THE ENHANCEMENT OF PHYTOCHEMICAL COMPOUNDS IN FRESH PRODUCES BY ABIOTIC STRESS APPLICATION AT POSTHARVEST HANDLING STAGE A REVIEW

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ABSTRACT

Fresh produces is one of functional food based on its phytochemical contents. The great amounts of the phytochemical compounds in fresh produces become the main core of quality jugdement from fresh produses as a functional food. The use of proper postharvest handling system of fresh produces can be as a tool to protect the loss of the external quality and also can be used to enhance the levels of phytochemical compounds therein at the same time. A good management of plant stresses in respect to key enzymes activation of phytocemicals pathway during postharvest handling treatments of fresh produces can trigger distinct change of contained phytochemicals that can promote their healthy beneficial effect for human life.

Keywords: fresh produces, postharvest handling,enhancement, phytochemical compounds

INTRODUCTION

Many researchers have been informing the potential for exploitation of plant products as a source of beneficial compounds for the production of nutraceuticals, functional foods and food additives (Gil-Chávez *et al*., 2013). The consumption and acceptance of functional food has been increasing on customers in conjunction with the awareness that by healthy eating is a better way to administer drugs used instead of disease (William,2006). Due to the increasing of consumers health awarenes there is shift on their judgment of food quality form appereance to judging the quality based on nutritional value (Kader,2003 and Klee,2010). The consideration to the need of high content of healty beneficial nutritional compounds has been strengthened by the willingness of a group of consumer to spent more money to obtained these kind of food (Klee,2010).

One of functional food resources from plants, can be obtained form fresh produces (fresh fruits and vegetables). It is well known that fruit and vegetables are important components of a healthy diet, and their continous consumption may help to prevent major diseases, such as cardiovascular diseases (Pieter van't Veer,1999; Wang *et al*.,2014; Ness *et al.*, 2005), certain cancers (Pieter van't Veer, 1999; Soerjomataram *et al*., 2010), and anti obesity (Nuutila *et al*., 2003; Singh *et al*., 2007). Epidemiologic studies have also shown many health benefits associated with the consumption of fruit and vegetables (Hung *et al*., 2004;

McCann *et al*., 2005). Consumption of fruit and vegetables to help in the deterrence of free-radicals, thereby reducing oxidative damage which can lead to several chronic diseases (Hung *et al*., 2004; Prior, 2003).

The beneficial effects of fruits and vegetables has been associated with non-essential constituents, known as phytochemicals or bioactive compounds, which have a related bioactivity when they are often consumed as part of a daily diet (Mudgal *et al*., 2010). The kind of these phytochemical consist of a wide range of objects. The commonly phytochemicals that contained in plants including in fruit and vegetables are phenolic compounds, alkaloids, terpenoids, steroid and glucosinolate. A range of phytochemicals have been reported in fruit and vegetables and are typically grouped based on function, chemical structure and also based on source. A beneficially fresh produces will have high value if the high concentration of their phytochemical compounds can maintained from farmer to consumer, thus, after harvest handling play an important role in this stage. Basiclly, the produce quality that is imprescriptible, can not be improved significantly after harvest, which is expected to only execute for a window of time (shelf life) typical (Suslaw T, 2000).

Postharvest handlings such as cleaning, sorting, packaging, transportation, storage, postharvest treatments practices including food processing and non toxic substances application involve in level of phytochemical compounds in fresh produces. There are two main factors; storage factors and postharvest treatments practice that have be considered (Tiwari and Cummins, 2013 ; Schreiner and Keil, 2006). The optimization of these factors is an essential step to maintain and/or enhance the level of phytochemicals that affected to their bioactivity.

The consideration of these factors is in association of fresh produces response to the stresses that obtain during this stage. Due to their natural as living organism, fresh produces marketable property can be affected by various condition such as temperature and humidity changed, the composition of the atmosphere, the level of harm microorganism which surrounding them and injury condition. Inappropriate condition will cause the undesirable stress that can produce the loss of fresh produce quality such as appearance, texture, color, flavor and nutritional value including the phytochemical compounds. Therefore, to meet the shift in consumer needs to high level of phytochemical compounds in fresh produces that promote to their healty life without avoiding the need for external quality attributes of its fresh produces, good knowledge about storage, nontoxic subtances additive and food processing need to be a consideration point at postharvest practice stage to meet the consumer satisfaction.

According to Ayala-Zavala et al., 2005, the exposure postharvest treatments such as temperature storage treatments, UV-C irradiation, maturity effectors, atmosphere modification, minimal processing and chemical applcation to fruits and vegetables affected to their phytochemicals level. Baenas et al (2014) mentioned that the enhancement production of phytochemicals on fresh produces can be applied during postharvest practice by using elicitors treatment.

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Postharvest handling management of fruits and vegetables with certain limits can prolong their shelf life. The use of proper postharvest handling system elevate nutritional value such using the low temperature storage, heat treatment, irradiation to increase phytochemicals compounds which become the most desirable phenomenon during distribution of fresh produces. Therefore. the study of postharvest handling in order to maintain/enhance phytochemical compounds in fresh produces must be taken into consideration for developing novel postharvest technology.

Therefore, aims of this brief review are to present an overview of the fresh produces storage and processing treatments as the postharvest handling practice in asscosiation with their elicitation affect to enhance the contained beneficial phytochemical compounds and to discussion the implications of this in term of postharvest research develoment.

THE PROPERTIES OF FRESH PRODUCE PHYTOCHEMICALS

Naturally, fresh produces contain in rich abundance of phytochemicals (Rechkemmer, 2001). As a secondary metabolites in plants including in fresh fruits and vegetables, phytochemicals mostly exert their biological effect on other organisms and environment as defensive substances, antifeedants, attractants and pheromones (Hanson, 2003). Therefore, due to the huge compound of phytochemicals make the classification of them is complicated.. Generally, there are four main classes of phytochemicals that widely studied on fresh produces: phenolic compounds, terpenoids, glucosinolates, alkaloids (Crozier *et al*.,2006). In association of food consumption, phytochemicals perform tremendous in vitro antioxidative ability which hypothesized has close relationship with human healthiness (Duthie *et al*., 2000). Due to the antioxidant activity of phytochemicals that contained in fresh produces make some people classify fruits and vegetables as functional foods (Laura A. de la Rosa *et al*., 2010).

The fact that most of phytochemicals act as antioxidant attribute fruit and vegetables becomes important components of a healthy diet, and their continous consumption may help to prevent many major diseases. Consumption of fruit and vegetables to help in the deterrence of free-radicals, thereby reducing oxidative damage which can lead to several chronic diseases (Hung *et al*., 2004; Prior, 2003). Need to confrim that consume of phytochemicals in fresh produces may help to prevent from major deseases but may not to cure. Therefore, people need to realized that sustainable eating a healty diet such as fruits and vegetables that containing high level of phytochemical compounds is an inherent need to preserve their healthiness. The epidemiological study informs that well consumption of high content phytochemicals fruits and vegetables with no smoking habits and contonously infection control combination can reduce the emergence of several chronic deseases including cardiovascular disease and different type of cancer (Ames at al., 1995; Graham and Mettlin, 1981; Giovannucci, 1999; Liu, 2004; Syngletary *et al*., 2005; Percival *et al*., 2006). Consequently, the World Health Organization (WHO) recommends a high consumption of friuts and vegetables in a daily with minimum intake as 400 g per person . Increasing and maintaining

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phytochemicals level in the fresh produces is one concerted effort to raise publict interest about the advantage of consuming health- promoting phytochemicals in fresh produces themself.

The level of a particular phytochemicals in different fruits and vegetables varies depending on cultivar (Nuutila, *et al*., 2003; Singh, *et al*., 2007), cultivar variation, climatic conditions, growing locations, agronomic factors, harvest factors (including maturity stage) (Naczk & Shahidi., 2006; Padilla *et al*., 2007; Vallejo *et al*.,2003). Apart from these pre-harvest factors, various postharvest handling factors also have a major influence on the existence of phytochemicals in fruits and vegetables and their products. In distribution chain of fresh produces from farmer to cunsumers, postharvest handling factors play an important role in correlation with quality maintanance of fresh produces product including their contained phytochemicals level.

According to Rajashekar *et al* (2009), as the antioxidants, the phytochemicals as the product of plant secondary metabolism appear to have similiar protective fuction in plants against oxidative damage caused by various stresses. To cope with the stresses, basicly plants have two kind of strategy that they can tolerate it or can either avoid it (Hodges *et al*., 2004). However, to tolerate oxidative stress with an adaptive mechanism, plants tend to shift toward secondary metabolism in accumulting the production of phytochemicals protective antioxidants. Therefore, with a proper enviromental controlled stress application on fresh produces may organize a facility to improve their cointained beneficial health-promote phytochemicals (Rajsahekar *et al*.,2009). For example, among many kinds of flavonoid in plants, flavonols are the most abundant flavonoids in plants and probably the most important flavonoids participating in stress responses that having a wide range of potent physiological activities (Stafford, 1991; Pollastri and Tattini, 2011).

However, enviromental controlled stress application (abiotic stress) as an external stressfull signal, is not directly involved in the phytochemiclas metabolism of plants, instead of activating its coresponding efectors such as nitric oxide (NO), this data has been discused by jiao et al.,2016 on their experiment that succesfull to generate of NO that induced isoflavones by UV-B treatment. Their results showed that UV-B-triggered NO generation induced isoflavone accumulation by up-regulating the activity and gene expression of key enzymes (phenylalanine ammonia lyase, PAL; chalcone isomerase, CHI; chalcone synthase, CHS; isoflavone synthase, IFS) that participate in isoflavone biosynthesis.

POSTHARVEST HANDLING PRACTICE IN ASSOCIATION WITH PHYTOCHEMICALS IN FRESH PRODUCES

As been known that biological effect of fruits and vegetables is came form the the amounts and types of phytochemicals that are present in the fresh tissues. As mentioned previously, to enhancing the synthesis of phytochemicals in postharvest handling stage of fresh produces, applied the controled abiotic streeses as an elicitor can activating an array of mechanisms, similar to the defense responses to pathogen infections or environmental stimulating and triggering the plant metabolism activity (Baenas *et al*.,2014). Typical abiotic elicitor treatments has been used in postharvest handling practices to enhance the phytochemical content and quality composition in many fruits and vegetables, such as the application of low or high temperature treatments, atmosphere controled/modified, wave irradiation, surface coating application, minimal process operation and chemical elicitors application. As mentioned previously, that storage factors and food processing operation are the main concern of pyhtochemical stability in fresh produces at postharvest handling stage, the application of elicitor treatments have been done on these factors.

In application of temperature control, the application of temperature stress is often related to enhanced activities of enzymes involved in antioxidant systems of plants. Plants exposed to uncompfortable temperatures will use several non-enzymatic and enzymatic antioxidants to cope with the harmful effects of oxidative stress; higher activities of antioxidant defense enzymes are correlated with higher stress tolerance. Different plant have revealed that enhancing antioxidant defenseconfers stress tolerance to either high temperature or low temperature stress (Hasanuzzaman *et al*.,2013).

In addition to controled temperature, enviromental modification during fresh produces postharvest handling by increasing oxygen concentration in the internal and external fruits atmosphere can cause the increase in the production of free radicals that could result in oxidative stress in the fresh produces tissue. This condition can triggering responses of the antioxidant system and affected to occurence of phytochemical compounds include their bioactivity (Ayala-Zavala *et al*.,2007). It can be concluded that strengthening in oxidative stess modification in fresh produces tissue during storage become an intersting subject to be developed that make postharvest treatment not only enhance the fresh produces shelf lafe but may also elevate their healthy benefecial effect.

According to Tiwari and Cummins (2013), food processing operations as a post handling practice are a kind of applied postharvest technology that cotrollable to optimize in order to reduce of loss phytochemicals in fresh produces them self. Minimal processing operation such as cutting will effect to injuries occured in fresh produces, either naturally or mechanically in cellular disruption and can allow enzymes to come into contact with their subtrate, water loss and oxygen entry can trigger stress and defence response including modulation of the metabolic pathway leading to altered expression of phytochemicals such as phenolic compounds. According to Alarcón-Flores *et al* (2014), among phytochemicals, phenolic compounds are most easily influenced by cutting injuries.

The use of wave irradiation in postharvest handling practice such as gamma, ultraviolet and other specific wavelength irradiation also can promote the production of phytochemicals in fresh produces. Enzym activation such as PAL activation by UV irradiation involved in increasing phenolic compounds that similiar to low temperature effect (Rajashekar at al.,2009). Futhermore, improvement of constitutive inhibitor such as antimicrobial compounds and phytoalexins and activation of specific proteins such as chitinase and glucanase also activied by irradiation stress that exposed surround the fresh produces (Forbes and Smith, 1999).

Another kind of postharvest handling treatment such as application surface coating by non toxic additive subtances also can stimulte the enhancement of phytochemicals of fresh produces. For example, edible coating application has beneficial effect to increasing phytochemicals in fresh cut produce during postharvest handling practice. Usually, edible coating material can protect the products againts oxidative rancidity and discoloration (Baldwin *et al*.,1995). In the correlation with phytochemicals development, edible coating can inhibit enzyme poliphenol oxidase activation which can cause degradation phenolic compounds in fresh cut produces (Jiang *et al*., 2005).

STORAGE PRACTICE AS ELICITORS

Low or high temperature storage

Shelf life of fresh produces under ambient condition is very limited due to the increase in the rate of respiration after harvest that make them are more susceptible to disease organisms. The respiration of fresh fruits and vegetables can be reduced with many techniques such as low-temperature preservation, canning, dehydration, freeze-drying, controlled atmosphere, and hypobaric and modified atmosphere. Dehydration also control the activities of microorganisms by the removal of water under controlled conditions of temperature, pressure and relative humidity.

Metabolic rate of fruits and vegetables are directly associated to a variety of storage enviromental condition such as temperature, light and atmosphere (Hopkin and Huner, 2009). Storage treatments is one effort in postharvest stage with approaces to enhance shelf life of fresh produces with basicly priciple that revolved in trying to maintain respiration rate, desease development and decay formation by various methods such as temperature controling, humidity controling, controling or modified of existence of oxygen. Among these storage methode, the selection of a proper temperature and manipulation the axistence of oxigen were the ways that reported can be as an elicitor to enhance the level of pyhtochemicals as healty beneficial compounds in fresh produces (schreiner and Keil, 2006) Mainly, temperature control and controled / modified atmosphere methods are critical conditions in maintaining respiration rate of the products during storage in correalation with metabolic activity.

In postharvest handling stage such as storage practice , the phytochemical compounds biosynthesis stimulate consistenly. In case the metabolic activity was due to the applied storage conditions. Therefore, harvesting time affected to the profile of phytochemical compounds in fresh produce. According to schreiner and Keil, 2006, premature and on time mature harvesting time with good maintainance of respiration rate in optimal storage temperature will increasing the phytochemicals when products were still in the ripening process. This phenomonen are more pronounce at higher temperature of up to 25^0C. In the consideration of proper storage temperature selection, product's physiology need to be adjusted. In consequence product's genotype, chiling injury sensitivity will have a close relationship with the elicitation activity during optimal storage treatment of fresch produces.

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For instance, the evolution of the content of some major flavonols was measured in red and white onion bulbs during 7 months of storage, under refrigerated and under traditional bulk storage in the field has reported by Rodrigues *et al* (2010). The report informed that total flavonols increased up to 64% after 6 or 7 months of storage. In the red onions, the increase after 6 months storage usually has place when the flavonol post-harvest levels are low (40–64% increase), whereas for white onions the increase after 6-months storage is important for onions with higher levels after harvest (44–60% increase). These results suggest that storage at fluctuating ambient temperatures can positively affect flavonol metabolism, while keeping the flavonols profile.

Comparation of the effect of two different storage temperatures on the quantity of flavonoids in the persimmon fruit reported by Tulin OZ and Kefalas (2010), the profile of persimmon fruit flavonoids at three different maturation stages at 20°C and 0°C was studied. The highest level is found at 20°C. The fluctuation of the flavonoid profile was more extended at 20°C than at 0°C, where the levels between the first and the second development stages were practically the same. At 20°C the levels of flavonoids increased significantly with the developing stage. It may be concluded that flavonoids increased with ripening at both storage temperatures. The storage conditions are very important for the quantity of flavonoids in persimmon fruit. High temperatures treatment seem to induce flavonoid accumulation. Prono-Widayat *et al*, 2003 also reported that in pepino fruits showed an increasing of β-carotene in high temperature at 18 ^{0}C in both of premature and mature fruits. The use of low temperature at 5 ^{0}C has no effect of β-carotene in this study.

Low temperature storage treatments on the phytochemicals profile on the fresh produces also have the obvious effect. Rajashekar at al (2009) informed that the use of low temperatures is the most commonly used storage method. In addition to easy to organize, low temperature storage also can be combined with other various postharvest treatments. However, these methods have good elicit ability of the phytochemicals level of fresh produces especially on the effect of stimuulate the metabolism of phenyl propanoid pathway which is the source the most of the phenolic compounds.

Low Temperature stress comprises of chilling (20^{o}C) and freezing temperatures (<0^{o}C) also effected to the cellular change of the fresh produces . This response will lead to the excess accumulation of toxic compounds which may cause occurence the reactive oxygen species (ROS). The end result of ROS accumulation is oxidative stress (Mitler, 2002; Yin and Yi, 2008; Suzuki and Mitler,2006). Therefore, under low temperature stresses, plants have various enzymatic and non-enzymatic defense systems to minimize the deleterious effects of ROS which include the enzymes (Hasanuzzaman *et al*.,2013).

As reported by Kjeldsen *et al*.,2003, during 4 months of refrigerated storage, the concentration of total volatiles phytochemicals (terpenoids groups) increased significantly on intact first-class winter carrots cv. Bolero and in cv.Carlo. During this period the concentration of monoterpenes doubled in cv. Bolero and increased 3-fold in cv. Carlo, while that of sesquiterpenes increased almost 5-fold in cv. Bolero and 6-fold in cv. Carlo. After 4 months of refrigerated storage, the mono- and sesquiterpenes in cv. Bolero

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accounted for around 25 and 75% of the total volatile mass, respectively, as compared to 41 and 58% at the beginning of the period indicating that secondary plant metabolism was very active during postharvest storage of carrots. In contrast, the concentrations of mono- and sesquiterpenes and total volatiles as well as the relative concentrations fluctuated around the same level during frozen storage of cv. Bolero and cv. Carlo. For phenylpropanoids, which constituted 0.3% of the total volatile mass, the levels were almost the same during the 4 months of frozen storage, whereas there was a minor increase in the concentration during refrigerated storage. The significant increase in the concentration of terpenoids during refrigerated storage from 1 to 4 months showed that terpene biosynthesis has stimulated during storage. Whether this metabolic activity was due to the applied storage conditions or other factors is not known; however, the present results indicate that mono and sesquiterpenes play a central role in relation to changes in the sensory quality of refrigerated carrots in line with sugars and other nonvolatile compounds (Seljasen *et al*., 2001; Simon P., 1985).

The association of maturity and controled temperature treatments also reported by R.B Jones, 2006 that anthocyanins in a number of fruits such as apples and berries tend to increase with ripening process, and this increase can continue after harvest under the right storage conditions. For examples, anthocyanin content increased in blueberries during 3 weeks of storage at 5°C (Connor *et al*., 2002), or at 1°C or 15°C in cherries, with an up to 5-fold increase at 15°C (Goncalves *et al*., 2004). Furthermore, The combination of low temperature storage treatments (4 ^{0}C) and cutting processed also observed can increase the content of phytochemicals during the storage of eggplants, carrots and grapes regardless of the presence of absence of light (Alarcón-Flores *et al,* 2014).

Controled atmosphere (CA) or Modified atmosphere storage (MA)

Altered gas composition with oxigen concentration reduced and carbon dioxide concentration increased that surrounding the product atmosphere during storage also can cause a kind of postharvest stress and led and escalation of phytochemicals but these method not too very common in correlation of enhancement phytochemicals in fresh produces due to their effectivity. Just a litlle information available about the achievement of alterred gas composition application for elevating the phytochemicals during storage compare than the use of controled temperature such as low temperature treatments. Among others, the anthocyanin enhancement in strawberries stored at 5°C if CO2 atmospheres reached 10 kPa (Holcroft & Kader, 1998), or in high (95%) O2 in purple carrots (Alasalver *et al*., 2005). Selcuk and Erkan (2015) also reported that during storage on the MAP treatments in 6°C and 90–95% RH 120 days storage of sweet pomegranates cv. Hicrannar give the result that increased of total phenolic compounds but for the sour sweet pomegranateo cv. Hicrannar in 210 days Total phenolic compounds, increased slightly until the irst 120 days of storage, and then decreased during the rest of the storage. Moreover in certain postharvest condition such as high oxygen treatment (60-100%) on blueberry fruits may increased the total phenolic compounds (Zheng *et al*., 2003).

On the MAP treatment on spinach, Gil *et al* (1999) reported that the spinach has content ten compounds of flavonoid. The flavonoid content on the spinach after storage remained very stable both in air and MAP and no degradation during the storage period was observed (3 and 7 days of storage at 10°C.).

In contras to phenolic compounds, glucosinolate showed the convenient adaptation with these storage methods. The effect of CA or MA storage on glucosinolate content in broccoli, 'Marathon' broccoli heads stored for 25 days at 4°C, under a CA atmosphere of 1.5% O2 and 6% CO2 contained significantly higher glucoraphanin levels than heads stored in air at the same temperature (Rangkadilok *et al*., 2002).

Radishes packed in modified atmosphere (8.3 kPa O2 + 5.4 kPa CO2) showed an accumulation of glucosinolates after 5 days of storage (Schreiner *et al.*, 2003). Also, the glucosinolate content of broccoli stored in a controlled atmosphere (0.5 kPa O2 + 20 kPa CO2) increased continuously during 7 days of storage (Hansen *et al.*, 1995). Hansen *et al.* (1995) proposed that this increase in glucosinolate content could be associated with a de novo glucosinolate biosynthesis based on metabolites (e.g., amino acids) originating from the decomposition of other compounds. This process also seems to take place in radish packed in a modified atmosphere (Schreiner *et al.*, 2003). Presumably, the glucosinolate increase in controlled and modified atmospheres is a stress response of the product to the increased CO2 and decreased O2 concentrations. The hypothesis of stressinduced stressinduced accumulation of glucosinolates is supported by Verkerk *et al.* (2001). They detected increased levels of indole glucosinolates after chopping and storage of cabbage and broccoli under ambient conditions, indicating a stress response on mechanical impact.

POSTHARVEST TREATMENTS AS ELICITORS

Fresh cut produces

Fresh-cut products are wounded tissues, and consequently they deteriorate more rapidly and their physiology differs from that of intact fruit and vegetables (Lamikanra, 2002). The processes of peeling, coring, chopping, slicing, dicing, or shredding injure cells, releasing their contents at the sites of wounding. Subcellular compartmentalization is disrupted at the cut surfaces, and the mixing of substrates and enzymes that are normally separated can initiate reactions that normally do not occur (Gonz´alez-Aguilar *et al*., 2005), which could affect the phytochemical content and antioxidant capacity of the produce.

In general, it was observed that the content of phenolic acids increased in fresh-cut products. This fact could be explained considering that when a sharp blade was used for cutting, it produced a lower release of phenolic acids and lowered the polyphenol oxidase (PPO) activity compared to when a knife was used. This cutting process is known to be a key player in the browning process of various raw and cut fruit and vegetables (Mayer, 2006 and Mishra *et al*., 2012). During the storage time, increasing in phenolic content ont the fresh produces in the first time periode of storage may be depending on storage temperature, duration for fresh produces and style of cut that caused wound on the fresh cut products (Padda and Picha.,2008).

Ali shiri *et al* (2011) reported that different methode of cutting for fruit can be affect to the phenolic content. fresh cut grape quality were evaluated over 14 days storage at 5°C that harvested by two different methods (1-berry and 4-berries cutting), packaged in polyethylene terephthalate (PET) and polyvinylchloride (PVC) bags. The phenolic content in 1-berry cutting increased over the storage time, but its content declined in 4-berries cutting. Therefore, increasing in phenolic content at 1-berry cutting may be due to a stress in berries during grape removal from the caps. At 4-berries cutting phenolic content decreased during storage that can be related to the postharvest fruit metabolic processes, such as respiration, ethylene production and enzyme activity.

Alarcón-Flores *et al* (2014) reported for phenolic acids in eggplant, which presented higher values in fresh-cut products compare than fresh products, this phenomenon may be due to the influenced of PPO activity. Their concluded, for eggplants, carrots, and grapes will have similar properties with respect to their content in phytochemicals in fresh and fresh-cut products. Except for tomato, that better to be consumed as fresh product due the dereasing of its phytochemicals by cutting processed.

WAVE IRRADIATION

In general, the use of wave irradiation such as gamma or ultraviolet irradiation, typically used as desinfectans to control food borne pathogens, but it can utilized as elicitor to increase various of phytochemicals especially phenolic compounds (Thomas-barberan and Espin, 2001; Schreiner and keil, 2006). The increased of phenolic compounds has a cerrelationship with the increased activity of phenylalanine ammonia-lyase due to the irradiation process. Moreover ultraviolet irradiation also increases the activity of other enzyme involved in flavonoid synthesis. Gamma rariation has assumed can increase in favorable oxidative stress by dehydration condition due to the ability to chenge membarne permeability of products such as happened in garlic. Therefor due to the less of water , condition, pH decrease occured that can trigger a synthesis of anthocyanin and lignin decomposition (Schreiner and keil, 2006).

Generally, there are three classes of the type ultraviolet treatments on postharvest application: UV C (200-280 nm),UV-B (280-320 nm) and UV-A (315-400 nm).(Kowaltski.,2009). However, in correlation with enhancement of phytochemicals, many reports has been informed about the effect of ultraviolet treatments in type UV-B and UV-C. Falcone Ferreyra et al (2012) has resumed for the flavonoid response againts UV-B radiation by regulating flavonol synthase (FLS) gen. They hypothesized that the high transcript levels of ZmFLS genes may also contribute to the adaptation to this stress condition with higher UV-B fluxes thus can produce more flavonols.

According to Civello (2014), the effect of ultraviolet treatments performance in order to phytochemical elevation can not seperated from the influence of many experimental factors such as time of exposure, dose and intensity (energy), product physilogy (ripenig or developmental stage, temperature and treatment uniformity.

UV-B application has been reported to elevate the phenolic compounds, flavonoids and flavonol concentration in the both peel and flesh of two commercial tomato cultivar (Money marker and the mutant genotype *high pigment-1)* that harvested at mature green (Castagna *et al*., 2014). In addition to tomato experiment, UV-B application also showed good performance to stimulate the development of phytochemicals in peaches and nectarines. Scatinno *et al* (2014) concluded that the use of an appropriate UV-B dose in peaches and nectrines induced positive effects on polyphenol accumulation but it also has to be considered about the choice of the genotype since the metabolic response was different depending on the cultivar considered.

Therefore, Bravo *et al* (2013) reported that low UV-C dose in ligh red tomato can induced a significant improvement on lycopen and phenolic compounds concentration. How ever, they have also been informed that the beneficial effect is dependent on the treatment condition since the finding of the negative effect of UV-C exposure at 12 h due to the inducement of photooxidation. Moreover, Minhua *et al* (2015) also reported the effect of postharvest UV-C treatments on peach fruits. They found that peach fruit exposed to 3.0 kJ·m^{-2}UV-C light significantly delayed the losses of titratable acidity and vitamin C content, increased fruit red color, and maintained higher sensory quality of peach fruit during storage. The 3.0 kJ·m^{-2} UV-C treatment also enhanced the PAL activity, and promoted the accumulation of total phenolics at first 3 days of storage.

Moreover, the application of gamma irradiation in association of phytochemicals induction also depent on the teratment condition. Mami *et al* (2013) reported on five different doses of gamma irradiation were used for white button mushroom post harvest treatments (0.5, 1, 1.5 and 2 kGy). There were significant differences between irradiated and nonirradiated mushrooms in evaluated indices. However, the phenolic compounds revealed that mushrooms in doses of 1.5 and 1 kGy contained more phenols than 0, 0.5 and 2 kGy. Similarlly, Moosavi *et al* (2013) found thet the phenolic compounds of stroed almonds increased at the dose of 10 kGy gamma irradiation compare to non stored treatment. While the flavonoids and antioxidant values were constant.In addition of 10 kGy dose, 2 kGy dose has give slightly increased the antiradical activity of both stored and non stored almonds while but the other doses (6 and 10 kGy gamma irradiation) significantly reduced antiradical activity that containd in the commodity.

The use of other wavelenght irradiation such as flouresence, blue and red LED light during storage also reported by Eun Young Ko et al.,2014 for onion commodity. Effect of different light wavelengths on onion after harvest and storage, with fluorescent, blue (450 nm), red (660 nm) and uV-A light influenced the quercetin and quercetin glucosides profile. In a peeled onion, all the light treatments elevated quercetin content in bulb.

ADDITIVE SUBTANCES APPLICATION.

The effect of additive substance applied to harvested fresh produces were investigated mainly in respect to quality property of fresh produces such as nutrtitional value Numerous additive substance applied such as salicylic acid, methyl jasmonate and ethylene has been done for enhancement phytochemicals during post harvest treatments. (schreiner and Keil, 2006). According to Zhao *et al* (2005): Bondaryk (1994) and schreiner and Keil (2006) , the main purpose of these additive substances is to induced pathogen infestation and mechanical wounding but they have also been used to trigger signal cassades that stimulate phytochemical syinthesis as the impact of defense response activation.

Another option to overcome the application of additive substance as an effort to increase the nutritional content including pytochemicals is edible coating treatment, especially for fresh cut produces (Laura A. de la Rosa *et al*.,2010). Edible coatings from renewable sources can function as barriers to water vapor, gases, and other solutes and also as carriers of many functional ingredients, such as antimicrobial and antioxidant agents, thus enhancing quality and extending shelf life of fresh and minimally processed fruits and vegetables (Lin and Zhao, 2007).

The enhancement of phenolic compounds on fruits by chitosan edible coating treatments has been reported. Petriccione *et al* 2015 reported that edible coating treatment with concentration 1 % and 2 % of chitosan solution and stored at 2 °C for nine days increased the level of phenolic compounds flavonoid in the strawberry fruits. Another source of edible coating material also given positive effect on phytochemicals such as 1 % quar gum in persimmon fruits (Saha *et al*., 2015), 5% and 10 % arabic gums in sweet lemons (Eskandari *et al*.,2014), cassava starch coatings incorporated with propolis combinations in strawberry fruits (Thomas *et al*.,2016) and the combination of alginate and antibrowning agent in fresh cut manggo (Robles-Sánchez *et al*.,2013).

CONCLUSION

In correlation of functional food development, to obtained the high quality of healthy beneficial fresh produces, beside good crop practice, the application of post harvest technology also need to be applied. Nowadays, the quality judgement not only determined from the external quality of attributes but also from its nutrient content in particular phytochemical compounds that have the ability to prevent major diseases. Since many factors that have to be influenced the quality after handling treatments, multidiciplinary research must be involved. The affect of the different types of treatments to the physiology of plants is still unclear .More studies need to be doing for a better understanding both key enzymes activation and defence mechanism leading to induced resistance as well as the promotion of phytochemicals biosyntesis. Therefore, the development of post-harvest technology research approaches omics (meta- bolomic, genomic, proteomics and integrative multiomics) techniques need to be integrated in order to synchronizing the achievement of high level of phytochemicals and high external quality attributes fresh attributes. These approaces could lead to identification and associate biochemical pathway of key regulatory factors involved in induction of phytochmicals accumulation and freshness maintanance of fresh produces.

REFERENCES

https://doi.org/10.25077/aijans.v2.i01.1-18.2021

Alan Crozier, Takao Yokota, Indu B. Jaganath, Serena C. Marks, Michael Saltmarsh and Michael N. Clifford. 2006. Secondary Metabolites in Fruits, Vegetables, Beverages and Other Plant-Based Dietary Components, Blackwell Publishing Ltd:209

Alarcón-Flores,MI.,R. Romero-Gonzalez,J.L.M. Vidal, F.J.E.Gonzalez, and A.G. Frenich. 2014. Monitoring of phytochemicals in fresh and fresh-cut vegetables : A Comparison.Food chem.,142:392-399

Alasalvar C, Al-Farsi M, Quantick PC, Shahidi F, Wiktorowitz R. 2005. Effect of chill storage and modified atmosphere packaging (MAP)on antioxidant activity, anthocyanins, carotenoids, phenolics and sensory quality of ready-to-eat shredded orange and purple carrots. Food Chemistry., 89(1): 69-76.

Ali Eskandari., Mokhtar Heidari., Mohammad hosein daneshvar and Sadegh taheri. 2014. Studying effects of edible coatings of Arabic Gum and olive oil on the storage life and maintain quality of postharvest Sweet Lemon (*Citrus Lemontta*)., IJACS7(4):207-213

Ames BN, Gold LW and Willett WC. 1995. The causes and prevention of cancer. Proc Natl Acad Sci USA., 92(12):5258–5265.

Ana Sofia Rodrigues,María Rosa Pérez-Gregorio,Mercedes Sonia García-Falcón,Jesús Simal-Gándara and Domingos P.F. Almeida. 2010. Effect of post-harvest practices on flavonoid content of red and white onion cultivars. Food Control., 21,878–884

Ayse Tulin Oz., Panagiotis Kefalas. 2010. Quantity of the flavonoid profile peaks during storage and ripening in persimmon fruit. Journal of Food, Agriculture & Environment., 8 (3&4),108-110

Antonella Castagna.,Chiara Dall'Asta.,Emma Chiavaro., Gianni Galaverna and Annamaria Ranieri. 2014. Effect of Post-harvest UV-B Irradiation on Polyphenol Profile and Antioxidant Activity in Flesh and Peel of Tomato Fruits. Food Bioprocess Technol., 7:2241–2250

Anuradha Saha., Rajinder Kumar Gupta., Ram Roshan Sharma., Kuldeep Kumar., and Yogesh Kumar Tyagi. 2015. Edible Coating and its effect on shelf life and quality of 'Hachiya', an astringent variety of persimmon fruit. Asian Journal of Biochemical and Pharmaceutical Research.,3 (5):182-192

Ariela Betsy Thomas., Rita de Cássia Mirela Resende Nassur, Ana Carolina Vilas Boas and Luiz Carlos de Oliveira Lima. 2016. Cassava starch edible coating incorporated with propolis on bioactive compounds in strawberries. Ciência e Agrotecnologia., 40(1):87-96

Baenas, N., Garcı´a-Viguera, C and Moreno, D.A. 2014. Elicitation: a tool for enriching the bioactive composition of foods. Molecules.,19 (9), 13541–13563, Biotechnology.

Baldwin E.A.,Nisperos-Carriedo M.O., Baker R.A. 1995. Use of edible coatings to preserve quality of lightly (and slighlty) processed products. Critical Reviews in Food Science and Nutrition., 35:509-524

Bondaryk, P. R. 1994. Potent effect of jasmonates on indole glucosinolates in oilseed rape and mustard. Phytochem., 35: 301–305.

Claudia Scattino , Antonella Castagna , Susanne Neugart , Helen M. Chan , Monika Schreiner , Carlos H. Crisosto , Pietro Tonutti , Annamaria Ranieri. 2014. Post-harvest UV-B irradiation induces changes of phenol contents and corresponding biosynthetic gene expression in peaches and nectarines.Fo od Chemistry., 163 :51–60

Connor AM, Luby JJ, Hancock JF, Berkheimer S, Hanson EJ. 2002. Changes in fruit antioxidant activity among blueberry cultivars during coldtemperature storage. Journal of Agricultural & Food Chemistry., 50(4): 893-898.

Duthie, G. G., Duthie, S. J., and Kyle, J. A. M. 2000. Plant polyphenols in cancer and heart disease: implications as nutritional antioxidants. Nutr. Res. Rev. 13, 79–106.

D.Mark Hodges.,G.E Lester., K.D Munro and P.MA Toivonen. 2004. Oxidative Stress : Importance for Postharvest Quality. HortScience., 39(5):924-929

Eun Young Ko , Shivraj Hariram Nile , Kavita Sharma , Guan Hao Li , Se Won Park. 2015. Effect of different exposed lights on quercetin and quercetin glucoside content in onion (Allium cepa L.). Saudi Journal of Biological Sciences. 22, 398–403

Forbes-Smith, M. 1999. Induced resistance for the biological control of postharvest diseases of fruit and vegetables. Food Australia., 51: 382–385.

G. Joana Gil-Ch ́avez, Jos ́e A. Villa, J. Fernando Ayala-Zavala, J. Basilio Heredia, David Sepulveda, Elhadi M. Yahia,and Gustavo A. Gonz ́alez-Aguilar. 2013. Technologies for extraction and production of bioactive compounds to be used as nutraceuticals and food ingredientes: an overview. Comprehensive Reviews in Food Science and Food Safety., 12 (1), 5–23.

Graham S and Mettlin C. 1981. Fiber and other constituents of vegetables in cancer epidemiology. Progr Cancer Res Ther., 17:189–215.

Giovannucci E. 1999. Tomatoes, tomato-based products, lycopene, and cancer: review of the epidemiologic literature. J Natl Cancer Inst 91(4):317–331.

Gonzalez-Aguilar, G. B., Tiznado-Hernandez, M., Zavaleta-Gatica, R., and Martinez-Tellez, M. 2004. Methyl jasmonate treatments reduce chilling injury and activate the defense response of guava fruits. Biochem. Biophys. Res. Commun., 313: 694–701

Gonzalez-Aguilar GA, Ruiz-Cruz S, Soto-Valdez H, Vazquez-Ortiz F, Pacheco-Aguilar R and Wang CY. 2005. Biochemical changes of fresh-cut pineapple slices treated with antibrowning agents. Int J Food Sci Technol., 40(4):377–383.

Hung HC, Joshipura KJ, Jiang R, Hu FB, Hunter D, Smith-Warner SA, Colditz GA, Rosner B, Spiegelman D and Willett WC. 2004. Fruit and vegetable intake and risk of major chronic disease. Journal of the National Cancer Institute., 96(21), 1577–1584.

Hanson JR. 2003. The biosynthesis of secondary metabolites. In Natural Products, the secondary metabolites, The Royal Society of Chemistry: Cambridge, UK., 2: 112-121

Hopkins, W.G. and Hüner, N.P. 2004. Introduction to Plant Physiology, 4th Edition. John Wiley and Sons, Inc: 233-239.

Holcroft, D. M., Gil, M. I., and Kader, A. A. 1998. Effect of carbon dioxide on anthocyanins, phenylalanine ammonia lyase and glucosyltransferase in the arils of stored pomegranates. J. Am. Soc. Hort. Sci., 123: 136–140

Hansen, M., Moller, P., and Sorensen, H. 1995. Glucosinolates in broccoli stored under controlled atmosphere. J. Amer. Soc. Hort. Sci., 120: 1069–1074.

Jiang YM, Li JR, Jiang WB. 2005. Effects of chitosan coating on shelf life of cold-stored litchi fruit at ambient temperature. LWT Food Sci Technol., 38: 757–761

Jones, R.B., Faragher, J.D., Winkler, S. 2006. A review of the influence of postharvest treatments on quality and glucosinolate content in broccoli (Brassica oleracea var. italica) heads. Postharvest Biol. Technol., 41, 1–8.

Klee,H.J. 2010. Improving the flavor of fresh fruits:Genomic,biochemistry, and biotechnology.New Phytol.,187:44-56

Kader,A.A. 2003. Perspective on postharvest holticulture (1978-2003). Hortscience., 38:1004-1008

Khadijeh Sadat Moosavi, Siavash Hosseini, Gholamreza Dehghan and Ali Jahanban-Esfahlan. 2014. The Effect of Gamma Irradiation on Phytochemical Content and Antioxidant Activity of Stored and None Stored Almond (Amygdalus communis L.) Hull. Pharm Sci.20(3):102-106

Kjeldsen, F., Christensen, L. P., Edelenbos, M . 2003. Changes in Volatile Compounds of Carrots (Daucus carota L.) During Refrigerated and Frozen Storage. J. Agric. Food Chem. 51, 5400−5407.

Laura A. de la Rosa.,Emilio Alvarez-Parrilla and Gustavo A. Gonzalez-Aguilar. 2010. Fruit and Vegetable Phytochemicals Chemistry, Nutritional Value, and Stability ´. Blackwell Publishing.

Liu RH. 2004. Potential synergy of phytochemicals in cancer prevention: mechanism of action. J Nutr., 134:3479S-3485S.

Lamikanra O. 2002. Fresh-cut fruits and vegetables: science, technology, and market. Boca Raton: CRC Press.

Liang Minhua, Lei Jianmin, Shao Jiarong, Su Xinguo, Yang Zhenfeng and Chen Wei. 2015. Effect of UV-C Treatment on Phenolic Metabolism and Quality of Postharvest Peach Fruit. Journal of Nuclear Agricultural Sciences.29(6):188-193

Lin D and Zhao Y. 2007. Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables. Comprehen Rev Food Sci Food Saf 6:60–75.

Mittler, R. 2002. Oxidative stress, antioxidants and stress tolerance. Trends in Plant Science., 7, 405-410.

María L. Falcone Ferreyra , Sebastián P. Rius and Paula Casati. 2012. Flavonoids:biosynthesis,biologicalfunctions,andbiotechnologicalapplications. Frontier in Plant Science., 3(222):1-15

Mayer AM. 2006. Polyphenol oxidases in plants and fungi: going places? A review. Phytochemistry 67:2318–2331.

Mishra, B.B., S. Gautam and A. Sharma. 2012. Browning of fresh-cut eggplant: impact of cutting and storage. Postharvest Biol. Technol., 67: 44-51.

Marı´a I. Gil., Federico Ferreres., Francisco A. Toma´s-Barbera´n. 1999. Effect of Postharvest Storage and Processing on the Antioxidant Constituents (Flavonoids and Vitamin C) of Fresh-Cut Spinach, J. Agric. Food Chem., 47, 2213−2217

Mirza Hasanuzzaman, Kamrun Nahar and Masayuki Fujita. 2013. Extreme Temperature Responses, Oxidative Stress and Antioxidant Defense in Plants.InTech:169-205

V. Mudgal, N. Madaan, A. Mudgal and S. Mishra. 2010. Dietary polyphenols and human health. Asian Journal of Biochemistry., 5, 154–162.

McCann SE, Ambrosone CB, Moysich KB, Brasure J, Marshall JR, Freudenheim JL, Wilkinson GS, Graham S. 2005. Intakes of selected nutrients, foods, and phytochemicals and prostate cancer risk in western New York. Nutition andr Cancer. 53(1), 33–41.

Ness AR , Maynard M, Frankel S, Smith GD, Frobisher C, Leary SD, Emmett PM, Gunnell D. 2005. Diet in childhood and adult cardiovascular and all cause mortality: The Boyd Orr cohort. Heart., 91, 894–898.

Anna Maria Nuutila, Riitta Puupponen-Pimiä,Marjukka Aarni and Kirsi-Marja Oksman-Caldentey. 2003. Comparison of antioxidant activities of onion and garlic extracts by inhibition of lipid peroxidation and radical scavenging activity. Food Chemistry., 81(4), 485-493

Naczk, M and Shahidi, F. 2006. Phenolics in cereals, fruits and vegetables: Occurrence,extraction and analysis. Journal of Pharmaceutical and Biomedical Analysis., 41(5),1523–1542.

Nurten Selcuk and Mustafa Erkan. 2015. Changes in phenolic compounds and antioxidant activity of sour–sweet pomegranates cv. 'Hicaznar' during long-term storage under modified atmosphere packaging, Postharvest Biology and Technology., 109, 30–39

P. G. Williams. 2006. Can Health Claims for Foods Help Consumers Choose Better Diets?., http://ro.uow.edu.au/hbspapers/32.

Pieter van't Veer, Margje CJF Jansen, Mariska Klerk and Frans J Kok. 1999. Fruits and vegetables in the prevention of cancer and cardiovascular disease. Public Health Nutrition. 3(1), 103–107.

Prior, R. L. 2003. Fruits and vegetables in the prevention of cellular oxidative damage. The American Journal of Clinical Nutrition. 78(3), 570S–578S.

Guillermo Padilla,María Elena Cartea ,Pablo Velasco,Antonio de Haro and Amando Ordás. 2007. Variation of glucosinolates in vegetable crops of Brassica rapa. Phytochemistry., 68(4), 536–545.

Percival SS, Talcott ST, Chin ST, Mallak AC, Lound-Singleton A and Pettit-Moore J. 2006. Neoplastic transformation of BALB/3T3 cells and cell cycle of HL-60 cells are inhibited by mango (*Mangifera indica L.*) juice and mango juice extract. J Nutr., 136:1300–1304.

Prono-Widayat, H., Schreiner, M., Huyskens-Keil, S., and L¨ udders, P. 2003. Effect of ripening stage and storage temperature on postharvest quality of pepino (*Solanum muricatum* Ait.). J. Food Agric. Environ., 1, 35–41

Pedro Marcos Civello., Natalia Villarreal., María Eugenia Gómez Lobato1 and Gustavo Adolfo Martínez. 2014. Physiological effects of postharvest UV treatments: recent progress. Stewart Postharvest Review., 3:8

Pollastri,S.,and Tattini,M. 2011. Flavonols:old compounds for old roles. Ann.Bot., 108, 1225–1233.

Rechkemmer G. 2001. Funktionelle Lebensmittel-Zukunft de Ernahrung oder Marketing-Strategie.Forschungereport Sonderheft., 1:12–15.

Rajashekar, C.B., E.E. Carey, X. Zhao, and M.M Oh. 2009. Health-promoting phytochemicals in fruits and vegetables: Impact of abiotic stresses and crop production practices. Functional Plant Science and Biotechnology., 3:30-38.

Rangkadilok N, Tomkins B, Nicolas ME, Premier RR, Bennett RN, Eagling DR, Taylor PWJ. 2002. The effect of post-harvest and packaging treatments on glucoraphanin concentration in broccoli (*Brassica oleracea* var. *italica*). Journal of Agricultural & Food Chemistry., 50: 7386-7391.

Rosario Maribel Robles-Sánchez, María Alejandra Rojas-Graü, Isabel Odriozola-Serrano, Gustavo González-Aguilar and Olga Martin-Belloso. 2013. Influence of alginate-based edible coating as carrier of antibrowning agents on bioactive compounds and antioxidant activity in fresh-cut Kent mangoes. WT - Food Science and Technology., 50: 240-246

Suzuki, N, & Mittler, R. 2006. Reactive oxygen species and temperature stresses: a delicate balance between sig naling and destruction. Physiologia Plantarum., 126, 45-51.

Stafford,H.A. 1991. Flavonoid evo lution:anenzymic approach. Plant Physiol., 96, 680–685.

Sergio Bravo, Javier Garc ıa-Alonso, Gala Mart ın-Pozuelo, Victoria G omez, Ver onica Garcıa-Valverde, Inmaculada Navarro-Gonz alez and Mar ıa Jesus Periago. 2013. Effects of postharvest UV-C treatment on carotenoids and phenolic compounds of vine-ripe tomatoes. International Journal of Food Science and Technology., 48, 1744–1749

Schreiner, M., Huyskens-Keil, S., Krumbein, A., Prono-Widayat, H., Peters, P., and L¨ udders, P. 2003. Comparison of film packaging and surface coating on bioactive substances in fruit and vegetables. KTBL-Schrift., 414: 39–44.

Schreiner, M. & Huyskens-Keil, S. 2006. Phytochemicals in fruit and vegetables:Health promotion and postharvest elicitors. Critical Reviews in Plant Sciences., 25, 267- 278.

Randi Seljasen, Gunnar B Bengtsson, Halldor Hoftun and Gjermund Vogt. 2001. Sensory and chemical changes in five varieties of carrot (Daucus carota L.) in response to mechanical stress at harvest and post-harvest. J. Sci. Food Agric., 81, 436-447.

Simon, P. W. 1985. Carrot flavour: effects of genotype, growing conditions, storage, and processing. In EValuation of Quality of Fruits and Vegetables; Pattee, H. E., Ed.; AVI: Westport, CT. 315-328

Suslow, T . 2000. Postharvest handling for organic crops. Organic Vegetable Production in California. 7254, 1-3.

Syngletary KW, Jackson SJ, Milner JA. 2005. Non-nutritive components in foods as modifiers of the cancer process. In: Bendich A and Deckelbaum RJ, editors. Preventive Nutrition: the Comprehensive Guide for Health Professionals, 3rd ed. Totowa, NJ: Humana Press

Isabelle Soerjomataram, Dian Oomen,Valery Lemmens, Anke Oenema,Vassiliki Benetou, Antonia Trichopoulou, Jan Willem Coebergh, Jan Barendregt and Esther de Vries. 2010. Increased consumption of fruit and vegetables and future cancer incidence in selected European countries. European Journal of Cancer., 46, 2563–2580.

Jagdish Singh, A.K. Upadhyay, Kundan Prasad, Anant Bahadur and Mathura Rai. 2007. Variability of carotenes, vitamin C, E and phenolics in Brassica vegetables. Journal of Food Composition and Analysis., 20(2), 106-112.

Tomás-Barberán, Espín CJ. 2001. Phenolic compounds and related enzymes as determinants of quality in fruits and vegetables. J. Sci. Food Agric., 81: 853-876.

U. Tiwari., E. Cummins. 2013. Factor influencing levels of phytochemicals in selected fruit and vegetables during pre- and post-harvest food processing operation. Food Research International. 50, 497–506.

Vallejo, F., Tomás-Barberán, F.,García-Viguera, C. 2003. Effect of climatic suphur fertilisation conditions, on phenolic compounds and vitamin C, in the inflorescences of eight broccoli cultivars. European Food Research and Technology. 216, 395–401

Verkerk, R., Dekker, M., and Jongen, W. M. 2001. Post-harvest increase of indolyl glucosinolates in response to chopping and storage of Brassica vegetables. J. Sci. Food Agric. **81**: 953–958

Xia Wang, Yingying Ouyang , Jun Liu, Minmin Zhu, Gang Zhao, Wei Bao and Frank B Hu. 2014. Fruit and vegetable consumption and mortality from all causes, cardiovascular disease, and cancer: systematic review and dose-response meta-analysis of prospective cohort studies. BMJ 349:g4490

Yin, H, Chen, Q. M, & Yi, M. F. 2008. Effects of short-term heat stress on oxidative damage and responses of antioxidant system in *Lilium longiflorum*. Plant Growth Regulation., 54, 45-54.

Zheng, W., Wang, S. Y. 2003. Oxygen radical absorbing capacity of phenolics in blueberries, cranberries, chokeberries, and lingonberries. Journal of Agriculture and Food Chemistry. 51, 502–509.

Zhao, J., Davis, L. C., and Verporte, R. 2005. Elicitor signal transduction leading to production of plant secondary metabolites. Biotechnol. Advances., 23: 283–333.

https://doi.org/10.25077/aijans.v2.i01.1-18.2021