THE JOURNAL OF HORTICULTURAL SCIENCE AND BIOTECHNOLOGY
https://doi.org/10.1080/14620316.2025.2542405

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REVIEW

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An overview of essential methods for preservation of sweet potato roots: a mini-review

Nonjabulo L. Bambalele[a], Asanda Mditshwa[a], Samson Z. Tesfay[a], Sunette M. Laurie[b], Hussein Shimelis[c] and Lembe S. Magwaza[d,e]

[a]Department of Horticultural Sciences, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa; [b]Agricultural Research Council-Vegetables, Industrial and Medicinal Plants (ARC-VIMP), Pretoria, South Africa; [c]African Centre for Crop Improvement (ACCI), School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa; [d]Postharvest Research Group, Cranfield University, Bedfordshire, UK; [e]Department of Food Systems and Development, Faculty of Natural and Agricultural Sciences, University of Free State, Bloemfontein, South Africa

ABSTRACT

Sweet potato is an essential and nutritious staple root crop in many parts of the world. This crop is multipurpose, humans consume the storage roots, while above-ground biomass is used for livestock feed. However, the roots are susceptible to sprouting during postharvest storage. Additionally, sweet potatoes are prone to postharvest diseases such as root rot, black rot, and soft rot. Various technologies have been used to preserve the quality of sweet potatoes. Studies have shown that techniques such as hot water, essential oils, and edible coatings effectively control postharvest disorders and diseases. Furthermore, treatments such as ethylene have been used to preserve sweet potato quality. However, negative outcomes such as root decay have been reported. As a result, the combination of 1-methylcyclopropene (1-MCP) and ethylene has been evaluated as a potential strategy for maintaining the quality of sweet potatoes. This mini-review examines the key postharvest techniques used for sweet potatoes. Also, the challenges of ethylene, 1-MCP, and hot water treatment are critically discussed.

ARTICLE HISTORY
Received 26 February 2025
Accepted 28 July 2025

KEYWORDS
Sweet potato; postharvest; shelf-life; sprouting; chilling injury; diseases

Introduction

Sweet potatoes are tuberous roots that form part of a staple diet in numerous African countries (Sanoussi et al., 2017). The roots are favoured for their nutritional properties such as flavonoids, phenols, carotenoids, protein, and carbohydrates (Laurie et al., 2018). The South African sweet potato industry is continuously growing. In 2019, the industry had an approximate annual production of 93,000 tons, with a value of $15.7 million (Laurie et al., 2024). Sweet potatoes have a storage life of 28 to 50 days at temperatures between 13–16°C (de Araújo et al., 2021; S. Q. Wang et al., 2019). However, the roots have thin skin and a high moisture content of 50–80%, which makes them susceptible to factors such as chilling injury, fungal diseases, and sprouting (Sanchez et al., 2021; H. Zhang et al., 2021). Sprouting causes starch degradation, decreasing root's quality and nutritional value (Sun et al., 2025). Amylase degrades starch into simple sugars, providing the energy necessary for the sprouting of sweet potato roots (Sun et al., 2025). Starch is one of the essential components of sweet potato roots and plays a vital role during processing (Sun et al., 2025). Nevertheless, postharvest sprouting reduces the market value of sweet potatoes due to diminished nutritional quality and lower consumer acceptance (Lima et al., 2019; Sugri et al., 2017).

Therefore, researchers have evaluated the effect of various postharvest techniques in maintaining the quality of sweet potatoes. Postharvest treatments such as edible coatings, hot air or water, ethylene, and 1-methylcyclopropene (1-MCP) effectively preserve the quality of fresh produce. Ethylene has been used to control sprouting in sweet potatoes (Lima et al., 2021). However, continuous ethylene treatment is associated with end root splitting and decay (Kou et al., 2023). The combinational use of ethylene and 1-MCP has been proposed to overcome this challenge. 1-MCP inhibits ethylene production and decreases the rate of respiration, thus hindering biochemical processes involved in starch degradation and sprouting (Amoah & Terry, 2018; Kou et al., 2023). The advantages of 1-MCP and ethylene include minute residue, superior chemical stability, and non-toxicity (Kou et al., 2023). Nonetheless, elevated concentrations of 1-MCP and ethylene can have detrimental effects, including low sugar content, increased respiration rate, and root diseases. Therefore, the effectiveness of 1-MCP in suppressing sprouting and maintaining sweet potato quality is influenced by the concentration, cultivar, and treatment time (Kou et al., 2023).

CONTACT Nonjabulo L. Bambalele bambalelen@ukzn.ac.za Department of Horticultural Sciences, School of Agricultural, Earth and Environmental Sciences, University of KwaZulu-Natal, Pietermaritzburg, South Africa; Lembe S. Magwaza lembe.magwaza@cranfield.ac.uk Postharvest Research Group, Cranfield University, College Road, Bedfordshire MK43 0AL, UK

Essential oils have antimicrobial and antibacterial properties which are obtained from plant materials such as roots, leaves, bark, fruits, seeds, and herbs. Furthermore, they contain volatile compounds, and their characteristics are influenced by factors such as extraction method, geographical origin, storage condition, and botanical source (Vianna et al., 2021). Studies show that essential oils can control various postharvest pathogens such as *Ceratocystis fimbriata* and *Rhizopus stolonifer* in fresh produce (Wang et al., 2024; Yan et al., 2021). The antimicrobial activity of essential oils is ascribed to the paramount constituents and the type of pathogen. Additionally, cinnamaldehyde contains key compounds such as terpenes, limonene, eugenol, and E-cinnamoyl acetate, which suppresses the pathogen's cell wall and cytoplasmic membrane (Chouhan et al., 2017; Firmino et al., 2018). Moreover, the elevated levels of these compounds have been correlated with improved antimicrobial efficacy. This mini-review examines the key postharvest techniques used for sweet potatoes, focusing on the past ten years. Also, future gaps, advantages, and disadvantages will be discussed.

Synergism between 1-methylcyclopropene and ethylene in sprouting suppression

1-MCP is an ethylene inhibitor that is effective in preserving the quality of fresh produce. Various studies have shown that 1-MCP effectively delays sprouting and extends the sweet potatoes' shelf life. The effectiveness of 1-MCP in preserving the quality of sweet potatoes depends on factors such as concentration, cultivar, and harvest maturity (Amoah & Terry, 2018; Cao et al., 2021). Studies by Lima et al. (2019) revealed that 1-MCP (1 mg L^{-1}) augmented the soluble sugars of sweet potato ('BRS Rubissol') during storage for four weeks at 25°C. Contrarily, Amoah and Terry (2018) reported that 1-MCP (1 μL L^{-1}) decreased the soluble sugar content of 'Covington' sweet potatoes stored at 15°C for twenty weeks. The accumulation of soluble sugars in tuberous roots could be ascribed to starch degradation during sprouting. Sucrose and abscisic acid (ABA) are closely associated with the sprouting of sweet potato roots (Cao et al., 2021; Tosetti et al., 2021). During sprouting, the sucrose catabolizing enzyme Trehalose-6-phosphate activates ABA through ABA 8′ -hydroxylase (Sheikh et al., 2022).

Sweetness is a vital sensory parameter in sweet potatoes, consumers purchase the roots based on the sugar content. However, the target market and intended use of the roots are equally important. Consumer acceptance of sweet potatoes varies depending on their sugar content. For instance, consumers who use the root as a staple starch prefer minute sugar levels. Whereas, augmented sugar content negatively affects the processing quality of sweet potatoes and is preferred in American and European cuisines (Kou et al., 2023). The augmented sugar content is associated with internal browning in processed sweet potatoes (Fukuoka et al., 2020).

Ethylene is a plant hormone that is associated with various physiological processes during the plant's growth cycle (Kou et al., 2023). As earlier mentioned, ethylene has been used as a postharvest treatment to control sprouting in sweet potatoes (Lima et al., 2021). However, studies have demonstrated that ethylene exposure can lead to root decay and reduced sugar content (Kou et al., 2023). To solve some of these negative effects, 1-MCP is used as an ethylene antagonist. The treatment combination of ethylene and 1-MCP has shown effective results in controlling sprouting in sweet potatoes. According to Tosetti et al. (2021), combining ethylene with 1-MCP at 10 μL L^{-1} and 1 μL L^{-1}, respectively, suppressed sprouting for three weeks in 'VR808' potatoes stored at 8.5°C. To effectively control sprouting in sweet potatoes, continuous ethylene treatment is required (Kou et al., 2023). The control of sprouting in sweet potatoes by ethylene treatment could be attributed to ABA catabolism. In potatoes, ethylene upregulates gene expression of *CYP707A1_a*, thus inducing ABA catabolism (Tosetti et al., 2021). ABA is an important hormone that is responsible for root tuber formation and development. Therefore, ABA catabolism triggers dormancy in root tuber crops, thus delaying sprouting.

The treatment combination of ethylene (10 μL -L^{-1}) and 1-MCP (1 μL L^{-1}) inhibited sprouting in 'Owairaka Red' cultivar stored at 25°C for four weeks (Pankomera et al., 2016). Moreover, these authors show that the ethylene and 1-MCP treatment combination caused darkening of the flesh, enhanced the weight loss, and respiration rate. Therefore, the concentration of both treatments should ensure that sprouting and weight loss are delayed. These studies demonstrate the potential effect of the combined treatment in preserving the quality and extending the shelf-life of sweet potatoes. However, several questions still arise about these treatments. For instance, can 1-MCP utterly block ethylene receptors, thus inhibiting sprouting? Also, can ethylene maintain the sugar content in tuberous roots? Considering the involvement of ethylene in the production of aroma and flavour volatiles, what is the impact of 1-MCP on the sensory attributes of sweet potatoes? These are the gaps that need further investigation to optimise the impact of these treatments on postharvest quality.

Effect of cold storage on the chilling injury of sweet potatoes

Cold storage increases the shelf-life and maintains the fresh produce quality. However, sweet potatoes are susceptible to chilling injury (CI) during storage at low temperatures for a long time. The chilling injury in sweet potatoes is characterised by the browning of the internal skin, pitting, and surface rotting. Various studies revealed that the optimum storage temperature for sweet potatoes is 13–16°C (X. Li et al., 2018; S. Q. Wang et al., 2019). Ji et al. (2017) reported CI in 'Yulmi' sweet potato stored at 4°C for six weeks. Similarly, CI was observed after twenty days in 'BRS Rubissol' sweet potato stored at 6°C (de Araújo et al., 2021). The CI is associated with altering the membrane lipid composition, cell structure, and membrane (S. Q. Wang et al., 2019). Lipid oxidation occurs due to the excessive accumulation of reactive oxygen species (ROS), which leads to cell structure injury, electrolyte leakage, and CI (X. Li et al., 2018). de Araújo et al. (2021) showed a positive association between hydrogen peroxide (H_2O_2) and superoxide anion ($O^{2-)}$) and lipid peroxidation. The chilling injury could be due to the inability of the sweet potato to activate the ROS-scavenging enzymes such as ascorbate peroxidase (APX), catalase (CAT), and superoxide dismutase (SOD).

Enzymes SOD, CAT, and APX are responsible for eradicating the chilling-induced ROS in plant tissues. For instance, the low enzyme activity of CAT, SOD, and APX was reported in 'Xushu' sweet potatoes stored at 4°C for eight days (S. Q. Wang et al., 2019). The decreased enzyme activity could explain why this cultivar is intolerant to chilling temperatures. Also, the reduced enzyme activity could be attributed to the gene expression of *IbSOD*, *IbAPX*, and *IbCAT3*. The downregulation of these genes could be due to oxidative damage.

Impact of heat treatment on sweet potatoes

Hot water treatments (HWTs) are effectively used to control postharvest disorders and diseases in fresh produce. Temperature and treatment time are crucial in ensuring the efficacy of HWTs (Table 1). For instance, Stahr and Quesada-Ocampo (2020) evaluated the effect of various temperatures in controlling *C. fimbriata* causing black rot in 'Covington' sweet potatoes. The authors reported that decreasing temperature below 35°C enhanced the sporulation and disease severity of black rot in 'Covington' sweet potato. However, HWT at 55°C for 10 min inhibited mycelial growth and spore germination of *R. stolonifer* (L. Li et al., 2021). Suhaizan et al. (2019) reported that HWT (50°C, 10 min) reduced the disease development and severity of *R. stolonifer* in 'Gendut' sweet potato during storage at 27°C for twenty-five days. Similarly, L. Li et al. (2021) observed that HWT (55°C, 10 min) effectively controlled fungal disease causing soft rot in 'Xiguahong' sweet potato. The disease control of soft rot could be attributed to HWT destroying the pathogen membrane. The HWT could destroy the cell membrane structure, causing electrolyte leakage and thus cell death. The same study reported an increase in plasma membrane permeability in *Rhizopus stolonifer* following HWT.

Intermittent heat treatment delayed the occurrence of chilling injury for sixty days in 'Longshu No. 9' sweet potatoes stored at 5°C (Pan et al., 2019a). The same study reported a low chilling injury index in sweet potatoes subjected to intermittent heat treatment. Similarly, Cheng et al. (2024) reported that HWT at 45°C for three hours decreased the browning degree and CI rate of 'Longshu 9' sweet potato during storage at 5°C for fifty days. As earlier mentioned, storing sweet potatoes at low temperatures triggers the synthesis of ROS such as H_2O_2 and superoxide anion (O^{2-}). Notably, HWT has the ability to stimulate antioxidant enzyme activity, thereby enhancing the plant's defence mechanisms. Enzymes such as CAT, glutathione reductase (GR), SOD, and APX are produced during oxidative stress to scavenge ROS. Cheng et al. (2024) observed an increase in the enzyme activity of CAT, GR, SOD, and APX after HWT (45 ℃) in sweet potatoes stored at 5°C. Also, the enzyme activity of SOD and CAT was enhanced after HWT (Pan et al.,

Table 1. The effect of hot water treatment (HWT) on physicochemical and nutritional quality of sweet potato roots storage.

Cultivar	Treatment	Key findings	Reference
Beauregard & Evangeline	52°C for 20 min.	Increased *R. stolonifer* sporangiospores and susceptibility to Rhizopus soft rot.	Sweany et al. (2020)
Pushu13 & Xinxiang	35°C for 24 h.	Retained protein, flavone & starch content. Enhanced the enzyme activity of polyphenol oxidase, POD & APX in *R. stolonifer* inoculated roots. Also, reduced activities of polygalactosidase & cellulase.	Wu et al. (2023)
Xiguahong	65°C for 15 min.	Enhanced DPPH, and ROS activities as well as chlorogenic acid, *p*-coumaric acid, rutin, & flavonoid content.	Xin et al. (2022)
WS7 (Yellow colour), YS7 (Yellow colour), XY34 (Orange colour) & CS1 (Yellow colour)	100°C for 60 min.	Reduced the carotenoid and total folate content.	Pan et al. (2019b)
Longshu 9	48°C for 10 min.	Suppressed CI, delayed browning degree, MDA & ROS accumulation. Enhanced enzyme activity of APX, CAT & SOD.	X. Zhang et al. (2025)

2019a). The delayed CI could be due to the enzyme activity of CAT, GR, SOD, and APX suppressing the oxidative stress of the roots. Additionally, these enzymes break down H_2O_2 into O_2 and H_2O, thus preserving the sweet potato roots (Cheng et al., 2024). Therefore, the enhanced antioxidant enzyme activity induces cold resistance in sweet potato roots, thus mitigating CI effects and maintaining quality.

Additionally, the cold resistance in sweet potato roots could be attributed to the heat shock proteins. Heat stress stimulates the production of small heat shock proteins (sHSPs) (Khan & Shahwar, 2020). These proteins have an essential role in preventing oxidative damage, preserve membrane integrity and cold tolerance in plants (L. Wang et al., 2020; Wu et al., 2022). Yu et al. (2020) reported that mRNA and its target gene regulate the sweet potato seedling defence during chilling stress. The chilling stress modifies the *IbmiR319* gene expression. In wild tomatoes, *sha-miR319b* activated ROS-related genes *ZAT10*, *ZAT12*, and *CBF1*; chilling-related genes *MYB83* and *CBF1*, and inhibited *GAMYB-like1* (Shi et al., 2019). The *sha-miR319* is positively correlated with *CuZnSOD* and *CAT* gene expression (Shi et al., 2019). There is a knowledge gap about the role of heat shock proteins in enhancing the cold tolerance of sweet potatoes. Further research is required to gain a molecular understanding of heat shock factors in regulating heat shock genes in sweet potatoes during chilling stress.

Role of edible coatings in preserving sweet potato quality

Edible coatings are used to enhance fresh produce quality and are categorised into lipids, composites, and hydrocolloids (Matloob et al., 2023). These coatings are formulated with one or two of these components at various concentrations depending on the intended application (Table 2). Polysaccharide-based coatings such as gum, chitosan, and alginate are used due to their antimicrobial properties, ease of application, and excellent gas permeability (Matloob et al., 2023; Paidari et al., 2021). Lipid-based coatings are effective as water barriers, whereas protein and polysaccharide-based coatings furnish superior gas barrier properties (Yousuf et al., 2022). Various lipids such as fatty acids, waxes, and vegetable oils are added to coatings due to their hydrophobic nature. Lipid coatings include essential oils, which can be incorporated to enhance the antimicrobial properties of films and edible coatings (Yousuf et al., 2022). Gums, chitosan, and alginates are polysaccharides used to formulate coatings due to easy extraction, application, and ordered hydrogen bonding between polymer chains (Paidari et al., 2021; Xu et al., 2019). These edible films are biodegradable and contain antioxidant properties that are essential for human health.

Effectiveness of chitosan in sustaining sweet potato quality

Chitosan is a natural biopolymer that is attained by extracting the acetyl group, which alters the chitin morphology (Duan et al., 2019). It has antimicrobial properties against fungi and bacteria and has been used to control sweet potato postharvest diseases. Xing, Li, et al. (2018) reported that chitosan (2 μg μL^{-1}) retarded hyphae formation and spore germination of *C. fimbriata*. The toxicity of chitosan against pathogens is through membrane destruction, leading to increased membrane permeability. Chitosan alters the mycelial ultra structures and morphology such as distorted spores, shrank hyphae, and destroyed membranous organelles (Xing et al., 2017; Xing, Li, et al., 2018). Furthermore, chitosan inhibited ROS accumulation, causing oxidative damage to intercellular structures (T. Li et al., 2020). Suppressed enzyme activity of malondialdehyde and the magnitude of membrane disruption have also been reported after chitosan application (Xing, Li, et al., 2018). It can be speculated that chitosan destroys the pathogen's cell membrane, resulting in potassium ions leakage, reducing H^+/K^+ ATPase activities, thus causing necrosis and cell death (Xing, Xing, et al., 2018). Therefore, it can be deduced that membrane damage enhances intracellular components and chitosan binding, which increases the rate of pathogen disruption.

Chitosan 2% enhanced firmness loss in fresh-cut purple flesh sweet potato stored at 5°C for sixteen days (Chit et al., 2022). Contrarily, Guan et al. (2024) reported that chitosan 2% maintained firmness in 'Xinxiang' sweet potatoes during storage for thirtydays

Table 2. Effect of edible coatings on physicochemical and nutritional quality of sweet potatoes.

Coating material	Concentration	Cultivar	Key findings	Reference
Chitosan & Lemongrass essential oil	1% & 0.1%	Orange flesh	Reduced microbial growth, maintained total phenolic content, retarded weight loss, and pigment degradation.	Krishnan et al. (2025)
Aloe vera & Carrageenan	2% & 0.02%	Cilembu	Delayed browning index, TSS accumulation, and weight loss.	Darmawati and Ekawati (2022)
Chitosan	15 g/L	Orange flesh	Enhanced ascorbic acid, maintained carotenoid and flavonoid content.	Mudyantini et al. (2023)
Carnauba wax with glycerol monolaurate	35 g & 1.0 g	Xinxiang	Maintained the sensory attributes, decreased respiration rate, and suppressed the disease severity of black and soft rot.	Yang et al. (2018)

at 25°C. The contrasting results could be attributed to the storage temperature. The low temperatures cause cellular and membrane structure damage (Yu et al., 2020). This indicates that chitosan concentration doesn't increase the root's tolerance to CI. The retained membrane integrity could be attributed to suppressed membrane permeability and lipid peroxidase production (Guan et al., 2024). In the same study, chitosan was found to suppress the enzymatic activities of lipoxygenase and phospholipase, as well as the gene expression of *PLDα*, *PLC*, and *LOX*. This suggests that chitosan down-regulates lipid metabolism membrane genes, thus maintaining sweet potato quality.

Use of essential oils in controlling postharvest diseases

Essential oils are natural compounds with antimicrobial properties against various pathogens. They have been identified as a potential solution to inhibit the development of various postharvest sweet potato diseases. For instance, L. Li et al. (2024) reported that perilladehyde 2.5 μL inhibited spore germination and mycelial growth of *R. stolonifer*. Recently, C. Pan et al. (2023) reported that cinnamaldehyde effectively controlled root rot caused by *Fusarium solani* in sweet potatoes stored at 28°C for ten days. Additionally, Chen et al. (2024) evaluated the efficacy of various concentrations of cinnamaldehyde on *R. stolonifer*

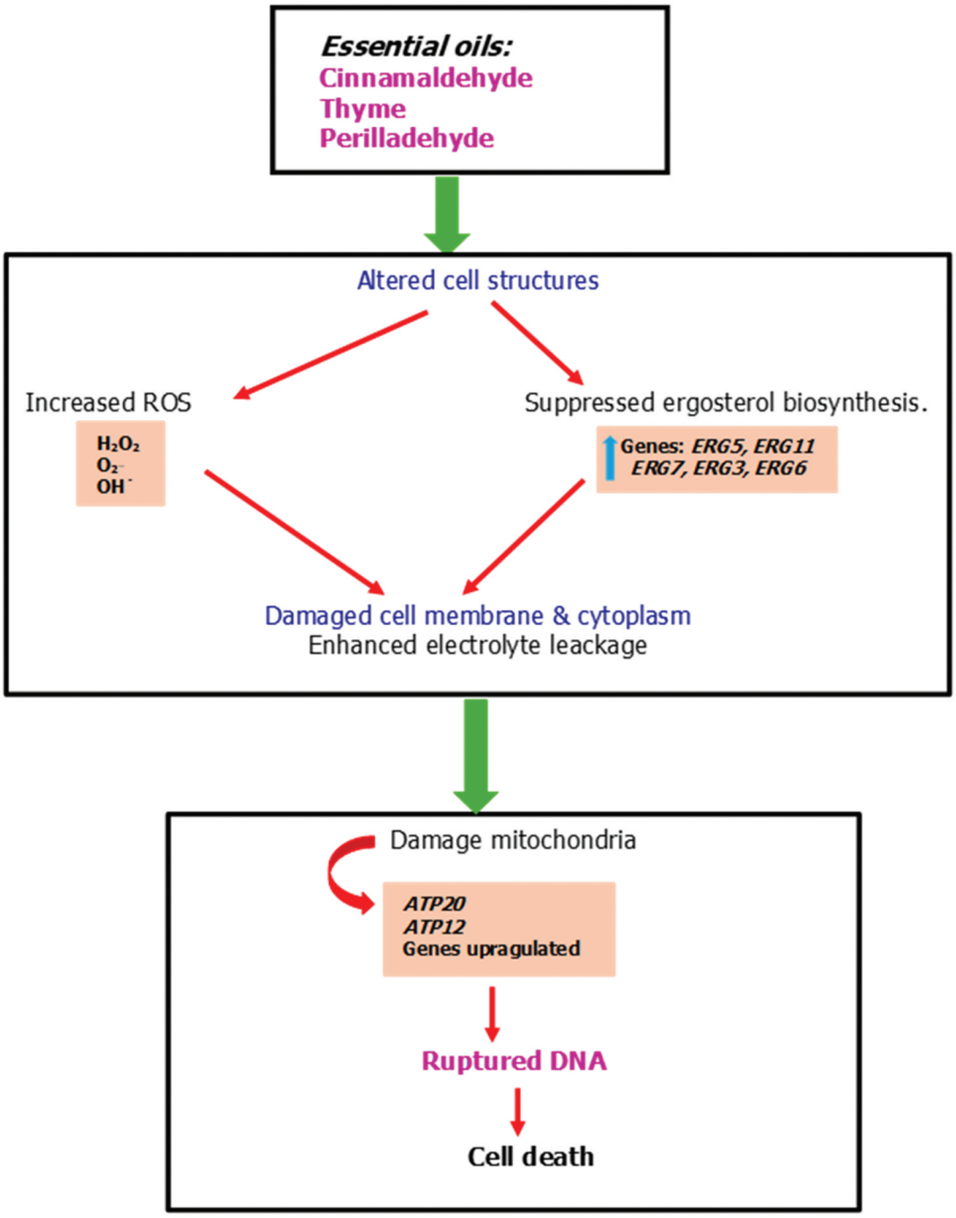

Figure 1. Essential oils suppress fungal pathogens primarily by disrupting the cell membrane. This disruption is triggered by the upregulation of genes involved in ergosterol biosynthesis, including *ERG6* (sterol 24-C-methyltransferase), *ERG11* (cytochrome P450 lanosterol C-14α-demethylase), *ERG7* (lanosterol synthase), *ERG5* (C-22 sterol desaturase), and *ERG3* (C-5 sterol desaturase). The altered expression of these genes compromises membrane integrity and cellular morphology. Additionally, essential oils impair energy metabolism by targeting genes associated with mitochondrial function.

causing soft rot in 'Xinxiang' sweet potatoes. Their findings indicated that cinnamaldehyde 100 μL L^{-1} effectively controlled soft rot for twenty days. Cinnamaldehyde is an essential oil extracted from the bark of various tree species of *Cinnamomum* (Chen et al., 2024). The antifungal activity of essential oils could be attributed to cell membrane disruption, mitochondrial damage, enhanced ROS accumulation, and reduced enzyme activity (Figure 1) (Chen et al., 2024).

Essential oils cause disruption of membrane integrity in pathogens. Disruption of membrane integrity could be due to suppressed ergosterol biosynthesis. Cinnamaldehyde up-regulates the ergosterol gene expression of *ERG7*, *ERG3*, and *ERG5* in *R. stolonifer* (Chen et al., 2024). Wei et al. (2020) reported that cinnamaldehyde upregulated the gene expression of *ERG4*, *ERG11*, and *ERG6* in *Fusarium sambucinum*. Ergosterol preserves the cell membrane morphology, therefore upregulating these genes is positively correlated with damage to cell membrane morphology in pathogens (C. Zhang et al., 2024). Cinnamaldehyde application may cause an enhanced ROS accumulation in *R. stolonifer*, which triggers oxidative stress (Chen et al., 2024). Moreover, increased ROS accumulation induces cell apoptotic through oxidative mitochondrial damage (C. Pan et al., 2023; B. Wang et al., 2024). Chen et al. (2024) observed that cinnamaldehyde upregulated the mitochondrial gene expression of *QCR7*, *IDH1*, and *COX4*. Moreover, cinnamaldehyde suppressed ribosomal gene expression of *RPS1*, *RPS5*, and *RPL*, responsible for cell growth. Therefore, it can be concluded that the hindered cell growth and mitochondrial disruption can induce ROS oxidative stress, leading to pathogen death. Perilladehyde enhances the activities of disease-resistance enzymes such as peroxidase (POD), SOD, and phenylalanine ammonialyse (PAL) in sweet potatoes (L. Li et al., 2024). During oxidative stress, the POD scavenges H_2O_2, thus eradicating the detrimental effect of H_2O_2.

Conclusion and future research

There is a growing need for postharvest technologies to enhance fresh produce quality. Various techniques such as HWTs, chitosan coatings, and essential oils have proven effective in maintaining the postharvest quality of sweet potatoes. Although HWT can aid in maintaining root quality, it poses challenges due to the sensitivity of temperature and exposure time. Excessive heat or prolonged exposure time can lead to quality deterioration and amplify the root's susceptibility to diseases such as soft rot. While some of these technologies are used commercially, they have not been fully adopted as postharvest treatments for sweet potatoes. For example, 1-MCP is widely used to preserve the quality of various fruits and vegetables, but its application to sweet potatoes remains limited. Future research should focus on better understanding the combined effects of ethylene and 1-MCP treatments, including optimal concentrations and exposure times, to effectively enhance sweet potato quality.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was funded by the National Research Foundation's Postdoctoral Grant [PSTD2204193764-PR-2023].

ORCID

Nonjabulo L. Bambalele http://orcid.org/0000-0003-2991-0414
Asanda Mditshwa http://orcid.org/0000-0003-3361-7835
Samson Z. Tesfay http://orcid.org/0000-0001-9568-4764
Sunette M. Laurie http://orcid.org/0000-0002-6719-508X
Hussein Shimelis http://orcid.org/0000-0003-2793-8392
Lembe S. Magwaza http://orcid.org/0000-0001-9809-2254

Author contributions

NLB: Conceptualisation, conducted research, source funding, writing the manuscript's first draft, writing review, and editing
AM: Conceptualisation, supervision, review, and edit manuscript
SZT: Review and editing
LSM: Conceptualisation, research, review and editing
SML: Review and editing
HS: Review and editing

Data availability statement

Data availability does not apply to this manuscript.

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Bambalele, Nonjabulo L.

2026-04

Bambalele NL, Mditshwa A, Tesfay SZ, et al., (2026) An overview of essential methods for preservation of sweet potato roots: a mini-review. The Journal of Horticultural Science and Biotechnology, Volume 101, Issue 2, April 2026, pp. 237-245

https://doi.org/10.1080/14620316.2025.2542405