Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2948

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **6 (1):** 1558-1563 (2018)

Review Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

A Review on Physicochemical Changes in Fresh Horticultural Produce under Cold Storage Condition

V. Arun Prasath[1*], Aarthy Viswanath[2] and S. Ganapathy[3]

[1]Teaching Assistant, [2]Research scholars and [3]Professor and Head,

Department of Food & Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore

*Corresponding Author E-mail: arun16foodengg@gmail.com

Received: 4.05.2017 | Revised: 10.06.2017 | Accepted: 13.06.2017

ABSTRACT

India is the second leading producer of fruits and vegetables with 76.4 million tonnes and 156.3 million tonnes respectively and about 13% of the world's production of fruits and vegetables is done in India[2]. About 30% of fruits and vegetables produced in India are wasted annually due to the non-availability of handling and storage facilities[1]. Also much of the produce do not move under continuous cold chain. The postharvest life and quality of fruits and vegetables is affected by temperature greatly than other factors. Quality loss after harvest occurs as a consequence of physiological and biological processes, the rates of which are influenced primarily by product temperature. There are many bottlenecks in the supply chain system of fruits and vegetables. Besides the lack of cold storage facilities, cooling as an essential postharvest operation. Study of physicochemical changes take place during cooling is essential to determine the quality of fruits and vegetables during storage period.

Key words: *Physiochemical changes, Cold Storage, Fruits and vegetables.*

INTRODUCTION

Cooling is the most active method to control postharvest ripening and spoilage of fruits and vegetables in practice[3]. After harvest, many horticultural products are susceptible to spoilage. For example the table grapes should be cooled promptly and thoroughly after harvest in order to reduce the losses during storage. The reasons why table grapes (and probably most other horticultural products) should be precooled thoroughly are to reduce water loss from the fruit, to retard development of decay caused by fungi, and to decrease the rate of respiration.

The reduction in temperature has the added advantage of reducing the production of ethylene and sensitivity of the produce it thereby retarding ripening and senescence[5]. It can therefore be stated that cooling is important in ensuring the freshness and quality of the produce delivered to the faraway markets, as it retards a number of deteriorative processes.

Cite this article: Prasath, V.A., Viswanath, A. and Ganapathy, S., A Review on Physicochemical Changes in Fresh Horticultural Produce under Cold Storage Condition, *Int. J. Pure App. Biosci.* **6(1):** 1558-1563 (2018). doi: http://dx.doi.org/10.18782/2320-7051.2948

Physiology of Fruits and Vegetables

Freshly harvested fruits and vegetables, though appearing as inanimate objects, continue to live in a dynamic state. Upon harvest, they lose the supply of nutrients, minerals, and water that the parent plant was delivering for necessary life functions. The fruit or vegetable continues to live by relying on the nutrients, minerals, and water that it has stored. Harvest time coincides with the maximum "potential quality" of the commodity. The nutrient and mineral contents are at the maximum, as these can only decrease as they are being used to keep the commodity alive. Further, the consumer quality may not beat its maximum when harvested. The commodity may be harvested while still immature, and the subsequent storage will allow it to ripen and become more flavourful. In both cases, postharvest physiology plays an important role in the quality of the commodity. The physiological processes that occur within the commodity after harvest are directly linked to its quality. Therefore, understanding of the major postharvest physiological processes is necessary in the implementation of proper postharvest systems. The aspects of physiology of major concern in postharvest systems are product respiration, product transpiration and ethylene synthesis.

Respiration

Respiration occurs continuously inflective cells of fruit or vegetable after harvest. It is an oxidation-reduction process in which photosynthetic substances are oxidised and that is reduced to form water. The chemical reaction under aerobic conditions are represented as the following.

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + 2872 \text{ kJ/mol} \quad \text{------(1)}$$

There action shown above is based on one mole of glucose ($C_6H_{12}O_6$). The above reaction is simplified for easy understanding. The entire reaction is actually made up of more than 50 component reactions, with each reaction occurring due to a different enzyme. The process of respiration can use many substrates other than$C_6H_{12}O_6$, such as starches, sucrose, fats, organic acids, and proteins.

When the process of respiration completely oxidises carbohydrates, such as glucose, sucrose, or starch, the amount of CO_2evolved will equal the amount of O_2absorbed. If other substrates are used, or if there is incomplete oxidation, then the amount of O_2 used and the amount of CO_2 evolved will not always be the same. The ratio of CO_2 to O_2 is referred to as the respiratory quotient (RQ) and may be expressed as follows:

$$RQ = \frac{CO_2 evolved\ (ml\ CO_2.kg^{-1}.h^{-1})}{O_2\ absorbed\ (ml\ O_2.kg^{-1}.h^{-1})} \quad \text{--------------(2)}$$

The value of RQ can be useful in determining what type of substrates the cells are using. The difficulty in this is that oxidation of much substance take place at the same time and the RQ value gives an average of the CO_2 and O_2 relations.

The respiration rate dependson enzymatic activity, which is a function of temperature. Thus, temperature plays a significant role on the overall respiration rate since respiration requires the action of over 50 enzymes and the level of enzyme activity is affected by temperature. The effect of temperature on the respiration rate is often quantified by determining the Temperature Coefficient (Q_{10}):

$$Q10 = \frac{[Respiration\ rate\ at\ (T°C + 10°C)]}{Respiration\ rate\ at\ T°C} \quad \text{------------------------(3)}$$

The Q_{10}maybecalculated based on the number ofml-kg^{-1}-h^{-1}ofCO_2 evolved or O_2absorbed. Generally, the respiration rate (Q_{10}) is increased by a factor of2to4for each temperature increase of 10°C.

Modification of the gas composition surrounding the produce after harvest maybe used to control the respiration rate. It has been observed that increasing theCO_2 level and decreasing the O_2 level tends to decrease the rate of respiration of some produce.

Transpiration

Transpiration is the movement of water from the fruit or vegetable to the surrounding atmosphere. This process reduces the overall weight of the produce. If a significant waterless occurs, the produce may experience shrivelling or become limp, resulting in lower customer satisfaction. Transpiration is a mass transfer process with the driving force being a water vapour pressure gradient. The relationship between the rate of water loss and the pressure difference is generally given as

$$M_T = C_T . W_p . (P_i – P_0) \quad \text{------------(4)}$$

Where

M_T = Transpiration rate ($g.s^{-1}$)

C_T = Transpiration coefficient ($g.kg^{-1}.s^{-1}.Pa^{-1}$)

W_p = Produce mass (kg)

$P_i – P_0$ = Water vapour pressure difference (Pa)

The respiration rate affects the transpiration rate due to the liberation of heat. This tends to increase the temperature of the produce and hence increases the water vapour pressure deficit. On the other hand, the process of respiration uses up substrates and produces water, the end result is a dilution of the substrates. This gives rise to a positive change in the water vapour pressure and therefore increases the transpiration rate. The process of transpiration itself can affect the rate of moisture loss. This happens in two ways: first, the loss of water will concentrate the water and substrate mixture. This concentration will over the saturation vapour pressure and hence increase the transpiration rate. Secondly, the cooling effect due to the evaporation of water from the product's surface causes localised cooling. In this cooling the water vapour pressure reduced and decrease the transpiration rate. Many other factors can affect the transpiration rate, such as size, shape, surface area, surface structure, and maturity of the fruits.

Ethylene production

The third major physiological process that must be dealt with in postharvest storage of fruits and vegetables is that of ethylene (C_2H_4) synthesis. In fruits, C_2H_4 is the hormone that triggers ripening and senescence. As cells deteriorate, they produce CO_2, which spreads through the fruit causing senescence to begin in other cells. This can be a substantial problem in the storage of fruits. One fruit that begins to ripen can produce high amounts ofC_2H_4 that starts a chain reaction causing more fruits to begin to ripen. Respiration rates increase for many produces in the presence of C_2H_4.

Ripening and the production of CO_2, may be delayed if the temperature of the produce is low, in the same way as respiration is slowed due to low temperature. Both low O_2 concentrations and low temperatures can slow the rate of C_2H_4 synthesis[9].

Quality Deterioration during Storage

Wilting due to water loss leads to senescence associated discoloration, mechanical injury, high respiration rate, and decay or rotting are the main causes of spoilage and postharvest loss of leafy vegetables. These causes of quality loss are physiological, pathological and mechanical in nature[8].

Physiological deterioration

A. Water loss and wilting

Leafy vegetables are mostly water (>90%) and have the propensity to lose water through transpiration. Water loss is the main cause of weight loss (loss in saleable weight) and wilting. A loss of 5-10% of fresh weight would make leafy vegetables to appear wilted and become unusable[8]. Water loss also induces degradation of nutritional components and imposes stress that rises respiration and ethylene production. Wilting is primarily due to water loss through the stomata[14]. Water loss was measured at 2.8% per hour at 35°C. Complete closure of all stomata occurs between 10-15% moisture losses.

B. Respiration and ethylene production

Prolonged exposure to ethylene, as low as 0.01 ppm, could cause significant losses of fresh produce. Ethylene easily accumulates in packages, packinghouses, storage areas, and even markets. Wills *et al*[18]., states that all plant tissues produce ethylene, although at varying levels. In markets (wholesale, retail, distribution centres), the main sources of ethylene, in addition to the fresh produce, include ripening fruit, decaying produce, and exhaust gases of vehicles; concentration could reach 0.02-0.06 ppm, which can cause a 10-30% loss in product shelf life. The effect of ethylene is cumulative, so continuous exposure to a low concentration throughout marketing can cause significant harm. The loss of shelf life will be most frustrating for the final consumer, as the loss of quality will not be evident during retailing. Aside accelerating aging, ethylene increases product susceptibility to decay. Yellowing is found to be controlled by the sugar level (the main energy substrate) rather than ethylene, which explains the poor performance of anti-ethylene agents (e.g. 1-methylcyclopropene) in extending shelf life[14].

Pathological decay

Vegetables are susceptible to postharvest diseases that render the produce unfit to sell. Postharvest diseases can be spread through field boxes contaminated by soil or decaying produce or both, contaminated water used to wash commodities before packing, decaying rejected produce left lying around the packinghouse, and contaminated healthy produce in packages. Microbial infection can occur both before and after harvest. The infection after harvest can be found at any time between the field and final consumer[8].

Chilling injury

It is a physiological disorder induced by low, non-freezing temperatures that affects both plants and fruit from tropical and subtropical origins[15]. It has been widely stated that the expression of chilling injury symptoms, particularly flesh browning or internal browning, develops faster and more intensely when stone fruits are stored at temperatures between 2.2 and 7.7°C (killing temperature zone) than those stored at 0°C or below but above their freezing point[10]. The symptoms of CI manifest themselves differently in different plant produce. In peaches and nectarines CI symptoms manifest themselves as dry, mealy, woolly (lack of juice), flesh or pit cavity browning, and flesh bleeding or internal reddening[10].

The internal browning may be related to tissue senescence, which leads to changes in membrane permeability and the interaction in between polyphenol oxidase andphenols, which are generally found in separate compartments in the cell[10].

Chillinginjury playsa crucial part in the postharvest storage offruits and vegetables. The main method of prolonging storage life of produce is by maintaining low temperature conditions, which is not possible with chilling sensitive produce. Symptoms of chilling injury are often not displayed at the low temperature conditions, but usually developing rapidly after being removed from low temperature storage.

A. Symptoms of chilling injury

Chilling injury symptoms to horticultural crops are diverse and these include pitting, sheet pitting, shriveling, wilting, scald, surface lesions, water soaking of tissues, internal discoloration (browning), breakdown of tissues, failure of fruits to ripen in the expected pattern, accelerated rate of senescence, increased susceptibility to decay, shortened storage, compositional changes related to consumer acceptance, and loss of normal growth capacity. Most of these symptoms are not unique to chilling injury, often making it difficult to diagnose the cause of commercial losses of these crops.

Mechanical injury

Vegetables are very susceptible to mechanical injury (physical damage). Tearing and crushing, midrib breakage, and head cracking or bursting are common forms of damage. Physical injuries increase physiological deterioration through browning as a result of oxidation of phenolic substances, and susceptibility to decay. Postharvest rots have been found to be more prevalent in bruised or damaged produce. Mechanical damage also increases moisture loss by as much as 3-4 times more than that of undamaged produce[4].

Membrane permeability

Membranes are dynamic structures that support numerous biochemical reactions and they are also major targets of environmental stresses[6]. Chilling impairments mainly consist of alteration of metabolic processes, reduction in enzymatic activities, decrease of photosynthetic capacity and changes in membrane fluidity. Such changes are often related to an increase in membrane permeability, affecting membrane integrity and cell compact mentation under stress situations.

Increased rates of solute and electrolyte leakage occur in a variety of chilled tissue and have been used to evaluate membrane damage following chilling, reviewed by Campos *et al*[6]. When exposed to chilling, plant cell membranes undergo changes in lipid and fatty acid composition in order to maintain cell functions at low temperatures.

Fruit browning (discolouration)

Browning is one of the undesirable reactions that occur in many fruits and vegetables.

This browning of fruits, also referred to as fruit discolouration, negatively affects the marketability of many fruits as a result of poor appearance. This physiological disorder occurs internally in some fruits (e.g. plums), externally in other fruits (e.g. litchis) and in some cases both internally and externally (e.g. in some white table grape cultivars). Fruit browning can be divided into enzymatic and non-enzymatic reactions.

1. Enzymatic browning

Enzymatic browning is catalyzed by polyphenol oxidase[17]. Polyphenol oxidases(PPO) or tyrosine's are enzymes with a dinuclear copper center, which are able to inset oxygen in a position *ortho*- to a prevailing hydroxyl group in an aromatic ring, followed by the oxidation of the diphenol to the equivalent quinone[12]. The most likely functions for PPO are its involvement in plant resistance against diseases and against insect herbivory[13]. Enzymatic browning is due to a lack of compartmentation within the cell. The lack of the cellular compartmentation results in phenolic being exposed to PPO. In some fruits this damage is triggered by exposure to chilling temperatures[7].

2. Non-enzymatic browning

Non-enzymatic browning is favoured by heat treatments and includes a wide number of reactions such as the Maillard reaction (MR), caramelisation and chemical oxidation of phenols[11]. The Maillard reaction is a complex reaction, since it is influenced by factors such as temperature, pH, time, water activity, type and concentration of buffer, reaction source and sugar involved. Changing any of these factors will alter reaction rate, reaction pathways and reaction end-products. The Maillard reaction takes place in three major stages, as reviewed by Sumaya-Martines *et al*[16].,:

- At an early stage of the reaction, the free amino group of proteins such as the e-NH groups of lysine, react with carbonyl groups of sugars to form a reversible Schiff base, which rearranges to stable, covalently bonded Amadori products. The radical scavenging activity is derived from the two uncoloured pigments.
- At intermediate stages, highly UV absorbing and colourless compounds are continually formed. In the advanced phase of the reaction, Amadori products undergo further transformation to fluorescent, coloured substances and cross-linked polymers.
- Formation of melanoidins and heterocycles compounds in the advanced stage of the Maillard reaction could explain the ability of glycated hydrolysate to react with radical compounds.

Maillard reactions in model systems lead to the formation of different chemical species, it promotes changes in antioxidant properties, which are positively correlated with the development of browning[11].

CONCLUSION

In pre-harvest stage, the carbohydrates are supplied by the mother plant to the fruit, hence less damage to the fruit, while the reserves in the harvested fruit are finite, which means these reactions cause more damage to the fruit postharvest[9]. Over and above the natural deterioration due to biochemical reactions taking place inside the harvested fruit, harvested fruits are more prone to pathogen attack and damage due to different environmental factors. The main aim of postharvest handling is to retain and deliver to the consumer the products that are still at their best quality.

Cooling provides an active and effective way to decrease the senescence (biochemical reactions) of the product[3] and retards the growth of many decay organisms during storage and transport of the fresh produce. This process of precooling thus retains freshness and quality of the produce, which in turn ensures customer satisfaction.

REFERENCES

1. Anonymous, Horticultural Crops Statistics and database at a Glance. Indian horticulture board, Government of India, pp. 7-65 (2014).
2. Anonymous, Horticultural database of fruits and vegetables. Indian horticulture board, Government of India, pp. 15-75 (2015).
3. Arin, S. and Akdemir, S., Quality properties changing of grapes during storage period. *J. Biol. Sci*., **4(2):** 253-257 (2004).
4. Bachmann, J. and Earles, R., Postharvest Handling of Fruits and Vegetables. ATTRA Horticulture Technical Note. 19 pp (2000).
5. Brosnan, T. and Da-Wen, S., Precooling techniques and applications for horticultural products. *Intl. J. Refrig*., **24:** 154-170 (2001).
6. Campos, P.S., Quartin, V., Ramalho, J.C., and Nunes, M.A., Electrolyte leakage and lipid degradation account for cold sensitivity in leaves of Coffea sp. *Plants, J*., 245pp (2003).
7. Jiang, Y., Duan, X., Joyce, Z. and Li, J., Advances in understanding of enzymatic browning in harvested litchi fruit. *Food chem*., **88:** 443-446 (2004).
8. Kanlayanarat, S., Postharvest technologies for fresh leafy vegetables in Thailand. Paper presented during the RETA 6376 Workshop on Best Practices in Postharvest Management of Leafy Vegetables in GMS Countries, 25-27 October 2007, Hanoi, Vietnam (2007).
9. Kays, S.J. and Paull, R.E., Postharvest Biology. Exon Press, USA (2004).
10. Lurie, S. and Crisosto, C.H., Chilling injury in peach and nectarines. Postharvest. *Biol. and Technol*., **37:** 195-208 (2005).
11. Manzocco, L., Calligaris, S., Mastrocola, D., Nicoli, M.C. and Lerici, C.R., 2001. Review of non-enzymatic browning and antioxidant capacity in processed food. *Journal of Food Science*, **56:** 104 pp.
12. Mayer, A.M., Polyphenol oxidases in plants and fungi: Growing places. A review. *Phytochem*., **67:** 2318-2331 (2006).
13. Mazzafera, P. and Robinson, S.P., Characterization of polyphenol oxidase in coffee. *Phytochem*., **23:** 285-296 (2000).
14. O’Hare, T.J., Able, A.J., Wong, L.S., Prasad, A. and McLauchlan, R., Fresh-cut Asian vegetables pakchoi as a model leafy vegetable. In: O’Hare, T., Bagshaw, J., Wu Li and Johnson, G.I., ed., Postharvest handling of fresh vegetables. Proceedings of a workshop held in Beijing, P.R.C., 9-11 May 2001. ACIAR Proceedings **105:** 113-115 (2001).
15. Sanchez-Ballesta, M.T., Gosalbes, M.J., Rodrigo, M.J., Granell, A., Zacarias, L. and Lafuente, M.T., Characterization of a ß-1, 3-glucanase from citrus fruit as related to chilling-induced injury and ethylene production. Postharvest. *Biol. and Technol*., **40:** 133-140 (2006).
16. Sumaya-Martinez, M.T., Thomas, S., Linard, B., Binet, A., and Guerard, F., Effect of Millard reaction conditions on browning and antiradical activity of sugar-tuna stomach hydrolysate model system. *Food Research Intl*., **38:** 1045-1050 (2005).
17. Valentines, M.C., Vilaplana, R., Torres, R., Usall, J. and Larrigaudiè, C., Specific roles of enzymatic browning and lignification in apple disease resistance. Postharvest. *Biol. and Technol*., **36:** 227-234 (2005).
18. Wills, R.B.H., Warton, M.A. and Ku, V.V., Ethylene levels associated with fruit and vegetables during marketing. Australian Journal of Experimental Agriculture **40:** 357–492 (2000).