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Review Article

POSTHARVEST PHYSIOLOGY OF FRUITS AND VEGETABLES AND THEIR MANAGEMENT TECHNOLOGY: A REVIEW

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ABSTRACT

This review basically provides knowledge regarding postharvest physiology, allied factors and management of harvested horticultural produce. Commodities with higher respiration and ethylene production tend to have shorter shelf life with low quality than those with lower respiration and ethylene production. Transpiration and respiration processes of harvested fruits and vegetables result in weight loss, softening and shriveling, loss of peel glossiness etc. Fruit and vegetable storage life is negatively impacted by ethylene production. Fungi and bacteria are the biggest offenders among almost all postharvest disorders of fruits and vegetables. One of the largest significant factors impacting the postharvest life of fruits and vegetables is temperature because it has an intense influence on the rate of physiological responses such as respiration, transpiration, ethylene production and disease development. The rate of respiration and the generation of ethylene are both regulated by high temperatures. On the other hand, high temperature with high relative humidity favors the disease's development but low temperature (5°C) and high relative humidity (RH 96%) result in low transpiration. Control or modified atmosphere storage (O_2 below 5%, CO_2 above 3%), vacuum pack, chemical treatments and edible coating are the effective ways for controlling respiration, ethylene production, transpiration and disease development but it is mainly dependent on types of fruits and vegetables.

Keywords: Postharvest Physiology, Storage life, Transpiration, Respiration, Ethylene, Temperature, Controlled Atmosphere, Modified Atmosphere, Coating.

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INTRODUCTION

The horticultural crops like fruits and vegetables are thought to be both commercially and nutritionally important food items. Because, these foods provide a major source of vitamins, minerals, fiber, sugars, antioxidants, organic acids as well as nutrients (Wu, 2010). There is strong evidence that consumption of fruits and vegetables helps prevent a number of chronic Non-Communicable Diseases (NCDs) including cardiovascular diseases, diabetes, obesity, cancer and respiratory disorders, typically because they contain key phytochemicals (Elhadi, 2019). World Health Organization (WHO) advises eating more than 400 g of fruits and vegetables daily to improve overall health and decrease the risk of certain NCDs, as it's a part of a healthy diet with low fat, sugar and sodium. Fruits and vegetables lose 10-15% of their weight after harvest, compared to 20-40% in undeveloped countries (Hossain *et al*., 2020). This suggests that roughly one-fourth of the output is never consumed (Kahramanoğlu, 2017). Improper post - harvest handling results in the loss of 30 to 60% of the world's total yield of fruits and vegetables (Elhadi, 2019; Choudhury *et al.,* 2019). Postharvest losses of horticultural crops can be defined as losses of harvested crops in quality and quantity until consumption (Wendimagegn, 2020). Horticultural crops are very perishable in nature, many physiological, biochemical and microbial deterioration happened to occur resulting huge economic losses (Choudhury *et al.,* 2019).

There are a number of physiological processes, including respiration, transpiration, and ethylene production, that play a significant role in the degeneration of horticultural crops. (Yahia, 2019). Continuous metabolic processes, water loss, physiological disorders, mechanical damage and pathological collapse are the main causes of deterioration of fresh fruits and vegetables (Wills *et al.,* 2007). The quality of fruit cannot be improved after harvest as all the parameters relating to quality are developed while the fruit is attached to plants.

Harvested crops are incapable of synthesizing carbohydrates due to leaf loss since they have no longer entree to water and nutrients formerly provided by the root system. As the detached plant parts are living, a substrate is essential for metabolism, which is drawn from tissue-stored carbohydrates, lipids, and proteins (DeLong and Prange, 2003). Postharvest diseases play a vital role in postharvest loss due to the lack of sophisticated postharvest storage facilities especially in developing countries (Singh *et al.,* 2017). The microbial decay is mainly caused by fungi, yeast, molds and bacteria, (Yahaya and Mardiyya, 2019). Postharvest physiology and technology have been the key factors for sustaining and extending the storage life of perishables commodities (Pedreschi, 2017). Postharvest physiology is the study on the physiological processes of living plant organs after harvesting. Specifically, its emphases on understanding and controlling respiratory process, dehydration, ethylene production and microbial infection (Wikipedia, 2020).

Some technologies, such as cooling and preservation, may extend the storage life of fruits and vegetables after harvest by controlling these physiological processes (Saltveit, 2019). To keep the high standard for a longer duration, slowing the respiration rate (Tano *et al.,* 2005). Proper postharvest management techniques can reduce water loss, delay respiration rate and ethylene production, and inhibit the development of decay causing pathogens e.g fungi, bacteria, yeast and moulds (Irtwange, 2006). Food safeties are the main concern to applying postharvest management technologies of horticultural crops by reduction in losses and maintaining the quality of the produce (Wu, 2010). The fact that newly harvested fruits and vegetables are still alive, respiring organisms that go through a number of physiological changes after harvesting, contributes to the high rate at which they are lost during postharvest handling (Kahramanoğlu, 2017). Scientific study of postharvest biology and technology is very important for the regulation of these physiological events critical for extending the shelf life together with maintenance of quality. Therefore, this review is designed to evaluate the physiological reasons involved in the deterioration of harvested fruits and vegetables; and to describe the management techniques of reducing the postharvest losses.

Physiological Status of fruits and vegetables: Postharvest physiology has direct role to postharvest management of fresh products by using proper storage and transport conditions (Wikipedia, 2020). There are many physiological processes (respiration, transpiration, ethylene, postharvest diseases) and external conditions (heat, humidity levels, air constitution, light) which causes deterioration of harvested goods (Kahramanoğlu, 2017). Respiration rate, ethylene production, and weight loss associated with transpiration are the major factors known to regulate the postharvest physiology of fruits and vegetables (Figure 1).

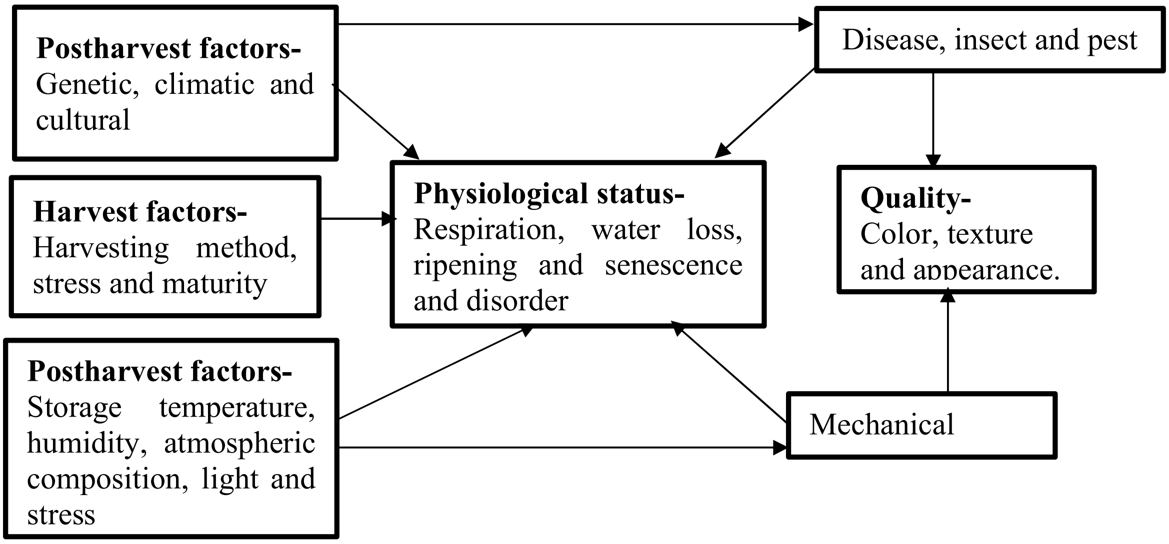

Figure 1. Schematic representation of factors affecting postharvest quality of fruits and vegetables (Source: Mishra and Gamage, 2007)

Respiration: Though fruits and vegetables have been separated from the plant, they persist living after harvest (Silva, 2008). Respiration is a primary step by which all living things convert deposited into energy. It consists of the catalytic hydrolysis of substances like carbs, proteins, fatty acids, organic acids, etc. in the ambient atmosphere O_2 to CO_2 and H_2O, and is followed by an energy release (Mishra and Gamage, 2007). During respiration, one mole glucose (180 g) produced 686 kcal. Respiration is combinedly completed by three metabolic pathways such as, glycolysis (anaerobic), the citric acid cycle (aerobic) and the electron transport chain (aerobic).

Respiratory pattern of harvested Fruits: Based on the pattern of respiration fruits are mainly classified into climacteric (e.g. Banana, apple, guava, papaya etc.) or non-climacteric (e.g. Orange, grape, olive, pineapple etc.) group (Elhadi, 2019). The respiration rate slows down in non-climacteric fruits and storage organs after harvest, in contrast rapidly increases in climacteric fruits (Kays and Paull, 2004); and this increase consist of four distinct phases (Figure 2; Saltveit, 2016).

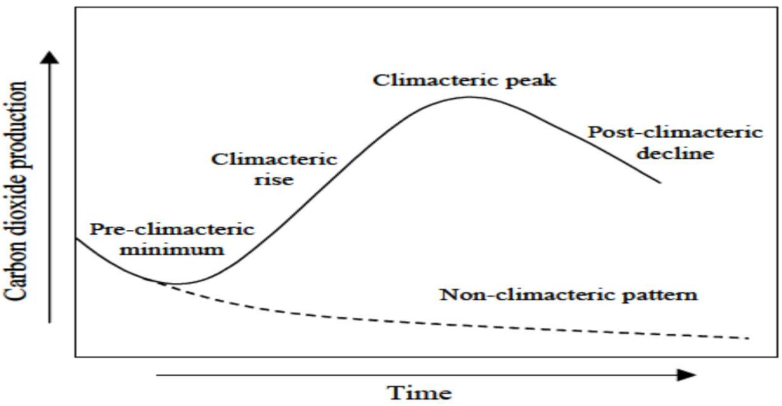

Figure 2. The climacteric and non-climacteric pattern/phases of respiration in ripening fruit.

Janave (2007) observed continuous weight loss in mango from picking day to full maturity (Figure 3A). In non-spongy fruits, the initial respiration rate decreased up to three days of storage. As the fruits started ripening, an abrupt rise in the respiratory burst was observed reaching a peak by day nine and declined further up to 13 days of storage (Figure 3B).

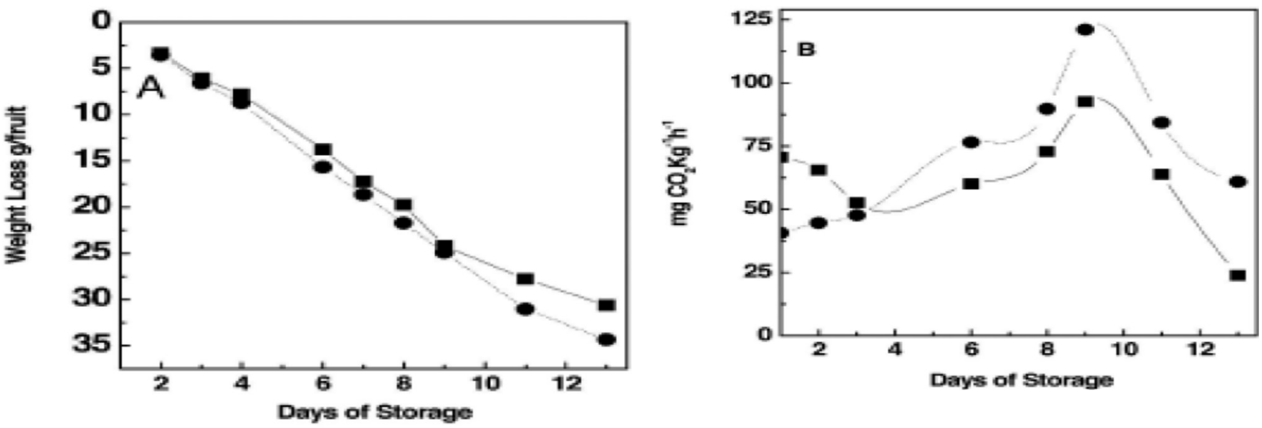

Figure 3. Fruit weight loss and respiration rate of Alphonso mango fruits: A. Fruit weight loss and B. the respiratory pattern of ripen non-spongy - ■ and ripe spongy ● fruits during postharvest ripening.

Respiration rate and storability: The storability of fruits and vegetables largely depends on the stage of maturity, their structure, respiration rate at harvest and the next physiological process (Brummell and Toivonen, 2018). Generally, the longevity of a crop is reduced if its respiratory rate is high relative to that of a crop with a relatively low respiration rate (Saltveit, 2019). Mushroom, broccoli, bean, cauliflower, berry etc. have high respiration rates compared to apples, citrus, onions, and potatoes which have limited rate of respiration (Table 1).

Bodbodak and Moshfeghifar (2016) concluded that respiration rate has a reverse relationship with storability. They reported that storage life of pear and asparagus are very shorter than avocado, turnip and apple due to their respiratory pattern (Figure 4; Patterson, 2010).

Effect of temperature on respiration: Temperature is one of the major factors affecting shelf life of horticultural crops, as it has a reflective effect on the rates of biological reactions, e.g., respiration and metabolism (Saltveit, 2019). According to the Van't Hoff rule, the velocity of a biological reaction accelerates 2 to 3-fold for every 10°C rise in temperature. A product with an average life span of 13 days at 20°C can be stored for up to 100 days at 0°C, but only for 4 days at 40°C (Table 2).

Table 1. Classification of fruits and vegetables on the basis of respiration rate.

Class	Range at 5ºC (mg CO_2 $kg^{-1}h^{-1}$)	Commodities
Very Low	<5	Nuts, dates
Low	5 to 10	Apple, citrus, grape, onion, potato
Moderate	10 to 20	Apricot, banana, cherry, pear, fig, cabbage, carrot, lettuce, pepper, tomato
High	20 to 40	Strawberry, blackberry, raspberry, cauliflower, lima bean, avocado
Very High	40 to 60	Snap bean, Brussels sprouts
Extremely High	>60	Broccoli, mushroom, pea, spinach

(Source: Saltveit, 2019, Gross *et al.,* 2016.)

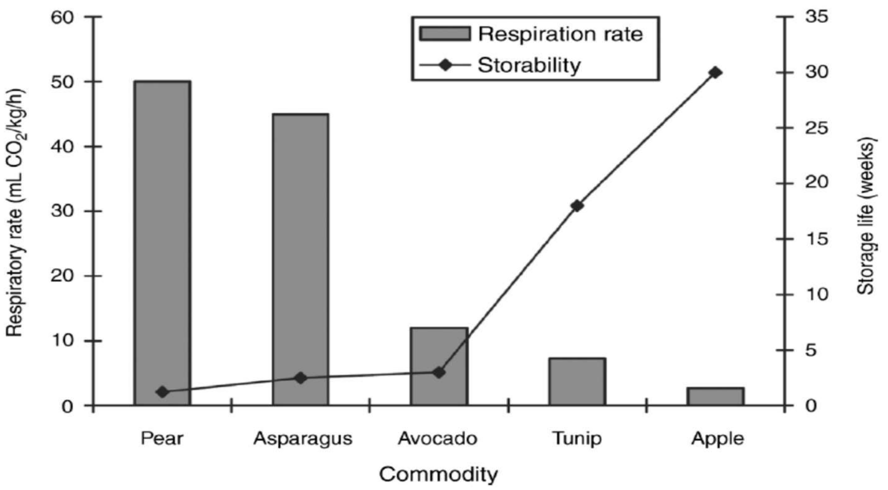

Figure 4. Relationship between respiration rate and storage life of certain fruits and vegetables at 5˚C.

Table 2. Effect of temperature on rate of deterioration and relative shelf life.

Temperature (⁰C)	Relative velocity of deterioration (rate)	Relative shelf life (days)
0	1.0	100
10	3.0	33
20	7.5	13
30	15.0	7
40	22.5	4

(Source: Saltveit, 2016)

Transpiration: Transpiration or water loss is also a major cause of harvested fruits and vegetables shrinkage and softening, lowering food value and nutrient content (Kader, 1992). The stomata, cuticle, epidermal cells, trichrome are responsible for regulating the transpiration rate of fruits and vegetables (Valenzuela *et al.,* 2017). The water content of dried seeds to fresh fruits and vegetable ranges from 10-95% (Diaz-Perez, 2019). Enhanced respiration, loss of water through transpiration, and metabolic activity all contributed to a dramatic increase in the physiological weight loss that occurs during storage. After 4 days of harvesting, physiological weight loss ranged from 0.00 to 12.22%, while after 8 days it ranged from 0.56 to 23.61% (Table 3) in mango. At 12 days, highest weight loss was observed in case of control fruits (26.41%), whereas it was found lowest at wax coated fruits (1.18%) (Mandal *et al.,* 2018).

Transpiration as a Function of Temperature and Relative Humidity: Transpiration rates are higher in warmer environments and lower when the relative humidity is higher. Pomegranate arils and aril-sacs showed highly variable transpiration rates across storage conditions (Figure 8). The lowest transpiration rate was found at of 5°C with 96% relative humidity, whereas the highest transpiration rate was found at 22°C with 76% relative humidity for both fruit fractions (Figure 5) (Aindongo *et al.,* 2014).

Table 3. Effect of edible coatings on percentage of weight loss, decay and shelf life of mango fruits due to transpiration.

Treatments	Weight loss (%)			Fruit decay (%)	Shelf life (Days)
	4 Days	8 Days	12 Days	12 Days	
Olive oil coated	9.38	14.67	17.95	22.73	16.35
Wax coated	0.00	0.56	1.18	10.05	19.65
Chitosan1%	2.86	5.25	7.53	11.25	18.25
Chitosan 2%	1.97	2.68	4.09	10.55	19.12
Carboxymethyl cellulose 1%	8.70	13.04	26.41	28.27	15.75
Carboxymethyl cellulose 2%	7.33	11.39	20.41	24.56	16.12
Aloe gel coated	4.23	9.64	10.80	18.25	17.35
No treatments (control)	12.22	23.61	26.41	30.79	15.50
S. Error m±	0.565	0.579	1.474	1.168	0.676
C.D. (P=0.05)	0.986	1.011	2.573	2.038	1.180

(Source: Mandal *et al.,* 2018)

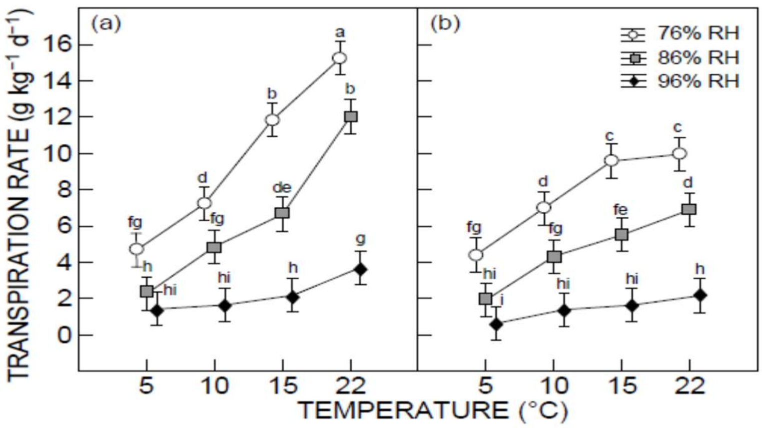

Figure 5. Effects of temperature and relative humidity (RH) on transpiration rate of arils (a) and aril-sacs of pomegranate (b). Different letters indicate a significant difference *p* = 0.02.

Ethylene Production: Ethylene act as a growth retardant is an important in controlling fruit physiology during its postharvest preservation period. Even though ethylene has such a profound effect on the freshness and flavor of fruits and vegetables (Martinez-Romero *et al.,* 2007). In many species, ethylene production coincides with fruit ripening and plays a key role in coordinating the various stages of ripening, including pigmentation, smell evolution, and texture (Klee and Giovannoni, 2011). While ripening is the most obvious response to ethylene in ripe fruit, low levels of ethylene exposure cause discoloration of green tissues and decreases life span of commodities like green vegetables and premature fruits (Valenzuela *et al.,* 2017).

Methionine is activated by ATP and is transformed to SAM (S-adenosylmethionine) through the action of SAM synthase. SAM is transformed to ACC (1- aminocyclopropane-1-carboxylic acid) in presence of ACC synthase (ACS) and ACC is transformed to ethylene with the help of ACC oxidase (ACO) (Figure 6).

Ethylene production rate: Maturity at harvest, disease prevalence, physical issues, temperatures up to 30 degrees Celsius, and water deficit all contribute to a higher ethylene productivity (Pesis, 2004). Exposure to very lower levels of exogenous ethylene can notably reduce the potential market life of most vegetables

(Blanke, 2014). The fruits and vegetables vary in their ethylene production rates (Table 4) (Dhall, 2013).

The role of ethylene on ripening of fruits and vegetables: Noticeable variations were reported in ripening period of tomato due to the different concentrations of Ethephon treatment (500, 1000 and 1500 ppm). Ethylene gas (100 ppm) ripened the fruit in 9 days, achieving the desired red color, desired stiffness, the least decaying, and an acceptable quality (Figure 7) (Dhall and Singh, 2013) in tomato.

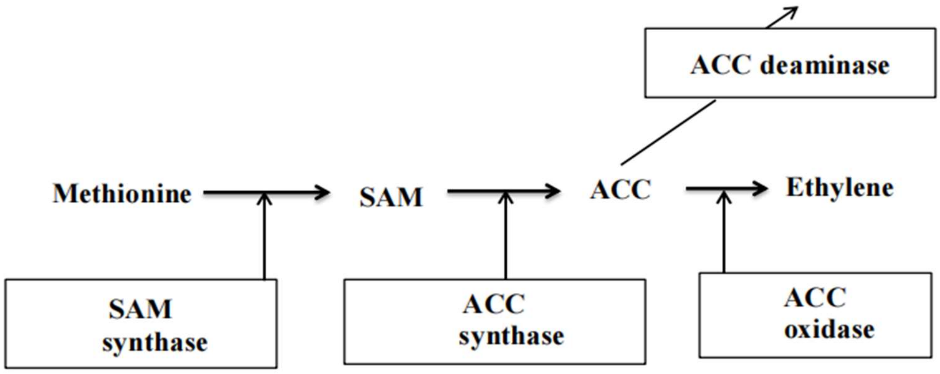

Figure 6. Pathway of ethylene biosynthesis with enzymatic action flow chart (Source: Patterson, 2010)

Table 4. Classification of horticultural crops according to ethylene production rates

Class	µl C_2H_4/kg-h at 20°C (68°F)	Commodities
Very low	<0.1	Asparagus, cauliflower, leafy vegetables, root vegetables, potato, citrus, grape, jujube, strawberry, pomegranate.
Low	0.1-1.0	Cucumber, eggplant, okra, watermelon, chili, bell pepper, pumpkin, olive, pineapple, blueberry, raspberry
Moderate	1.0-10.0	Tomato, banana, fig, guava, mango, plantain
High	10.0-100.0	Apple, apricot, avocado, kiwifruit, papaya, peach, pear, plum
Very high	>100.0	Sapota, passion fruit, cherimoya

(Source: Dhall, 2013)

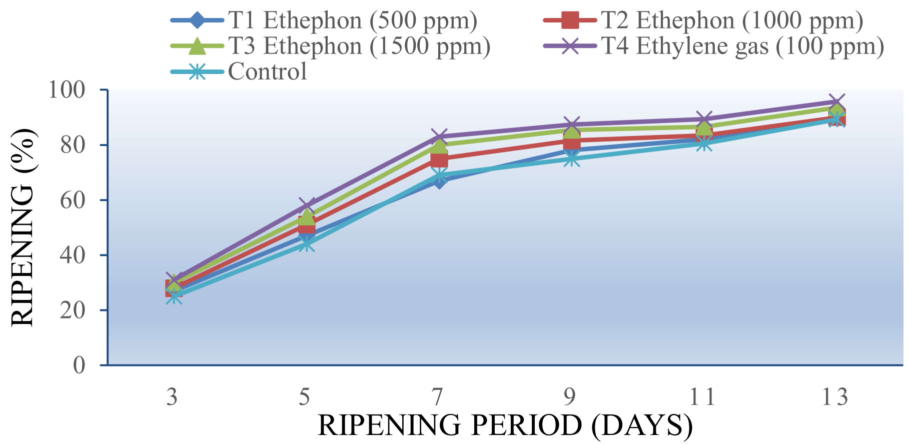

Figure7. Effects of Ethephon and ethylene gas on ripening (%) of tomato at 20 ± 1°C with 90-95% RH. (Source: Dhall and Singh, 2013).

Postharvest diseases: Infectious diseases that develop after harvest reduce quality and shorten their life span of produce. These can actually occur anywhere in the post-harvest process, from farm to consumer (Singh *et al.*, 2017). A host tissue's physiological condition is closely linked to the onset of postharvest disease (Singh *et al.*, 2017). Both bacteria and fungi, with the exception of some root crops, are the most common pathogens that attack produce. However, the main postharvest losses are caused by fungi, such as *Alternaria, Aspergillus, Colletotrichum, Botrytis, Monilinia, Diplodia,* *Penicillium, Rhizopus, Phomopsis, Mucor,* and *Sclerotinia*, and bacteria, such as *Pseudomonas and Erwinia* (Barkai-Golan, 2005; Sharma *et al.,* 2009). The juicy nature of fruits and vegetables make them suitable to be easily affected by these organisms (Elias *et al.,* 2010).

At temperature 25°C±2 and 45% relative humidity (RH), Cristina *et al.* (2018) tested the effects of citrus extracts on the shelf life of tomatoes. The results showed that under control conditions, the percentage of losses was highest on day 13 and gradually decreased thereafter. This trend was observed throughout the duration of the study. However, after evaluation of citrus extract treatment with different doses it was clear that damage did not exceed 80% (Figure 8; Cristina1 *et al.,* 2018).

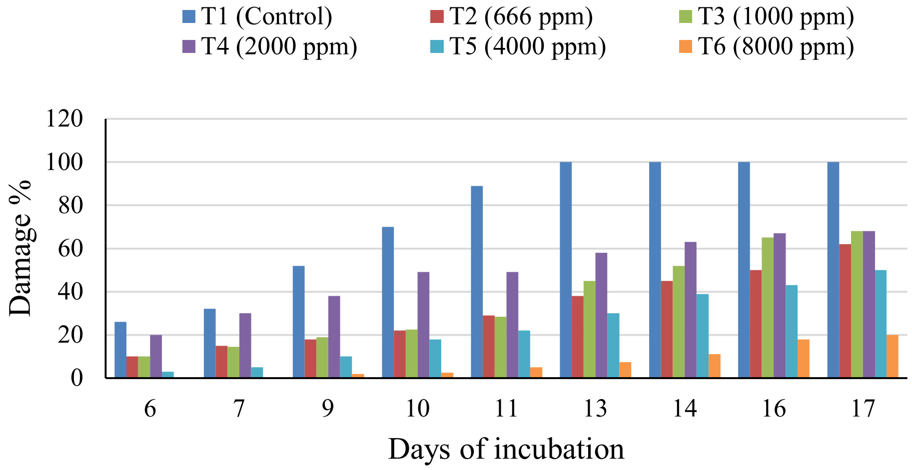

Figure 8. Percentage of losses of tomato damaged by different pathogens as influenced by different concentrations of citrus extract. (Source: Cristina1 *et al.,* 2018)

The dark blue column is T1 (control=0); the red column is T2 (666 ppm); the green column is T3 (1000 ppm); the purple column is T4 (2000 ppm); the sky blue column is the T5 (4000 ppm); and the orange column is T6 (8000 ppm).

Management techniques to improve postharvest quality: The key purposes of postharvest management technique are to prevent the deterioration of horticultural commodity as much as possible and to ensure maximum market value. The technology involved in postharvest management of fruits and vegetables are difficult because the products are different in structure, maturity stage, physiological status and perishability (Kays and Paull, 2004). However, some commonly used postharvest management techniques are summarized below:

Modification of storage environments: The term-controlled atmosphere (CA) or modified atmosphere (MA) refers to create an atmospheric composition around the produce which is different from normal air by adding or removing gases such as, O_2 (below 5%), CO_2 (above 3%), N_2 and ethylene (Kader and Saltveit, 2003). Advantageous effects of CA or MA storage are slowing down respiration, ethylene production and action and thus delay ripening and increase storage life (Irtwange, 2006). Gas control is more precise in CA than MA (Wu, 2010). Storage conditions in a controlled atmosphere that are recommended for a variety of fruits and vegetables are listed in Table 5. (Rama and Narasimham, 2003; Irtwange, 2006). This amount is determined by the weight, package permeability, and rate of product respiration. CA/MA is also used to regulate the transpiration rate of different fruits and vegetables. For storing fresh vegetables, Modified Atmosphere Packet with 6% O_2 and 11% CO_2 at 13°C are employed. At 13°C, spinach kept in ordinary bags (the control) ceased to be useable after 7 days, but spinach kept in MAP ceased to be usable after 9 days (Batziakas *et al.,* 2020).

Vacuum packaging: Before sealing, air is removed from the package using the vacuum packaging method. This process entails packing things in plastic film, releasing the air, and then sealing the container (Perdue and Marcondes, 2009). The impact of several packaging methods, including vacuum and modified environment packaging, on the longevity of guava storage (cv. Hisar Safeda) was studied by Rana *et al.,* (2018). Fruit respiration was increased with increasing period of storage at low temperature. It was maximum (27.8 ml/h/kg) in control fruits by 18th day of storage and then decreased to 23.5 ml/h/kg by 21 days of storage. Individual wrapping decreases the respiration rate significantly (Figure 9) in guava. At low temperature, among different wrapping methods, minimum respiration rate in vacuum pack followed by modified atmosphere pack was observed (Figure 8; Rana *et al.,* 2018).

Chemical treatments: Some chemicals such as 1-methylcyclopropene (1-MCP), Salicylic acid (SA) (Madhay *et al.,* 2018), ClO_2 gas (Guo, 2014), NO fumigation (Ku *et al.,* 2000) etc. are also used to decrease the respiration and ethylene production as well as interrupt fruit ripening and increases shelf life of fruits and vegetables in different countries without any negative health impact (Barua *et al.,* 2015; Manjunatha *et al.,* 2012).

Table 5. Recommended CA/MA potential for benefits during storage and transport of selected fruits and vegetables

Produce	Temperature (°C)	Controlled atmosphere (CA) or Modified atmosphere (MA)		Potential for benefit (*)
		O_2 (%)	CO_2 (%)	
Apple *(Malus pumila)*	0-2	2-3	1-5	A
Banana *(Musa spp.)*	12-16	2-5	2-5	A
Beans *(Phaseolus vulgaris L)*	5-10	2-3	4-7	C
Broccoli *(Brassica oleracea var. L.)*	0-5	1-2	5-10	A
Cabbage *(Brassica oleracea)*	0-5	2-3	3-6	A
Cauliflower *(Brassica oleracea var. botrytis)*	0-5	2-5	2-5	C
Carrot *(Daucus carota)*	0-5	None	None	D
Cucumber *(Cucumis sativus)*	8-12	3-5	0	C
Lemon *(Citrus limon)*	10-15	5-10	0-10	B
Mango *(Mangifera indica)*	10-15	5	5	C
Orange *(Citrus sinensis)*	5-10	5-10	0-5	C
Okra *(Abelmoschus esculentus)*	8-10	3-5	0	B
Onion *(Allium cepa)*	0	3	5	C
Papaya *(Carica papaya)*	10-15	2-5	5-8	C
Potato *(Solanum tuberosum)*	4-12	None	None	D
Pineapple *(Ananas comosus)*	5-10	2-5	5-10	C
Radish *(Raphanus sativus)*	0-5	None	None	D
Strawberry *(Fragaria ananassa)*	0-5	5-10	15-20	A
Spinach *(Spinacia oleracea)*	0-5	21	10-20	B
Tomato *(Solanum lycopersicum)*	8-12	1-5	0	B

*A= Excellent, B= Good, C= Fair, D= without benefit; Source: Rama and Narasimham, 2003; Irtwange, 2006.

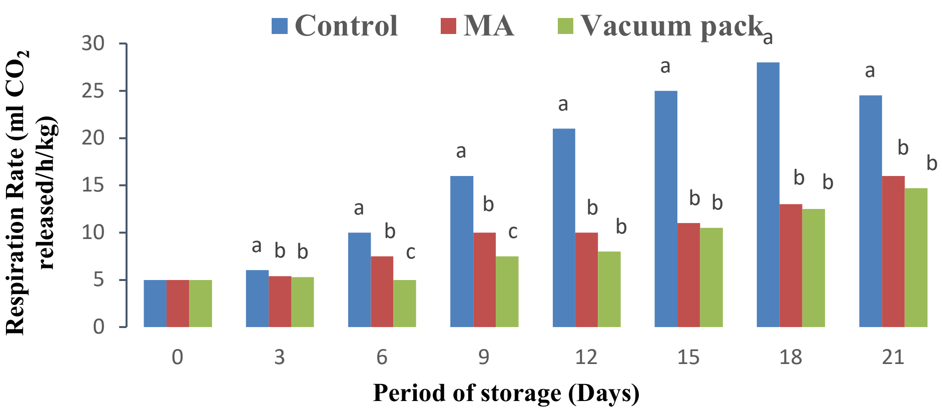

Figure 9. Respiration rate of guava stored at low temperature for 21 days in Vacuum pack and modified atmosphere packaging (MAP) at 7±3°C (Different letters are significantly different at *P*<0.05).

Chemical application to control respiration and ethylene production: Salicylic acid (SA) and 5-sulfosalicylic acid (SSA) were applied to guava fruits of the cv. Lalit at rates of 1 mM and 2 mM, respectively, and held at 10°C for 12 3 days followed storage under ambient condition (20 2°C, 3 days), acting as shelf-life stimulation period. The salicylic acid treatments inhibited the respiration rate and also slowed down the onset of the respiratory climacteric to 6 ± 3 and 9 ± 3 days of storage in 1 and 2 mM SA or SSA treatments, respectively (Figure 10a) (Madhav *et al.,* 2018; Guo, 2014). Tomato fruits at the mature green phase were treated with ClO_2 gas in a wrapped container for 12 hr., and then stored at 23˚C with 85% relative humidity (RH) for 23 days. The results indicated that use of ClO_2 gas was effective in dropping ethylene production than control fruit reaching maximum at day 9 (Figure 10b) (Madhav *et al.,* 2018; Guo, 2014).

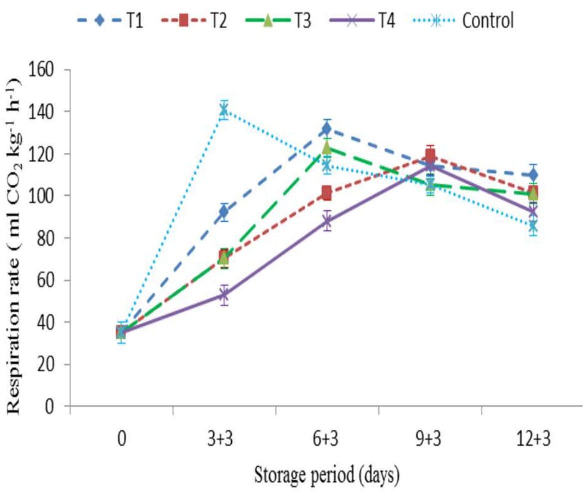

Figure 10a: Impact of salicylic acid treatments on respiration rate of guava (T1-SA @ 1 mM, T2-SA @ 2 mM, T3-SSA @ 1 mM, T4-SSA @ 2 mM and control).

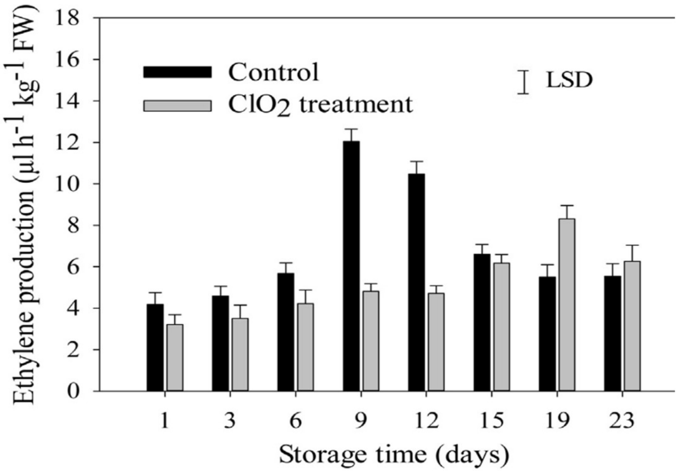

Figure 10b: Effects of ClO_2 treatment on ethylene production in tomato fruit at the mature green stage. Mean values ± standard deviation of three replicated measurements.

Table 6. Postharvest life of strawberries at 10°C in a MAP with high CO_2 and low O_2 levels with NO gas.

Atmosphere type	Postharvest life (days)
Air control	4.0
MAP	7.2
10 µL/L NO in air	6.0
10 µL/L NO in MAP	10.7
20 µL/L NO in MAP	10.3
LSD. (P = 0.05)	1.21

(Source: Soegiarto and Wills, 2006)

Postharvest disease control: Nitric oxide (NO) has profound effect in reducing mold growth and red color loss which are accountable for quality losses of strawberry, and it has also antimicrobial activity (Nathan and Shiloh, 2000). In comparison to air storage, the combined effects of NO and low oxygen storage greatly extended the shelf life of strawberries (Table 6) (Soegiarto and Wills, 2006).

Edible coating: Edible coating is a preservation technique through which the storage life of fruits and vegetables can be significantly increased even though maintaining the original quality of the product during storage (Baldwin, 1994). A chart of some edible coating materials is shown in Table 7 (Modified from Vaishali *et al.,* 2019) along with their functions and suitability to different fruits and vegetables.

Table 7. List of some edible coating with their function.

	Name of edible coating	Function	Fruits and vegetables
1.	Lipid based coating		
	- Wax coating (carnauba wax, bees wax, paraffin wax).	Reduce moisture loss	Apple, cucumber, eggplant, okra, tomato, carrot etc.
2.	Polysaccharide based coating		
	- Starch and its derivatives	Reduce respiration	Strawberry
	- Cellulose and its derivatives	Maintain crispness and flavor	Apple, carrot
	- Seaweed extracts (Alginates)	Retarding shrinkage, reduce oxidative rancidity	Apple, grapes
	- Chitosan (2-amino-2deoxy-ßD-	Decrease respiration rate, antimicrobial	Cucumber, tomato

	glucan)	activity	
	- Aloe vera	Antifungal, control respiration and transpiration	Table grapes
3.	Protein based coating		
	- Plant origin (zein and soy)	Lower permeability to water vapor and good O_2 barrier	Eggplant
	- Animal origin (whey and casein)	Good O_2 barrier	Apple, asparagus, strawberry

Source: Modified from Vaishali *et al.,* (2019).

Conclusions: Knowledge of the post-harvest physiology of fruits and vegetables has an immense contribution in taking steps to reduce post-harvest loss. Produces showing high respiration and high ethylene production have lower shelf-life with low quality. The study revealed that keeping fresh fruits and vegetables after harvest in a relatively lower temperature condition with high atmospheric humidity reduces the post-harvest losses of horticultural crops, especially fruits and vegetables.

Furthermore, high temperature and high humidity favor disease and insect pest infestation and is one of the vital factors to cause severe post-harvest losses. Food security and nutritional quality of produce can be ensured by minimizing post-harvest losses of fruits and vegetables through proper post-harvest management including control atmosphere or modified atmosphere (CA/MA) storage, vacuum packing, chemical treatments and disease control.

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Author contribution: This work was carried out in collaboration among all authors. Authors JF and MIH designed the conceptual framework of study, performed relevant literature search and wrote the initial draft of the manuscript. Author MR, TA, SP, MRI and DD drawn the pictures and assisted in the formulation of tabular constituents. Authors SRS reviewed and rewrote the manuscript. All authors read and approved the final manuscript.

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