*, 1996; Teixidó *et al.*, 1998) and Avogreen (*Bacillus subtilis* (B246), Pretoria, SA) (L. Korsten, University of Pretoria, personal communication).

Another approach to disease control is the use of natural plant products. Singh *et al.* (1980) found that certain essential oils exhibited strong antifungal activity against *Bipolaris oryzae* (Breda de Haan) Shoemaker. More recently, Wilson *et al.* (1997) successfully tested plant extracts and essential oils against *Botrytis cinerea* Pers. Fr., a postharvest pathogen of various fruit commodities. This research area has remained largely unexplored in the citrus environment.

For many years, food and dairy industries have made wide use of surfactants and disinfectants for cleaning processing plants and decontamination of raw foodstuffs (Park *et al.*, 1991). This approach to the control of postharvest diseases has been studied in several fruit commodities. The use of surfactants and disinfectants usually forms part of fruit washing, as it reduces the risk of dip tank water as a source of inoculum (Spotts &

Cervantes, 1992; Johnson & Sangchote, 1993). Various surfactants and disinfectants have been tested with success, including calcium chloride, Triton X-100 and ozone on apples (Conway *et al.*, 1992; Ong *et al.*, 1996; Roy *et al.*, 1996) and Agrisan, ethanol, Iodet, KOCl, Terminator, SU 319 and Stericlen on avocado (Boshoff *et al.*, 1995; Van Dyk *et al.*, 1997). Ethanol and Terminator reduced postharvest decay of mango (De Villiers & Korsten, 1996) and peach (Feliciano *et al.*, 1992; Margosan *et al.*, 1997; Zeneca Agrochemicals users pamphlet). Postharvest diseases of pear were controlled using sodium hypochlorite, flotation salts, Ortho X-77, Ag-98, chlorine dioxide and ozone (Spotts & Peters, 1980; Spotts, 1984; Spotts & Cervantes, 1987, 1989, 1992). Effective control of strawberry diseases was obtained using chitosan (El Ghaouth *et al.*, 1992). In the citrus industry, sodium dodecylbenzenesulfonate, ethanol and chlorine dioxide were found effective against green mould by Stange & Eckert (1994), Smilanick *et al.* (1995) and Lesar (1997), respectively, while sodium carbonate and potassium bicarbonate showed fungistatic ability (Smilanick *et al.*, 1999).

Several mechanisms of disease resistance operate simultaneously in fruit. Ben-Yehoshua *et al.* (1992) studied the role of preformed and induced antifungal materials in the resistance of citrus fruit to green mould. Subjecting fruit to fungal challenge and/or abiotic stress (heat or UV illumination) induce production of scoparone. This phytoalexin was more fungicidal to *P. digitatum* than preformed antifungal compounds such as citral. Heat treatment of citrus fruit to induce resistance has been widely studied, with reports as early as 1922 by Fawcett. Heat is usually applied to a fruit commodity via air or water (Barkai-Golan & Phillips, 1991). However, water is a more efficient heat transfer medium than air having a higher transfer coefficient (Jacobi *et al.*, 1993). Therefore, hot-water treatments are quicker and more effective in heat transfer to fruit than hot air treatments (Shellie & Mangan, 1993). Numerous investigations using heated water treatments have shown benefits for citrus postharvest disease control in many countries, including Israel (Rodov *et al.*, 1996), Italy (Dettori *et al.*, 1996), South Africa (De Villiers *et al.*, 1996) and the USA (Brown & Baraka, 1996). Hot water treatment of other fruit commodities such as nectarines and peaches, also substantially reduced postharvest decay (Margosan *et al.*, 1997), with similar results obtained in avocado (Plumbley *et al.*, 1993) and mango (Spalding & Reeder, 1986). In the papaya industry, immersion of fruit in hot water has been the principal postharvest treatment for decay control since 1964 (Akamine, 1967). Fungicides such as imazalil (Smilanick *et al.*, 1997) and biocontrol agents (De Villiers *et al.*, 1996) may be integrated with hot water treatments to enhance their efficacy.

Efficacy of all the above decay control strategies can be enhanced by proper handling and sanitation procedures (Sommer, 1982). It is well-known that careless harvesting and handling practices, along with high inoculum levels of postharvest pathogens in the fruit environment, are the main factors involved in the initiation of disease (Di Martino Aleppo & Lanza, 1996). Spores of pathogenic fungi are produced on decayed fruit and are transferred by air currents, water dip tanks and fruit handling equipment to sound fruit in the packhouse (Gardner *et al.*, 1986). According to Gardner *et al.* (1986), efficacy of a management strategy to reduce fruit contamination depends on several key elements, viz. a) isolation of spore-generating areas, b) careful handling of fruit, c) proper sanitation procedures for decontamination of fruit handling equipment, d) weekly assays to monitor pathogen spore populations, e) judicious use of fungicides and f) modification of existing packhouse operations to prevent dispersal of pathogen inoculum.

In this study, some of the alternative decay control strategies discussed were investigated, viz. introduction of an antagonist, warm water and integrated applications, determination of infection sites in packhouses and disinfestation with non-selective chemicals, all to form part of a total quality management system for citrus fruit which would ensure the required quality and product consistency demanded by consumers (Hilton, 1993).

Table 1 Published reports on biological control of citrus postharvest diseases

Antagonist	Pathogen	References
<i>Aureobasidium pullulans</i> (De Bary) G. Arnaud	<i>Penicillium digitatum</i> + <i>Penicillium italicum</i>	Wilson & Chalutz, 1989
<i>Bacillus pumilus</i>	<i>P. digitatum</i>	Huang <i>et al.</i> , 1992
<i>Bacillus subtilis</i>	<i>Alternaria citri</i> + <i>Geotrichum citri-aurantii</i> + <i>P. digitatum</i> <i>A. citri</i> + <i>Botrytis cinerea</i> + <i>Colletotrichum gloeosporioides</i> + <i>G. citri-aurantii</i> + <i>P. digitatum</i> + <i>P. italicum</i> <i>B. cinerea</i> + <i>P. digitatum</i>	Singh & Deverall, 1984 Arras, 1993 Arras & D'Hallewin, 1994
<i>Candida famata</i> (FC Harrison) SA Meyer & Yarrow	<i>P. digitatum</i> <i>P. digitatum</i>	Arras, 1996, 1999 D'Hallewin <i>et al.</i> , 1999
<i>Candida guilliermondii</i> (Castelani) Langeron & Guerra [teleomorph <i>Pichia guilliermondii</i> Wickerham]	<i>P. digitatum</i> <i>P. digitatum</i>	McGuire, 1994 Droby <i>et al.</i> , 1999
<i>Candida oleophila</i> Montrocher	<i>G. citri-aurantii</i> + <i>P. digitatum</i> <i>G. citri-aurantii</i> + <i>P. digitatum</i> + <i>P. italicum</i> <i>P. digitatum</i> <i>P. digitatum</i> <i>P. digitatum</i>	Shachnai <i>et al.</i> , 1996 Droby <i>et al.</i> , 1998 El-Neshawy & El-Sheikh Aly, 1998 Droby <i>et al.</i> , 1999 McGuire & Dimitroglou, 1999
<i>Candida sake</i>	<i>P. italicum</i> <i>P. digitatum</i>	Arras <i>et al.</i> , 1997 Droby <i>et al.</i> , 1999

<i>Debaryomyces hansenii</i> (Zopf) Lodder & Kreger van Rij	<i>G. citri-aurantii</i> + <i>P. digitatum</i> + <i>P. italicum</i> <i>P. digitatum</i> <i>P. digitatum</i> + <i>P. italicum</i> <i>G. citri-aurantii</i> + <i>P. digitatum</i> + <i>P. italicum</i> <i>P. italicum</i> <i>P. digitatum</i> + <i>P. italicum</i> <i>G. citri-aurantii</i> <i>B. cinerea</i> + <i>P. digitatum</i> + <i>P. italicum</i> <i>P. digitatum</i>	Chalutz <i>et al.</i> , 1988 Droby <i>et al.</i> , 1989 Wilson & Chalutz, 1989 Chalutz & Wilson, 1990 Chalutz & Wilson, 1992 Mehrotra <i>et al.</i> , 1996 Mehrotra <i>et al.</i> , 1998 Arras & Arru, 1999 Droby <i>et al.</i> , 1999
<i>Kluyveromyces</i> sp.	<i>P. digitatum</i>	Cheah & Tran, 1995
<i>Myrothecium roridum</i> Tode	<i>P. digitatum</i>	Appel <i>et al.</i> , 1988
<i>Myrothecium verrucaria</i> (Alb. & Schwein.) Ditmar	<i>P. digitatum</i>	Appel <i>et al.</i> , 1988
<i>Paecilomyces lilacinus</i> (Thom) Samson	<i>P. digitatum</i> + <i>P. italicum</i>	Wang <i>et al.</i> , 1996
<i>Pichia guilliermondii</i> Wickerham	<i>P. digitatum</i>	Droby <i>et al.</i> , 1993, 1997
<i>Pseudomonas cepacia</i>	<i>P. digitatum</i> + <i>P. italicum</i> <i>P. digitatum</i> <i>P. digitatum</i> <i>P. digitatum</i> <i>P. digitatum</i> + <i>P. italicum</i>	Wilson & Chalutz, 1989 Huang <i>et al.</i> , 1991 Smilanick & Denis-Arrue, 1992 Huang <i>et al.</i> , 1993a Huang <i>et al.</i> , 1993b
<i>Pseudomonas corrugate</i>	<i>P. digitatum</i>	Smilanick & Denis-Arrue, 1992
<i>Pseudomonas fluorescens</i>	<i>P. digitatum</i>	Smilanick & Denis-Arrue, 1992
<i>Pseudomonas glathei</i>	<i>P. digitatum</i>	Huang <i>et al.</i> , 1995

<i>Pseudomonas syringae</i>	<i>P. digitatum</i> + <i>P. italicum</i>	Wilson & Chalutz, 1989
	<i>P. digitatum</i>	Smilanick <i>et al.</i> , 1996
	<i>P. digitatum</i> + <i>P. italicum</i>	Bull <i>et al.</i> , 1997
	<i>P. digitatum</i>	Smilanick <i>et al.</i> , 1999
<i>Saccharomyces cerevisiae</i> Meyer ex. Hansen	<i>P. digitatum</i>	Cheah & Tran, 1995
<i>Trichoderma viride</i>	<i>G. citri-aurantii</i> + <i>P. digitatum</i>	De Matos, 1983
	<i>P. digitatum</i>	Borrás & Aguilar, 1990
	<i>C. gloeosporioides</i> + <i>G. citri-aurantii</i>	Borrás <i>et al.</i> , 1993

REFERENCES

Abstract of Agricultural Statistics. 2000. Department of Agriculture, SA.

Akamine, E.K. 1967. History of the hot water treatment of papaya. *Hawaii Farm Science* 16: 4-6.

Anonymous. 1998. Increased demand for citrus abroad. *Agriculture News* 2: 5.

Appel, D.J., Gees, R. & Coffey, M.D. 1988. Biological control of the postharvest pathogen *Penicillium digitatum* on Eureka lemons. *Phytopathology* 78: 1595.

Arras, G. 1993. Inhibition of postharvest fungal pathogens by *Bacillus subtilis* strains isolated from citrus fruit. *Advances in Horticultural Sciences* 7: 123-127.

Arras, G. 1996. Mode of action of an isolate of *Candida famata* in biological control of *Penicillium digitatum* in orange fruits. *Postharvest Biology and Technology* 8: 191-198.

Arras, G. & Arru, S. 1999. Integrated control of postharvest citrus decay and induction of phytoalexins by *Debaryomyces hansenii*. *Advances in Horticultural Science* 13: 76-81.

Arras, G., Dessi, R., Sanna, P., Arru, S. 1999. Inhibitory activity of yeasts isolated from fig fruits against *Penicillium digitatum*. *Acta Horticulturae* 485: 37-46.

Arras, G. & D'Hallewin, G. 1994. *In vitro* and *in vivo* control of *Penicillium digitatum* and *Botrytis cinerea* in citrus fruit by *Bacillus subtilis* strains. *Agricoltura Mediterranea* 124: 56-61.

Arras, G., Sanna, P. & Astone, V. 1997. Biological control of *Penicillium italicum* of citrus fruits by *Candida sake* and calcium salt. *Proceedings of the 49th International Symposium on Crop Protection* 4: 1071-1078.

Bancroft, M.N., Gardner, P.D., Eckert, J.W. & Baritelle, J.L. 1984. Comparison of decay control strategies in California lemon packinghouses. *Plant Disease* 68: 24-28.

- Barkai-Golan, R. & Phillips, D.J. 1991.** Postharvest heat treatment of fresh fruits and vegetables for decay control. *Plant Disease* 75: 1085-1089.
- Benbow, J.M & Sugar, D. 1999.** Fruit surface colonization and biological control of postharvest diseases of pear by preharvest yeast applications. *Plant Disease* 83: 839-844.
- Ben-Yehoshua, S., Rodov, V., Kim, J.J & Carmeli, S. 1992.** Preformed and induced antifungal materials of citrus fruits in relation to the enhancement of decay resistance by heat and ultraviolet treatments. *Journal of Agricultural Food Chemistry* 40: 1217-1221.
- Borrás, A.D. & Aguilar, R.V. 1990.** Biological control of *Penicillium digitatum* by *Trichoderma viride* on postharvest citrus fruits. *International Journal of Food Microbiology* 11: 179-184.
- Borrás, M.A.D., Cervera, V., Luis, G. & Vila, R. 1993.** Control of *Colletotrichum gloeosporioides* and *Geotrichum candidum* through action of *Trichoderma viride* and commercial fungicides. *Microbiologie, Aliments, Nutrition* 11: 425-428.
- Boshoff, M., Slabbert, M.J. & Korsten, L. 1995.** Effect of detergent sanitizers on postharvest diseases of avocado. *South African Avocado Growers' Association Yearbook* 18: 96-98.
- Branders, J. 1996.** Citrus export grows apace. *Citrus Journal* 6: 2.
- Brown, G.E. & Baraka, M.A. 1996.** Effect of washing sequence and heated solutions to degreened Hamlin oranges on *Diplodia* stem-end rot, fruit colour and phytotoxicity. *Proceedings of the 8th Congress of the International Society of Citriculture* 2: 1164-1170.
- Brown, G.E. & Eckert, J.W. 1989.** Postharvest fungal diseases. Pages 30-38 in: J.O. Whiteside, S.M. Garnsey & L.W. Timmer (eds). *Compendium of citrus diseases*. APS Press, St. Paul, Minnesota.
- Bull, C.T., Stack, J.D. & Smilanick, J.L. 1997.** *Pseudomonas syringae* strains ESC-10 and ESC-11 survive in wounds on citrus and control green and blue molds of citrus.

Biological Control 8: 81-88.

Bus, V.G., Bangers, A.J. & Risse, L.A. 1991. Occurrence of *Penicillium digitatum* and *P. italicum* resistant to benomyl, thiabendazole, and imazalil on citrus fruit from different geographic origins. *Plant Disease* 75: 1098-1100.

Chalutz, E. & Wilson, C.L. 1990. Postharvest biocontrol of green and blue mold and sour rot of citrus fruit by *Debaryomyces hansenii*. *Plant Disease* 74: 134-137.

Chalutz, E. & Wilson, C.L. 1992. Biological control of postharvest diseases of fruits and vegetables through manipulation of epiphytic plant microflora. Pages 259-266 in: D.D. Bills & S.D. Kung (eds). *Biotechnology and food safety. Proceedings of the 2nd International Symposium, Maryland.*

Chalutz, E., Cohen, L., Weiss, B. & Wilson, C.L. 1988. Biocontrol of postharvest diseases of citrus fruit by microbial antagonist. *Proceedings of the 6th Congress of the International Society of Citriculture* 3: 1467-1470.

Conway, W.S., Sams, C.E., McGuire, R.E. & Kelman, A. 1992. Calcium treatment of apples and potatoes to reduce postharvest decay. *Plant Disease* 76: 329-334.

Cheah, L.H. & Tran, T.B. 1995. Postharvest biocontrol of *Penicillium* rot of lemons with industrial yeasts. *Proceedings of the 48th New Zealand Plant Protection Conference* 1: 155-157.

Cook, R.J., Bruckart, W.L., Coulson, J.R., Gaettel, M.S., Humber, R.A., Lumsden, R.D., Maddox, J.V., McManus, M.L., Moore, L., Meyer, S.F., Quimby, P.C., Stack, J.P. & Vaughn, J.L. 1996. Safety of microorganisms intended for pest and plant disease control: a framework for scientific evaluation. *Biological Control* 7: 333-351.

Couey, H.M. 1989. Heat treatment for control of postharvest diseases and insect pests of fruit. *Horticultural Science* 24: 198-202.

De Matos, A.P. 1983. Chemical and microbiological factors influencing the infection of

- Droby, S., Lischinski, S., Cohen, L., Weiss, B., Daus, A., Chand-Goyal, T., Eckert, J.W. & Manulis, S. 1999.** Characterization of an epiphytic yeast population of grapefruit capable of suppression of green mold decay caused by *Penicillium digitatum*. *Biological Control* 16: 27-34.
- Droby, S., Wisniewski, M.E., Cohen, L., Weiss, B., Touitou, D., Eilam, Y. & Chalutz, E. 1997.** Influence of CaCl₂ on *Penicillium digitatum*, grapefruit peel tissue, and biocontrol activity of *Pichia guilliermondii*. *Phytopathology* 87: 310-315.
- Eckert, J.W. & Brown, G.E. 1989.** Postharvest fungal diseases. Pages 30-38 in: J.O. Whiteside, S.M. Garnsey & L.W. Timmer (eds). *Compendium of citrus diseases*. APS Press, St. Paul, Minnesota.
- Eckert, J.W. & Ogawa, J.M. 1985.** The chemical control of postharvest diseases: subtropical and tropical fruits. *Annual Review of Phytopathology* 23: 421-454.
- Eckert, J.W., Sievert, J.R. & Ratnayake, M. 1994.** Reduction of imazalil effectiveness against citrus green mold in California packinghouses by resistant biotypes of *Penicillium digitatum*. *Plant Disease* 78: 971-975.
- El Ghaouth, A., Arul, J., Grenier, J. & Asselin, A. 1992.** Antifungal activity of chitosan on two postharvest pathogens of strawberry fruits. *Phytopathology* 82: 398-402.
- Fawcett, H.S. 1922.** Packinghouse control of brown rot. *California Citrograph* 7: 232, 254.
- El-Neshawy, S.M. & El-Sheikh Aly, M.M. 1998.** Control of green mould on oranges by *Candida oleophila* and calcium treatments. *Annals of Agricultural Science* 3: 881-890.
- Feliciano, A., Feliciano, A.J., Vendrusculo, J., Adaskaveg, J.E. & Ogawa, J.M. 1992.** Efficacy of ethanol in postharvest benomyl - DCNA treatments for control of brown rot of peach. *Plant Disease* 76: 226-229.
- Gardner, P.D., Eckert, J.W., Baritelle, J.L. & Bancroft, M.N. 1986.** Management strategies for control of *Penicillium* decay in lemon packhouses: economic benefits. *Crop*

Protection 5: 26-32.

Hilton, D.J. 1993. Impact and vibration damage to fruit during handling and transportation. Pages 116-126 in: Postharvest handling of tropical fruits. B.R. Champ, E. Highley & G.I. Johnson (eds). The Australian Centre for International Agricultural Research, Brisbane, Australia.

Holmes, G.J., Eckert, J.W. & Pitt, J.I. 1994. Revised description of *Penicillium ulaiense* and its role as a pathogen of citrus fruit. *Phytopathology* 84: 719 – 727.

Huang, Y., Deverall, B.J. & Morris, S.C. 1991. Promotion of infection of orange fruit by *Penicillium digitatum* with a strain of *Pseudomonas cepacia*. *Phytopathology* 81: 615-618.

Huang, Y., Deverall, B.J. & Morris, S.C. 1993a. Effect of *Pseudomonas cepacia* on postharvest biocontrol of infection by *Penicillium digitatum* and on wound responses of citrus fruit. *Australasian Plant Pathology* 22: 84-93.

Huang, Y., Deverall, B.J. & Morris, S.C. 1995. Postharvest control of green mould on oranges by a strain of *Pseudomonas glathei* and enhancement of its biocontrol by heat treatment. *Postharvest Biology and Technology* 5: 129-137.

Huang, Y., Deverall, B.J., Morris, S.C. & Wild, B.L. 1993b. Biocontrol of postharvest orange diseases by a strain of *Pseudomonas cepacia* under semi-commercial conditions. *Postharvest Biology and Technology* 3: 293-304.

Huang, Y., Wild, B.L. & Morris, S.C. 1992. Postharvest biological control of *Penicillium digitatum* decay on citrus fruit by *Bacillus pumilus*. *Annals of Applied Biology* 120: 367-372.

Jacobi, K., Coates, L. & Wong, L. 1993. Heat disinfestation of mangoes: Effect on fruit quality and disease control. Pages 280-287 in: Postharvest handling of tropical fruits. B.R. Champ, E. Highley & G.I. Johnson (eds). The Australian Centre for International Agricultural Research, Brisbane, Australia.

Janisiewicz, W.J., Conway, W.S., Glenn, D.M. & Sams, C.E. 1998. Integrating biological

control and calcium treatment for controlling postharvest decay of apples. *Horticultural Science* 33: 105-109.

Janisiewicz, W.J. & Criof, A.M. 1992. Control of storage rots on various pear cultivars with a saprophytic strain of *Pseudomonas syringae*. *Plant Disease* 76: 555-560.

Johnson, G.I. & Sangchote, S. 1993. Control of postharvest diseases of tropical fruit. Challenges for the 21st century. Pages 140-161 in: Postharvest handling of tropical fruits. B.R. Champ, E. Highley & G.I. Johnson (eds). The Australian Centre for International Agricultural Research, Brisbane, Australia.

Koomen, I. & Jeffries, P. 1993. Effects of antagonistic microorganisms on the post-harvest development of *Colletotrichum gloeosporioides* on mango. *Plant Pathology* 42: 230-237.

Korsten, L., De Jager, E.S., De Villiers, E.E., Lourens, A., Kotzé, J.M. & Wehner, F.C. 1995. Evaluation of bacterial epiphytes isolated from avocado leaf and fruit surfaces for biocontrol of avocado postharvest diseases. *Plant Disease* 79: 1149-1156.

Korsten, L., De Villiers, E.E., De Jager, E.S., Van Harmelen, M.W.S. & Heitmann, A. 1993. Biological control of litchi fruit diseases. *South African Litchi Growers' Association Yearbook* 5: 36-40.

Lesar, K. 1997. *In vitro* evaluation of oxine (chlorine dioxide) as an alternative to calcium hypochloride for packhouse water sanitation. *Citrus Journal* 7: 26-28.

Margosan, D.A., Smilanick, J.L., Simmons, G.F. & Henson, D.J. 1997. Combination of hot water and ethanol to control postharvest decay of peaches and nectarines. *Plant Disease* 81: 1405-1409.

McGuire, R.G. 1994. Application of *Candida guilliermondii* in commercial citrus coatings of biocontrol of *Penicillium digitatum* on grapefruits. *Biological Control* 4: 1-7.

McGuire, R.G. & Dimitroglou, D.A. 1999. Evaluation of shellac and sucrose ester fruit

coating formulations that support biological control of post-harvest grapefruit decay. *Biocontrol Science and Technology* 9: 53-65.

Mehrotra, N.K., Neeta, S., Ghosh, R. & Nigam, M. 1996. Biological control of green mould disease of citrus fruit by yeast. *Indian Phytopathology* 49: 350-354.

Mehrotra, N.K., Neeta, S., Nigam, M. & Ghosh, R. 1998. Biological control of sour-rot of *Citrus* fruits by yeast. *Biological Sciences* 68: 133-139.

Ong, K.C., Cash, J.N., Zabik, M.J., Siddiq, M. & Jones, A.L. 1996. Chlorine and ozone washes for pesticide removal from apples and processed apple sauce. *Food Chemistry* 55: 153-160.

Park, D.L., Rua, S.M. & Accker, R.F. 1991. Direct application of a new hypochlorite sanitizer for reducing bacterial contamination on foods. *Journal of Food Protection* 54: 960-965.

Pelser, P. du T. 1988. Aanbevelings vir bestryding van na-oesbederf by sitrusvrugte. SA Co-operative Citrus Exchange Ltd., Pretoria, SA.

Plumbley, R.A., Prusky, D. & Kobilier, I. 1993. The effect of hot-water treatment on the levels of antifungal diene and quiescene of *Colletotrichum gloeosporioides* in avocado fruits. *Plant Pathology* 42: 116-120.

Pusey, P.L., Hotchkiss, N.W., Dulmage, H.T., Baumgardner, R.A., Zehr, E.I., Reilly, C.C. & Wilson, C.L. 1988. Pilot tests for commercial production and application of *Bacillus subtilis* (B-3) for postharvest control of peach brown rot. *Plant Disease* 72: 622-626.

Rodov, V., Peretz, J., Ben-Yehoshua, S., Agar, T. & D'Hallewin, G. 1996. Heat applications as complete or partial substitutes for postharvest fungicide treatments of grapefruit and oroblanco fruits. *Proceedings of the 8th Congress of the International Society of Citriculture* 2:1153-1157.

- Roy, S., Conway, W.S., Buta, J.G., Watada, A.E., Sams, C.E. & Wergin W.P. 1996.** Surfactants affect calcium uptake from postharvest treatment of "Golden Delicious" apples. *Journal of the American Society of Horticultural Science* 121: 1179-1184.
- Shachnai, A. & Barash, I. 1982.** Evaluation of the fungicides CGA 64251, guazatine, sodium o-phenylphenate, and imazalil for control of sour rot on lemon fruits. *Plant Disease* 66: 733-735.
- Shachnai, A., Chalutz, E., Droby, S., Cohen, L., Weiss, B., Daus, A., Katz, H., Bercovitz, A., Keren-Tzur, M. & Binyamini, Y. 1996.** Commercial use of Aspire™ for the control of postharvest decay of citrus fruit in the packhouse. *Proceedings of the 8th International Congress of the Society for Citriculture 2*: 1174-1177.
- Shellie, K.C. & Mangan, R. 1993.** Disinfestation: Effect of non-chemical treatments on market quality of fruit. Pages 304-310 in: Postharvest handling of tropical fruits. B.R. Champ, E. Highley & G.I. Johnson (eds). The Australian Centre for International Agricultural Research, Brisbane, Australia.
- Singh, V. & Deverall, B.J. 1984.** *Bacillus subtilis* as a control agent against fungal pathogens of citrus fruit. *Transactions of the British Mycological Society* 83: 487-490.
- Singh, A.K., Dickshit, A., Sharma, M.L. & Dixit, S.N. 1980.** Fungitoxic activity of some essential oils. *Economic Botany* 34: 186-190.
- Smilanick, J.L. & Denis-Arrue, R. 1992.** Control of green mold of lemons with *Pseudomonas* species. *Plant Disease* 76: 481-485.
- Smilanick, J.L., Gouin-Behe, C.C., Margosan, D.A., Bull, C.T. & Mackey, B.E. 1996.** Virulence on citrus of *Pseudomonas syringae* strains that control postharvest green mold of citrus fruit. *Plant Disease* 80: 1123-1128.
- Smilanick, J.L., Margosan, D.A. & Henson, D.J. 1995.** Evaluation of heated solutions of sulfur dioxide, ethanol and hydrogen peroxide to control postharvest green mold of lemons. *Plant Disease* 79: 742-747.

- Smilanick, J.L., Margosan, D.A., Mlikota, F., Usall, J. & Michael, I.F. 1999.** Control of citrus green mold by carbonate and bicarbonate salts and the influence of commercial postharvest practices on their efficacy. *Plant Disease* 83: 139-145.
- Smilanick, J.L., Michael, I.F., Mansour, M.F., Mackey, B.E., Margosan, D.A., Flores, D. & Weist, C.F. 1997.** Improved control of green mold of citrus with imazalil in warm water compared with its use in wax. *Plant Disease* 81: 1299-1304.
- Sommer, N.F. 1982.** Postharvest handling practices and postharvest diseases of fruit. *Plant Disease* 66: 357-364.
- Spalding, D.H. & Reeder, W.F. 1986.** Decay and acceptability of mangos treated with combinations of hot water, imazalil, and γ -radiation. *Plant Disease* 70: 1149-1151.
- Spotts, R.A. & Peters, 1980.** Chlorine and chlorine dioxide for control of d'Anjou pear decay. *Plant Disease* 64: 1095-1097.
- Spotts, R.A. 1984.** Effect of a surfactant on control of decay of Anjou pear with several fungicides. *Plant Disease* 68: 860-862.
- Spotts, R.A. & Cervantes, L.A. 1987.** Effects of the nonionic surfactant Ag-98 on three decay fungi of Anjou pear. *Plant Disease* 71: 240-242.
- Spotts, R.A. & Cervantes, L.A. 1989.** Evaluation of disinfection-flotation salt-surfactant combinations on decay fungi of pear in a model dump tank. *Phytopathology* 79: 121-126.
- Spotts, R.A. & Cervantes, L.A. 1992.** Effect of ozonated water on postharvest pathogens of pear in laboratory and packhouse tests. *Plant Disease* 76: 256-259.
- Stanbury, J.S. 1996.** The nature and scope of the Southern Africa citrus industry. *Proceedings of the 8th Congress of the International Society of Citriculture* 1: 7-11.
- Stange, R.R. & Eckert, J.W. 1994.** Influence of postharvest handling and surfactants on control of green mold of lemons by curing. *Phytopathology* 84: 612-616.

- Teixidó, N., Viñas, I., Usall, J. & Magan, N. 1998.** Control of blue mold of apples by preharvest application of *Candida sake* grown in media with different water activity. *Phytopathology* 88: 960-964.
- Van Dyk, K., De Villiers, E.E. & Korsten, L. 1997.** Alternative control of avocado postharvest diseases. *South African Avocado Growers' Association Yearbook* 20: 109-112.
- Van Staden, F. 1994.** New technology – A must. *Citrus Journal* 4: 2.
- Wang, M.Z., Zhou, H.Z., Fu, Y.P. & Wang, C.H. 1996.** The antifungal activities of the fungus 36-1 to several plant pathogens. *Chinese Journal of Biological Control* 12: 20-23.
- Wilson, C.L. & Chalutz, E. 1989.** Postharvest biological control of *Penicillium* rots of citrus with antagonistic yeasts and bacteria. *Scientia Horticulturae* 40: 105-112.
- Wilson, C.L., Solar, J.M., El Ghaouth, A. & Wisniewski, M.E. 1997.** Rapid evaluation of plant extracts and essential oils for antifungal activity against *Botrytis cinerea*. *Plant Disease* 81: 204-210.
- Wisniewski, M.E. & Wilson, C.L. 1992.** Biological control of postharvest diseases of fruit and vegetables: Recent advances. *Horticultural Science* 27: 94-97.