CALCIUM-RELATED POST-HARVEST PHYSIOLOGICAL DISORDERS OF FRUITS AND VEGETABLES FOUND IN ESWATINI: A REVIEW

ABSTRACT

Calcium (Ca^{2+}) related physiological disorders of fruits and vegetables are abnormalities of fruits and vegetables which are not caused by infectious diseases, insects, nematodes or animals. Fruit and vegetable abnormalities occur due to environmental stress, nutritional deficiencies or excess In the plant. In this study, information was sought through informal surveys, review of literature and interviews with key post-harvest handling and storage participants and direct observation of fruits and vegetables in the markets. Calcium related post-harvest physiological disorders of fruits and vegetables encountered in this study included: cavity-spot, black end and cork, bronzing, skin freckles, fruit and crown, fasciation, soft-nose/spongy-tissue, granulation, low temperature breakdown/flesh browning, water-core, senescent-breakdown, superficial-scald, bitter pit, leaf tip-burn, golden specks and blossom-end rot. Post-harvest physiological disorders result in direct economic losses and pose a threat to food and nutritional security. Various ways of alleviating particular Ca^{2+} related post-harvest related physiological disorders are suggested.

Keywords: Calcium, post-harvest physiological disorders, fruits and vegetables, management, sustainable development goals (SDGs), climate change

INTRODUCTION

Eswatini although it is still a developing country, it is classified under the middle income group, however it is still faced with poverty problems and struggling with HIV and AIDS pandemic [35]. There are high hopes of the 2022 vision by that time the country would have leap flogged to a near fully developed country. The backbone of the country's economy is largely dominated by agriculture whose contribution to the gross domestic product (GDP) is about 11% [31].

Postharvest physiological disorders of fruits and vegetables are problems or abnormalities that are not caused by insects or diseases, but rather by the climate (temperature, rain, humidity) and by management practices that change the micro-climate endured by the fruit plant, for example, pruning, irrigation, fertilization and harvest procedures. They mostly

appear during the growing season or after harvest when the fruits are being stored, and affect the appearance and usability of the fruit by the consumer [11].

The importance of calcium (Ca^{2+}) in the nutrition of plants has long been recognised. Inadequate concentration of calcium has been associated with the development of physiological disorders in many types of fruits and vegetables. Plant parts affected include fruits, storage roots or tubers and the leaves of compact leafy vegetables. Calcium is an important mineral nutrient affecting fruit quality. One of its roles is in maintaining cell wall integrity and bonding between cells by combining with soluble pectin to form insoluble calcium-pectate [11]. As a result, fruit with high levels of calcium are firmer and have longer potential storage life. It has received considerable attention in recent years because of its desirable effects, particularly in fruits where it can reduce respiration, delay ripening, extend storage life, increase firmness and vitamin C content, and reduce storage rot [28], however, [4] explained that many of the postharvest disorders afflicting both storage organs like fruits, vegetables, roots, and young enclosed leafy structures are related to calcium content of the respective tissues. [12] showed that mineral cations including calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}) and ammonium (NH^{4+}) play some role in the development of postharvest disorders.

Mineral nutrients are generally applied to plants to ensure adequate growth and yield and these effects are explained in terms of the function of these elements in plant metabolism. However, mineral nutrients may also exert secondary influences on the growth and yield of plants by causing changes in chemical composition, plant morphology and anatomy which may affect their resistance to pests and diseases [3]. Research that has been conducted indicates that the application of certain calcium salts to fruit crops can affect disease incidence and in particular, reduce rotting. Calcium salts may influence rotting in several different ways [6].

Although most of soils in the agro-ecological zones of Eswatini have adequate calcium, fruit and vegetable disorders related to calcium have been observed [22]. This is because its uptake by plants is closely related to the soil moisture supply, with roots being unable to take up calcium whenever the soil becomes either too wet or too dry. These disorders are due to inefficient distribution of calcium rather than poor calcium uptake [21]. Transport of calcium

within the fruit tree is largely restricted to the xylem, with almost no transport in the phloem, thus, most calcium is deposited in leaves, and relatively little is routed to fruits [23]. It is not transported from leaf to leaf, or from leaves to fruits and other tissues. Because calcium moves slowly through exchange in the xylem and is dependent upon water flow, disruptions in that flow can lead to localized deficiencies in calcium. Plant organs with low transpiration rates or that are rapidly expanding such as fruits and storage roots often do not receive enough calcium to support that growth [9].

Methodology

The study was a qualitative research. Information was sought through desk review of existing literature and informal surveys in the four agro-ecological zones of the country were carried out. Observations were made throughout the postharvest handling chain. Samples of fruits and vegetables crops found on sale in the markets were observed, disorders were identified and described.

Agro-ecological zones of Eswatini

The country has four geographical zones with distinct topography, geology, soils, vegetation and climatic patterns. In the west is the Highveld, which is mountainous and has a vegetation of mainly commercial forests with the bulk of the land being used for subsistence farming [29; 14). It experiences a temperature range of 4.5 to 33˚C [31]. It has rivers, waterfalls and gorges with some protected and natural areas including Malolotsha, Hawane and Phophonyane [13]. The Middleveld is characterized with temperatures ranging from 2.5 to 37.2°C [31]. This region has fertile valleys which favour intensive farming. It has the most diversely cultivated and heavily populated area in the country [31]. Protected nature reserve areas include Mantenga and Milwane [13]. Further east, there is the Lowveld with the largest area coverage of 40% of the country and is drought prone. There is the Western Lowveld which is underlain by sandstone/ claystone and the Eastern Lowveld which is underlain by basalt [13]. It has a vegetation of shrubs, and mean temperature ranges from 2.6 to 41.8˚C with the bulk of commercial farms growing crops under irrigation, including the three sugar estates in the country and citrus fruit plantations. The nature reserves in the area are: Mlawula, Hlane, Shewula, Mbuluzi, Simunye and Nisela game reserves [31; 14]. The fourth region is the escarpment called Lubombo plateau with an altitude of 600m above sea level and climatic conditions similar to the Middleveld. Given the mountainous topography of the

Lubombo plateau, only one eighth of the land is arable and the rest is suitable for animal grazing [13].

Description of individual calcium related physiological disorders found in the Kingdom of Eswatini are discussed below:

Blossom-end rot: This disorder affects most of the Solanaceae and Curcubitaceae family. In watermelons, the symptoms include browning and shrivelling which occur at the blossom end, followed by a secondary decay caused by microorganisms that progress inward. The affected fruits are misshapen, with brown, leathery, rotten lesions on the blossom-end [5]. In tomatoes, the symptoms on mature or immature (green) fruits include a discoloured, sunken spot at the blossom-end of the fruit, cell membranes are disorganised and tissue necrosis develops underneath the skin [19]. [22] reported that the discoloured spot then dries out and becomes leathery, hence rendering it unmarketable. A black sunken spot develops at the blossom-end which later on spreads with water-soaked region around it.

Golden-specks: Golden specks are often observed around the calyx and shoulders of the mature tomato and green pepper fruits [19]. Golden specks are known to be a disorder due to excess calcium in the fruit. It has been identified as cells containing a granular mass of tiny calcium oxide crystals with a golden appearance. The presence of golden specks on tomatoes affects their external appearance and reduces their shelf life [5].

Leaf tip-burn: Tip-burn is caused by a localised shortage of calcium that affects the emerging leaves of most horticultural crops. It appears that shortage of calcium is associated with low-transpiring tissues and can occur in plants generally well supplied with water and nutrients from the soil [25]. This disorder is mostly observed on the leafy vegetables like cabbage, Brussels sprouts, cauliflower, lettuce and Swiss-chard. Its symptoms include rolled up leaves at margins which are ragged and discoloured; white in narrow band, followed by necrosis and death of the growing point (20; 5]. Brown necrotic spots which develop have a tendency of breaking down during transport or in storage, thereby providing ingress to opportunistic decay causing organism [21].

Bitter-pit: Bitter pit is primarily a postharvest disorder of apples, pears and guavas in storage but it also develops late in the growing season while these fruits are attached to the tree [17].

The bitter pit disorder starts internally and finally causes external blemishes. The tissue below the skin becomes dark and corky. Under storage, the affected skin appears to be water-soaked around the calyx and spots generally turn darker and become more sunken than the surrounding skin, taking on a deep-red colour on blush areas and remaining bright green on green or yellow surfaces [33]. Susceptibility of fruit to bitter pit has three components: genetic, climatic and orchard management. Hot dry summers are much more associated with higher bitter-pit disorder incidence than cooler summers. Growers should be considering changes in weather patterns as part of their plans for calcium spray applications as increasing bitter pit levels appear associated with the warmer weather conditions in the summers of the Highveld of Swaziland [21].

Superficial-scald: Superficial scald is a very common postharvest disorder of apples, guavas, pears, tomatoes, green pepper and plums [15]. The appearance and severity depends on the susceptibility of the variety with Granny Smith and Red Delicious being among the worst affected. The skin of the affected fruit turns brown in patches, especially on the shaded side, and may become rough [6]. Only the surface of the fruit is affected, with the flesh remaining firm and of eating quality. The margins between normal and affected skin are diffuse. Browning develops rapidly once the fruit is moved from cold storage to room temperature [7]. The major factors in scald development are variety, climate, harvest time, storage period, cooling rate, ventilation, and ethylene in the storage environment. High N and low Ca can make scald susceptibility worst, but more clearly in cooler growing regions than warmer ones [30].

Senescent-breakdown: This physiological disorder is associated with fruits that have been stored too long and more susceptible to fruits that lack calcium as they grow. Fruits which are more prone to this physiological disorder include apples, guavas, pears, and grapes. The cortical tissues of the fruit are typically dry and mealy [32; 24]. Senescent breakdown occurs earlier and with greater severity in large fruits that are harvested late. This physiological disorder can be controlled by cooling the fruits more rapidly and improved ventilation. The application of Ca sprays can reduce senescent breakdown incidence and postharvest Ca drenches or dips can further decrease this physiological disorder [24; 7; 6].

Water-core: Water-core development is associated with more mature fruit at harvest, cool night time temperatures during the harvest period, and stress conditions in the orchard. Fruits

which develop water-core include plums, nectarines, peaches, tomatoes, eggplant, green pepper and grapes [4]. Development of water-core can be delayed by calcium sprays, but the e□ects of night time temperatures will eventually overwhelm the calcium effects in susceptible fruit. Thus, even fruit with high Ca^{2+} levels can develop water-core in high risk seasons. Fruit with severe water-core should not be stored for long periods, especially in controlled atmosphere (CA) storage, as they can develop water-core associated breakdown [23].

Flesh-browning: Evidence exists that some reduction of low temperature breakdown can be reduced by pre-harvest potassium and calcium spray and postharvest calcium drenches, but commercially consistent and significant e□ects are hard to find [32]. Fruits which exhibit flesh browning include apples, pears, guavas, and eggplant. Postharvest calcium applications have resulted in any significant reduction of browning [3].

Granulation: Granulation is a serious problem of citrus; it is a condition in which the juice-sacs shrivel because of gel formation [16]. On oranges it is commonly seen on young, vigorously growing trees on rough lemon rootstocks. The affected juice sacs become hard and dry; fruits become grey in colour, enlarged in size, have flat and insipid taste and assume a granular texture. The fruit develop a flat, insipid taste as they lose some of their sugar and acid [30]. Granulation also leads to low juice levels and loss of taste. It is much more prevalent in relatively larger sized fruits than in small fruit and in young than in old trees. Late maturity and persistent cold weather throughout the period of maturity have been found to increase the incidence of granulation [16].

Soft-nose: This disorder is known as tip pulp, insidious fruit rot and yeasty fruit rot. Fruits affected by this physiological disorder include mangoes, plum and avocadoes. The typical symptom is breakdown of the flesh towards the apex of the fruit before ripening [10]. Mesocarp cells in fruits of the mango cultivars Kent and Tommy show marked cell separation and cell wall disintegration [4; 23]. The characteristics symptom is that of excess calcium and nitrogen deficiency. To control this physiological disorder it is important to harvest fruits at ¾th maturity stage, apply calcium containing fertilizers like calcium ammonium nitrate and the use of sod culture [32].

Fruit and crown fasciation: this physiological disorder is more dominant in pineapples. Fasciated fruits are deformed to such an extent that they are totally useless [26]. In certain cases, proliferation is so extreme that fruit is highly flattened and twisted with innumerable crowns. Fruit and crown fasciation is associated with high vigour of plants, which take longer time to flower. High fertility of soil, warm weather and calcium or zinc deficiency may favour fasciation [26].

Skin-freckles: Although the cause and factors that influence this disorder are unknown, some believe it to be calcium deficiency [18]. Freckle-like blemishes occur on unripe papaya fruits especially of the cultivar Sunrise solo [8]. The freckle diameter increase during the last phase of fruit growth as the fruits approached the maturity. More freckles are seen on the exposed side of the fruit away from the stem. Remedies to control this physiological disorder include the use of calcium sprays and wrapping young fruits in white paper bags [29].

Bronzing: Bronzing of apples, guava, banana, strawberry and tomato has been observed in places having low soil fertility, lack calcium and low soil pH. Affected plants show purple to red specks scattered all over the leaves [1]. Under aggravated condition, total defoliation and fruits characterized with brown coloured patterns on the skin, with reduced yield are noticed. Foliar application of calcium sprays, 0.5 % di-ammonium phosphate and zinc sulphate in combination at weekly intervals for two months reduced the bronzing in apples [2].

Pulp-spot: This physiological disorder is more common in avocados. It is caused by lack of calcium in the plants as the fruits mature. The first symptoms of pulp spot are noticed soon after the fruit is cut. The spots are initially smooth and glassy, of 1.0 mm in diameter and occur along the vascular bundle. The spots discolour after being exposed to the atmosphere and are generally brown to dark brown within 30 minutes [34]. The severity of pulp spot varies from season to season and the incidence drops rapidly as the season advances. To control this physiological disorder it is important to ensure that the soil has enough calcium and the use of calcium sprays can reduce the incidence of pulp spot [27].

Cavity-spot: This physiological disorder is common in carrots. This disorder appears as a cavity in the cortex, in most cases the subtending epidermis collapses to form a pitted lesion.

The cavity-spot disorder is induced by deficiency of calcium [5]. This is associated with an increased accumulation of potassium which leads to a decreased accumulation of calcium. It is important to increase calcium levels in the growing medium to reduce the incidences of this physiological disorder. To avoid build of potassium in the plant, application of fertiliser should be kept minimal and only be done when the crop requires it the most [18].

The various calcium related physiological disorders of fruits and vegetables found in the Kingdom of Eswatini are summarised in Table 1 below.

Name of physiological disorder	Cause	Crops affected	Symptoms	Control
1. Blossom end-rot	Calcium deficiency in the fruit and excess water stress in the soil	Tomato, eggplant, squashes, green-pepper and melons	The affected fruits are misshapen, with brown, leathery, rotten lesions on the blossom-end. A black sunken spot develops at the blossom-end which later on spreads with water-soaked region around it.	Improve calcium levels in the soil and ensure that water is always available to the plants so that they can absorb calcium from the soil with ease.
2. Golden specks	Golden specks are known to be a disorder due to excess calcium in the fruit.	Tomatoes and green pepper	Golden specks are often observed around the calyx and shoulders of mature tomato and green pepper fruits	Try to control calcium levels in the soils
3. Leaf tip-burn	Tip-burn is caused by a localised shortage of calcium that affects the emerging leaves	Cabbage, Brussels sprouts, cauliflower, lettuce and Swiss-chard.	Its symptoms include rolled up leaves at margins which are ragged and discoloured; white in narrow band, followed by necrosis and death of the growing point	Improve calcium in the soil by applying fertilisers that contain calcium

	of most horticultural crops.			
4. Bitter-pit	Susceptibility of fruit to bitter pit has three components: genetic, climatic and orchard management	Apples, pears and guavas in storage but it also develops late in the growing season while these fruits are attached to the tree	The bitter pit disorder starts internally and finally causes external blemishes. The tissue below the skin becomes dark and corky. Under storage, the affected skin appears to be water-soaked around the calyx and spots generally turn darker and become more sunken than the surrounding skin, taking on a deep-red colour on blush areas and remaining bright green on green or yellow surfaces	Plant resistant varieties and frequent application of calcium sprays especially in hot dry summers
5. Superficial-scald	Variety, climate, harvest time, ventilation, and ethylene in the storage environment. High N and low Ca can make scald susceptibility worst	Apples, guavas, pears, tomatoes, green pepper and plums	The skin of the affected fruit turns brown in patches, especially on the shaded side, and may become rough	Choose resistant varieties, harvest at the right time, improve ventilation in storage rooms, reduce nitrogen levels in the soils if they are too high and increase calcium levels
6. Senescent-breakdown	This physiological disorder is associated with fruits that have been stored too long and more susceptible to fruits that lack calcium as they grow.	Apples, guavas, pears, grapes and potatoes	The cortical tissues of the fruit are typically dry and mealy	This physiological disorder can be controlled by cooling the fruits more rapidly and improved ventilation. The application of Ca sprays can reduce senescent

				breakdown incidence and postharvest Ca drenches or dips can further decrease this physiological disorder
7. Water-core	Calcium deficiency. Water-core development can also common with more mature fruit at harvest, cool night time temperatures during the harvest period, and stress conditions in the orchard.	Apples, plums, nectarines, peaches, tomatoes, eggplant, green pepper and grapes	Water-soaked regions in the flesh of the fruit. When water core is severe, affected areas are hard and glassy and may be externally visible.	Development of water-core can be delayed by calcium sprays. Ensure good management in the garden or orchard and picking fruits before extensive water-core develops.
8. Flesh-browning	It is caused by limited oxygen and or high CO_2 in storage and calcium deficiency in the fruit	Apples, pears, guavas, and eggplant	Internal browning of the fruit which damages the cortex of the fruit under certain controlled atmosphere storage conditions.	Pre-harvest potassium and calcium spray and postharvest calcium drenches and improving ventilation during storage can control this physiological disorder
9. Granulation	Calcium deficiency, late maturity and persistent cold weather throughout the period of maturity have been found to increase the incidence of granulation	Citrus	Juice-sacs shrivel because of gel formation. The affected juice sacs become hard and dry; fruits become grey in colour, enlarged in size, have flat and insipid taste and assume a granular texture.	Improve calcium levels in the soil, plant early maturing cultivars and cultivars that are tolerant to cold
10. Soft-nose	Excess calcium and nitrogen deficiency	Mangoes, plums, avocadoes	The typical symptom is breakdown of the flesh towards the apex of the fruit before	Harvest fruits at ¾ maturity stage, apply calcium containing fertilizers like

			ripening. The mesocarp cells in the fruits show marked cell separation and cell-wall disintegration	calcium ammonium nitrate and the use of sod culture
11. Fruit and crown fasciation	Fruit and crown fasciation is associated with high vigour of plants, which take longer time to flower. High fertility of soil, warm weather and calcium or zinc deficiency may favour fasciation	Pineapples	Fasciated fruits are deformed. The fruit maybe highly flattened and twisted with innumerable crowns.	Plant plants which flower and mature early, avoid planting pineapples in too fertile soils and improve calcium and zinc content in the soil.
12. Skin-freckles	Calcium deficiency	Papaya fruits especially of the cultivar Sunrise solo	Freckle-like blemishes. The freckle diameter increase during the last phase of fruit growth as the fruits approached the maturity.	Remedies to control this physiological disorder include the use of calcium sprays and wrapping young fruits in white paper bags
13. Bronzing	Low soil fertility, lack calcium and low soil pH	Apples, guava, banana, strawberry and tomato	Affected plants show purple to red specks scattered all over the leaves. Under aggravated condition, total defoliation and fruits characterized with brown coloured patterns on the skin, with reduced yield are noticed.	Foliar application of calcium sprays, 0.5 % di-ammonium phosphate and zinc sulphate in combination at weekly intervals for two months reduced the bronzing
14. Pulp-spot	It is caused by lack of calcium in the plants as the fruits mature.	Avocadoes	The first symptoms of pulp spot are noticed soon after the fruit is cut. The spots are initially smooth and	Ensure that the soil has enough calcium and the use of calcium sprays to reduce the incidence of pulp-spot.

			glassy, of 1.0 mm in diameter and occur along the vascular bundle. The spots discolour after being exposed to the atmosphere and are generally brown to dark brown within 30 minutes	
15. Cavity-spot	Calcium deficiency	Carrots	This disorder appears as a cavity in the cortex, in most cases the subtending epidermis collapses to form a pitted lesion. The cavity-spot disorder is induced by deficiency of calcium. This is associated with an increased accumulation of potassium which leads to a decreased accumulation of calcium.	It is important to increase calcium levels in the growing medium and application of fertilisers containing potassium should be kept minimal and only be done when the crop requires it the most.

CONCLUSION

Calcium (Ca^{2+}) cations are crucial for the integrity of cell-walls in plants and plant organs. Deficiency of Ca^{2+} or excess of Ca^{2+} in plants may cause Ca^{2+} related physiological disorders which potentially threaten food and nutritional security. Calcium related physiological occur in all four agro-ecological zones of the Kingdom of Eswatini, starting in the field and in the post-harvest handling chain. Some fruits and vegetables are imported into the country already pre-disposed to Ca^{2+} related post-harvest physiological disorders. Adequate measures should be taken to avoid importation of such commodities. Climate change due to global warming is likely to worsen particular physiological disorders. There is need to educate especially growers about Ca^{2+} physiological disorders in order to manage them and ultimately avoid them in the subsequent post-harvest handling chain. All stakeholders in the post-harvest chain

should be made aware of these physiological disorders so that they are able to deal with them. In what ever way stakeholders deal or manage Ca2+ related physiological disorders they need to do so bearing in mind the need to achieve the SDGs pertaining to people and the planet,

LITERATURE CITED

1. Alandes, L., Hernando, I., Quiles, A., Perez-Munuera, I., and Lluch, M. A. Cell wall stability of fresh-cut fuji apples treated with calcium lactate. Journal of Food Science.2006; 71(9), 615-620.
2. Albanese, D., Cinquanta, L., & Di Matteo, M. Effects of an innovative dipping treatment on the cold storage of minimally processed Annurca apples. Food Chemistry. 105(3). 2007; 1054-1060.
3. Autio, W.R. and Bramlage, W.J. Foliar calcium sprays for apples; 2001. U. Mass Fact sheet F-19R. www.umass.edu/ fruitadvisor/factsheets/folcalcium.pdf [Accessed 16 February 2018].
4. Bangerth, F. Calcium-Related Physiological Disorders of Plants. Annual Review of Phytopathology. 1979; 17: 97-122.
5. Bhat, K.L. Physiological Disorders of Vegetable Crops. Daya Publishing House, India; 2009.
6. Bramlage, W.J. Interactions of orchard factors and mineral nutrition on quality of pome fruit. Acta Horticulture. 1993; 326:15-28.
7. Bramlage, W.J. and Weis, S.A. Postharvest fruit quality and storage life in relation to mineral nutrients. New York Fruit Quarterly. 2004; 12(2): 11-12.
8. Cenci, S.A., Soares, A.G., Bibino J.M.S. and Soiya, M.L.M. Study of the storage of 'Sunrise' and 'Solo' papaya fruits under controlled atmospheres. Proc.7th Intl. Contr. Atmos. Res. Conf. July 1997, Univ. of Calif., Davis CA, Abstract No. 112, 1997.
9. Curry, E.A. Physiology of Braeburn Maturity and Disorders: A Discussion. Postharvest Information Network, WSU Tree Fruit Research & Extension Centre, Washington; 1998.
10. De Souza, B. S., O'Hare, T. J., Durigan, J. F., and de Souza, P. S. Impact of atmosphere, organic acids, and calcium on quality of fresh-cut 'Kensington' mango. Postharvest Biology and Technology. 2006; 42(2), 161-167.

11. Domoto, P. Calcium helps prevent “bad apples. The Iowa Horticulturist. 1998; 14 (4): 16-18.
12. Ferguson, I.B. and Watkins, C.B. Bitter pit in apple fruit. Horticultural Reviews. 1989; 11:289-355.
13. Government of Swaziland. The Swaziland National Biodiversity Strategy and Action Plan. Government of Swaziland, Mbabane, Swaziland; 2005.
14. Government of Swaziland. Swaziland Review: Ministry of Commerce and Industry. Government of Swaziland, Mbabane, Swaziland.
15. Guan, W. Q., and Fan, X. T. Combination of sodium chlorite and calcium propionate reduces enzymatic browning and microbial population of fresh-cut "Granny Smith" apples. Journal of Food Science. 2010; 75(2), 72-77.
16. Hoffmann, H. Citrus Disorders. Department of Food and Agriculture. Sydney, Australia; 2009.
17. Ingle, M. and D'Souza, M.C. Physiology and control of superficial scald of apples: A review. Horticultural Science. 1989; 24:28-31.
18. Kader, A.A., Sommer, N.F. and Arpaia, M.L. Postharvest handling systems: tropical fruits, p. 385–398. In: A.A. Kader (ed.). Postharvest technology of horticultural crops, 3rd ed. Univ. of Calif. Press, Oakland; 2002.
19. Kinet, J.M. and Peet, M.M. Tomato. In: Wien, H.C. (ed). The Physiology of Vegetable Crops. CAB International. pp. 207-245; 1997.
20. Masarirambi, M.T., Nxumalo, K.A., Musi, P.J. and Rugube, L.M. Common physiological disorders of lettuce (*Lactuca sativa*) found in Swaziland: A Review. American-Eurasian J. Agric. & Environ. Sci. 2018; 18 (1): 50-56.
21. Masarirambi, M.T., Mhazo, N., Oseni, T.O. and Shongwe, V.D. Physiological disorders of Brassicas/Cole crops found in Swaziland. African Journal of Plant Science, 2011; 5 (1). 8-14.
22. Masarirambi, M.T., Mhazo, N., Oseni, T.O. and Shongwe, V.D. Common physiological disorders of tomato (*Lycopersicon esculentum*) fruit found in Swaziland. Journal of Agriculture and Social Science. 2009; 5:123-127.
23. Mengel, E.K. and Kirkby, E.A. Calcium In: Principles of plant nutrition. International Potash Institute, Bern. pp. 437-454; 1982.
24. Nxumalo, K.A., Masarirambi, M.T., Mabuza, M., Muziri, T. and Masarirambi, T. Common physiological disorders of White/Irish potato (*Solanum tuberosum*) Tubers

Produced in Swaziland: A Review. Journal of Agronomy and Agricultural Science. 2017; 1: 001.

25. Peirce, L.C. Vegetables: Characteristics, Production, and Marketing. John Wiley and Sons, New York, New York, USA; 1987.

26. Perera, N., Gamage, T. V., Wakeling, L., Gamlath, G. G. S., & Versteeg, C. Colour and texture of apples high pressure processed in pineapple juice. Innovative Food Science & Emerging Technologies. 2010; 11(1), 39-46.

27. Schoeman, A.S. A guide to garden pests and diseases in South Africa: Struik publishers. p.110; 2002.

28. Shear, C.B. Interaction of calcium and nitrogen and time of calcium availability in relation to the development of apple disorders. In: J. Wehrman (ed.) Proc. 7th Intern. Colloq. Plant Anal. Fertility Problems. German Soc. Plant Nutrition, Hanover. pp. 427-436; 1974.

29. Siddiq, M., Ahmed, J., Lobo, M.G. and Ozadali, F. Tropical and subtropical fruits: Postharvest physiology, processing and packaging. Wiley Press, Ames, IA; 2012.

30. Stiles, W.C. and Reid, W.S. Orchard nutrition management. Cornell Cooperative Extension Bulletin 219; 1991.

31. Thompson, C.F. Swaziland Business Year Book. Christina Forsyth Thompson, Mbabane, Swaziland; 2009.

32. Watkins, C., Schupp, J. and Rosenberger, D. Calcium nutrition and control of calcium-related disorders. New York Fruit Quarterly. 2004; 12(2): 15-21.

33. Witney, G.W., Kushad, M.M. and Barden, J.A. Induction of bitter pit in apple. Scientia Horticulture. 1991; 47:173-176.

34. Woolf, A.B., Wexler, A., Prusky, D. Kobiler, E., Lurie, S.: Direct Sunlight Influences Postharvest Temperature Responses and Ripening of Five Avocado Cultivars. Journal of the American Society for Horticultural Science. 2000; 125 (3): 370-376.

35. Zwane, P.E. and Masarirambi, M.T. Kenalf (*Hibiscus cannabinus*) and allied fibres for sustainable development in Swaziland. Journal of Agriculture and Social Science. 2009; 5:35:39.