Sri Lanka Journal of Food and Agriculture 6(1): 57-66, 2020
DOI: http://doi.org/10.4038/sljfa.v6i1.82

Sri Lanka Journal of Food and Agriculture (SLJFA)

ISSN: 2424-6913
Journal homepage: www.slcarp.lk

Review

Fruit ripening: Importance of artificial fruit ripening in commercial agriculture and safe use of the technology for consumer health

I.G.N. Hewajulige* and H.D.S.R. Premaseela

Food Technology Section, Industrial Technology Institute (ITI), Malabe, Sri Lanka
* Corresponding Author: ilmi@iti.lk https://orcid.org/0000-0002-4157-572X

Article History:
Received: 9 February 2020
Accepted: 30 June 2020

Abstract: Fruit ripening is the final phase of fruit development, which results in various physicochemical, nutritional and organoleptic changes of fruits including changes in taste, texture, appearance and aroma. Ethylene (C_2H_4), which is a gaseous plant hormone, plays a key regulatory role in fruit ripening. Ethylene is described as an autocatalytic agent as the exposure of fruits to small quantity of ethylene could induce the production of its own ethylene in larger quantities. Various changes in the matrix of the fruit tissues such as breakdown of chlorophyll, conversion of starch into sugars, large organic compounds to small organic compounds, and pectin to less soluble forms take place triggered by such ethylene produced within the fruit. However, due to the soft nature, the naturally-ripened fruits may be subjected to mechanical damages during transportation leading to loss of consumer attraction. Therefore, mature fruits are ripened artificially before sale to meet the increasing demand and to ensure their cosmetic appearance. Many fruit wholesalers make fruits ripen using artificial ripening agents' such as calcium carbide, ethylene, ethephon and smoke. Most of the chemicals used as ripening agents accelerate fruit ripening, change the nutritional quality of fruits and are harmful for human health. Therefore, it is important to build an awareness among fruit producers, traders and consumers on the correct selection and use of fruit ripening methods. This review discusses the research-based knowledge shared across the world on fruit ripening, major physicochemical changes in the fruits during the ripening process, commercial ripening agents, and how such different ripening agents affect the fruit quality and consumer health.

Keywords: Artificial fruit ripening agents, Ethylene, Ethaphon, Calcium carbide, Smoke, Human health hazards

Introduction

Fruits are an essential component in the human daily diet as they provide nutrients such as vitamins (A, C and E), minerals (calcium, magnesium, potassium, zinc, phosphorous), fibre, antioxidants, and phytonutrients. Beta carotene, lycopene and ascorbic acid like antioxidants present in fruits neutralize the free radicals produced in the body, which are considered to be responsible for heart diseases, blood vessel damage, inflammatory diseases, and cancer. The consumption of fruits in Sri Lanka has increased considerably in recent years due to awareness about their health benefits and availability year round.

Fruits are consumed at the edible ripe stage after they have attained the physiological maturity, which takes place at the latter part of the process of fruit growth, development, and senescence. Ripening is the final phase in fruit development, and it involves a complex series of events such as change in colour, softening of the pericarp, and changes in sweetness and flavor, making the fruits both tasty and attractive to eat (Seymour *et al.,* 1993; Brady, 1987). This is achieved by changes in the composition such as conversion of starch to simple sugars, acids to neutral, large organic compounds to small organic compounds, less soluble pectin to soluble pectin, etc. All these processes initiate when the fruits have reached their optimum maturity. Therefore, palatability and nutritional quality of fruits are highly dependent on its consumption at an optimum stage of ripeness. Ethylene, a hormone that is naturally produced within the fruits, regulates fruit ripening by initiating and/or controlling a series of chemical and biochemical activities.

Ethylene and Its' Action in Plants

In 1901, a Russian Scientist named Dimitry Neljubow, discovered ethylene as the biologically active component of illumination gas, which was responsible for horizontal growth of etiolated pea seedlings which he has cultivated. In 1934 Riichard Gane identified that plants could synthesize ethylene and in 1935 William Crocker proposed ethylene as the responsible hormone for fruit ripening and senescence of vegetative tissues (Soares and Mello-Farias, 2006). Later, it was observed that a strong increase in ethylene production was associated with peak in respiration during tomato ripening (Zegzouti, 1997). As a result, researchers have come up with new findings over the years on how ethylene effects on many phases of plant growth and development. Further, ethylene is produced in response to stress, such as wounding, very low and very high temperatures, flooding or drought, treatments with other hormones, heavy metals, and attack by pathogens (Pech *et al*., 1992).

Ethylene hormone has two carbons with unsaturated double bond structure as C_2H_4. As it is a peptide hormone ethylene is insoluble in lipids. Therefore, it does not penetrate the cell membrane to carry the chemical message to the nucleus. Instead, it binds with the receptor site on the plasma membrane. Primary action site of ethylene is said to be ribosomes. Shimokawa and Kasi (1968) found the first evidence about the sites. Once this binding takes place, ethylene triggers a signal transduction through secondary messengers until it reaches the nucleus. At the nucleus, it triggers a specific gene of the DNA to produce an mRNA (messenger RNA) molecule that is specific for the ethylene effect through a process called transcription. Many copies of these mRNA produced by the first amplification process will enter the cytoplasm. Ribosomes will join the mRNA strands and translate many times into a gene product such as an enzyme (2^{nd} amplification step). Enzymes are then modified to become functional and capable of high catalytic activity even at low concentrations. They catalyze the production of many copies of an important cellular product (3^{rd} amplification step), which are responsible for the ripening action at the target sites (Soares and Mello-Farias, 2006).

Physicochemical Changes in Fruit Ripening

During maturation, several structural and biochemical changes occur in fruits with response to the ethylene action, which causes specific organoleptic qualities, such as modifications in the external aspect, texture and flavour of the fruit (Seymour *et al*., 1993). Change in the colour during ripening of tomato fruits is a result of transformation of chloroplasts into chromoplasts and from the degradation of chlorophyll, as well as from the accumulation of pigments such as carotenes and lycopenes, which are causes orange and red colour of the fruit (Gray *et al.,* 1992).

Alterations in the texture of the fruit, more specifically the loss of firmness, due to structural changes in the principal cell wall components such as cellulose, hemicellulose and pectin occurs during the maturation process (Soares and Mello-Farias, 2006). Finally, the accumulation of sugars such as glucose, fructose and organic acids in vacuoles and the production of complex volatile compounds is responsible for the aroma and flavour of the fruit (Seymour *et al*., 1993).

<u>Moisture content</u>

Mohapatra *et al.* (2016) reported that there was an increase in moisture content of pulp during ripening of bananas. Increase in moisture content of pulp of the fruits was assumed due to increase in sugar content in the pulp as a result of starch hydrolysis to sugar. This resulted in migration of moisture from peel to pulp (Mohapatra *et al*., 2010).

<u>Total soluble solids (TSS)</u>

In most ripen fruits including banana causes sugar formation as a result of starch hydrolysis (Hibler and Hardey, 1994). Chan *et al.* (1979) have reported that the TSS hardly changes in papaya after harvest, as papaya fruits have no starch reserves for production of soluble solids during ripening. In mango, sucrose being the predominant sugar, it increases several folds during ripening and the increase in sugar content is attributed to breakdown of starch, which is virtually absent at the edible stage (Kumar *et al*., 1994).

Pulp to peel ratio

Pulp to peel ratio is elevated with consequent increase in ripening in most fruits, probably due to that the weight of the fruit pulp increases with decrease in peel weight during ripening. Palmer (1971) reported an increasing pulp to peel ratio of banana, resulting due to accumulation of moisture in the pulp derived from carbohydrate breakdown and osmotic transfer from peel to pulp.

Cell wall loosening and degradation

Softening of fruit tissue is a major component of ripening, occurring in most fruits in conjunction with other climacteric changes. It is accompanied by losses in galactose, arabinose and uronide residues from the cell wall (Gross and Wallner, 1979; Knee and Bartley, 1981), and increases in soluble pectins (Sawamura *et al*., 1978; Ben-Arie *et al*., 1979; Bartley *et al*., 1982). Ripening of papaya is characterized by changes in tissue softness that is believed to be initiated in the inner mesocarp tissues close to the seed and to progress outward (Selmat, 1993).

Weight

Difference in vapor pressure causes osmotic withdrawal of fruit moisture and hence, weight reduction after harvesting. Water loss after harvesting causes fruit mass reduction and may also induce senescence (Mohapatra *et al.,* 2016). Therefore, physiological weight loss is one of the significant physicochemical features in fruit ripening.

Titratable acidity (TA)

In banana flesh, the total amount of acid mainly: malic, citric and oxalic acid increases during ripening, while the first two acids are responsible for tartness in the unripe banana, oxalic acid is contributed to astringent taste of the fruit (Seymour, 1993). As the fruit ripe, these acids tend to reduce and, giving a sweet taste, caused mainly from the hydrolyzed sugar from the starch degradation. However according to Subbaiah *et al.* (2014) titratable acidity increases from the initial value reaches a peak and declines later during the ripening process in Embul banana variety. Selvaraj *et al.* (1982) and Ghanta *et al.* (1994) have reported of a decrease in TA with ripening in papaya, while de Arriola *et al.* (1980) and Paull (1993) reported of an increase. Yonea *et al.* (1990) reported that postharvest ripening of mango fruit is characterized by softening of the flesh, decrease in acidity and an increase in sugars, while cultivar differences were not observed to be dramatic for these parameters.

Texture

Biochemical and other properties cause changes in peel thickness, TSS and moisture content resulting in alteration in textural properties of peel in banana during ripening (Mohapatra *et al.,* 2016). Tapre and Jain (2012) reported that the softening of banana fruits during ripening treatment is a result of a series of transformations such as breakdown of starch to sugar, breakdown of pectin substances, and the movement of water from the rind of the banana to pulp during ripening.

Climacteric and Non-Climacteric Fruits

Fruits are classified into two groups based on the involvement of ethylene during maturation. Climacteric fruits, such as banana, mango, papaya, tomato, avocado, melon, apple, pear, peach and kiwifruit are characterized by an extraordinary increment in ethylene production which accompanies the respiratory peak during ripening, called the 'climacteric crisis' (Abeles *et al*., 1992). Non-climacteric fruits are those whose maturation does not depend on ethylene, such as cherry, strawberry, rambutan and pineapple. Variation of internal ethylene concentrations of non-climacteric fruit is very low during their growth and ripening. Wills *et al*. (1998) reported that fruits that show a significant deviation from the reducing pattern of respiration rate during ripening, such as a distinct increase in respiration rates (a respiratory climacteric) of varying intensity and duration, proportionately with ripening, are classified as 'climacteric' and those that show a pattern of declining respiration rate with ripening are classified as 'non-climacteric'. For most climacteric fruits, the internal ethylene concentration increases along with respiration rate. The increase of ethylene concentration triggers an increase in respiration rate (metabolic activity), resulting in the biochemical and physiological transformations that occur during ripening.

Commercial Ripening

Transporting and distributing fruits from the farmers' orchards to consumers' baskets can take several days and during this time the naturally ripened fruits may become over ripe and inedible (Hossain *et al.,* 2015). Commercial ripening is an essential part of the fruit business as ripe fruits are not suitable to carry and distribute due to their fast rotting. A part of naturally ripened fruits can also be damaged during harsh condition of transportation. It indeed increase great economic loss for the fruit sellers and therefore, to minimize the loss, fruit sellers sometimes prefer collecting fruits at mature green stage and artificially ripen them before selling to the consumers (Mursalat *et al.*, 2013). Fruit sellers artificially ripen green fruits even during the due season to meet the high demand and make high profit of seasonal fruits. Under natural conditions, banana ripens slowly leading to high weight loss, uneven ripening and poor colour development (Subbaiah *et al.*, 2013). Ripening agents are substances, which hasten the ripening process, and it comes in different forms. These include ethylene gas, ethephon, ethylene glycol, Ethrel and calcium carbide (Singal *et al.,* 2012).

Ethylene treatment

Ethylene is known to be the plant hormone that triggers fruit ripening. It has been reported that if ethylene is applied exogenously it helps fruit ripening (Medlicott, 1988). Ethylene treatment is usually given at the packing house or at the point of distribution (Ur-Rahman *et al.,* 2008). Commercially ethylene gas is used to ripen banana. Natural ripening of mature banana may result in softening with non-uniform, dull, pale yellow and unattractive color (Eduardo, 2012). Therefore, in order for the fruit to attain a bright yellow peel color, a firm pulp texture, and good flavor, bananas are commercially ripened by releasing ethylene into a sealed chamber under controlled temperature and relative humidity (Eduardo, 2012). However, ethylene gas may be prove explosive when it reaches a higher concentration. Hence, it has to be used very carefully. Ethylene is a natural hormone produced in many fruits after fruit development which does not cause any health hazard for consumers of the fruits.

The only safe and worldwide-accepted method is using ethylene, for ripening when done under controlled temperature and relative humidity conditions. Therefore, unripe fruit should be ripened by exposure to an exogenous source of ethylene gas (Robinson and Sauco, 2010) as it would stimulate natural ripening until the fruit itself starts producing ethylene in large quantities. Therefore, in developed countries ethylene generators and ethylene cylinders are being used to ripe fruits using highly regulated ripening chambers maintaining calculated ethylene concentrations, exposure time, optimum temperature, RH and ventilation. Controlled ripening is for providing retailers and wholesalers with fruits at a stage of ripeness desired by consumers. A very small concentration (1 ppm) of ethylene in air is sufficient to promote the fruit ripening process (Brady, 1987). The time of exposure to initiate full ripening may vary, but for climacteric fruits exposure of 12 hours or more are usually sufficient. Full ripening may take several days after the ethylene treatment (Reid, 2002).

The effectiveness of exogenous treatment of ethylene in achieving faster and more uniform ripening depends on the type of fruit being treated, its maturity, the temperature and Relative Humidity of the ripening room, ethylene concentration, and duration of exposure to ethylene. In general, optimal ripening conditions for fruits are shown in Table 1.

Table 1. Optimal ripening conditions for fruits

Parameter	**Optimum conditions**
Temperature	18 °C to 25 °C (65 °F to 75 °F)
RH	90 to 95%
Ethylene concentration	10 to 100 ppm
Duration of treatment	24 to 72 hours, depending on the fruit type and maturity stage
Ventilation	Adequate air exchange to prevent CO_2 accumulation, which reduced the effectiveness of C_2H_4

Source: Reid (2002)

Analogues of ethylene

The action of ethylene and propylene on the ripening processes of fruits has been long debated. Under certain conditions, both these gases appeared to be capable of hastening the ripening of some fruits, whether the action of these gases is due to the fact that they are unsaturated compounds or to some other property was in question (Hartshorn, 1931). Reid (2002) reported that certain analogues of ethylene have the potential to bind with receptor sites and mediate the ripening action, *e.g.* acetylene, CO_2, methyl jasmonate, calcium carbide, ethephon, and ethylene glycol. Propylene causes similar reaction as ethylene, but 100 times the amount is needed compared with ethylene, while the need for acetylene is 3000 times greater than ethylene. Vinyl chloride, carbon monoxide, and 1-butene also bring out similar reactions that of ethylene although the activity is lower than ethylene (Kumar and Purohit, 1998).

Burg and Burg (1967) discovered that this was due to the chemical structure of the above mentioned compounds resembling ethylene in certain ways. The molecular requirement to mimic ethylene should be that these compounds should be unsaturated compounds having an unsaturated bond adjacent to the terminal carbon atom. The activity of the compound is inversely proportional to the size of the molecule. CO_2 having a close structural analogue to ethylene therefore, is a competitive inhibitor of ethylene action and the effects are opposite to that of ethylene (Kumar and Purohit, 1998). Unsaturated hydrocarbons, particularly like acetylene can promote ripening and induce colour changes effectively but the organoleptic qualities will be differed (Siddiqui and Dhua, 2010).

Among the widely used artificial ripening agents, ethylene and methyl jasmonate are reported as non-toxic for human consumption; however, they are relatively expensive (Hossain *et al.*, 2015). Therefore, in many developing countries, low-cost chemicals such as calcium carbide, ethylene glycol, and ethephon are reported to be commonly used to artificially trigger the ripening process (Islam *et al.*, 2016).

<u>Smoke treatment</u>

Banana like fruits are harvested at complete maturity while they are green and unripe, and subsequently allowed to ripen at ambient conditions. To meet the consumer requirement, green banana bunches are artificially ripened in many instances. Smoke treatment is one of the most common traditional methods adopted to induce ripening (Ram *et al.,* 1979). In this method, banana bunches are subjected to smoke treatment usually generated by burning kerosene stove inside the airtight chambers for 24 h. As a result, the temperature inside the chamber also increases besides evolving ethylene gas with traces of other gases like acetylene and carbon monoxide (Kulkarni *et al.*, 2011). Bouzayen *et al.* (2010) reported similar results. Smoke treatment also resulted in a rapid ripening process, with no considerable undesirable effect on banana quality but with reduced shelf life (Mebratie *et al.*, 2015).

In Sri Lanka, Pettah whole sale market is the main collection center where most of the fruits and vegetables are distributed to the market vendors for selling. Smoke treatment was a widely used practice for banana since ancient times as an artificial ripening technique before they were distributed for selling. Banana bunches were packed inside enclosed rooms with limited space and subjected for smoke treatment. This smoke was generated by burning banana leaves inside a pot usually blown by laborers. However, this was time consuming and ineffective option for ripening of fruits.

Fruits treated with smoke were found developing some off ripening effects such as black scars on the peel, uneven ripening and also poor external colour (yellow) development in addition to the relatively low quality attributes recorded through the sensory evaluation. This may be a result of lack of maintenance in optimum temperature and relative humidity (RH) in the ripening chamber (Kulkarni *et al.*, 2011). This type of smoke treatment is crude and ineffective as controlled ethylene treatment and also evolution of carbon monoxide is hazardous to health.

<u>Calcium carbide (CaC_2)</u>

Calcium carbide is another chemical used for ripening in many developing countries in earlier times due to being cheap (1 kg of this chemical costs Sri Lanka Rs 25–30, and can ripen 200 kg of mangoes). All that a trader has to do is to wrap a small quantity of CaC_2 in a paper packet, and keep this packet near a pile or box of fruits (Hossain *et al.*, 2015).

The CaC_2 reacts with moisture in fruits producing acetylene gas, which is an analogue of ethylene, and hasten the ripening process. Use of calcium carbide sometimes gives ripening colour to an immature fruit. CaC_2 was indiscriminately used in preference to other recommended practices of inducing ripening such as exposure of fruits to ethylene gas. Industrial grade of calcium carbide contains traces of arsenic and phosphorus hydride, which are hazardous for human health if ingested (Rahman *et al.*, 2008) and the gases emitted contain up to 95 and 3 ppm of arsine and phosphine gas, respectively, which are carcinogenic. A significant number of pregnant women consumed fruit ripened with carbide, the children born with abnormalities (Rahim, 2012). Calcium carbide is alkaline in nature and irritates the mucosal tissue in the abdominal region (Fattah and Ali, 2011). Cases of stomach upset after eating carbide ripened mangoes were evident as reported by Siddiqui and Dhua, 2010. Further, fruits ripened with CaC_2 are overly soft, less tasty and have a shorter shelf-life.

An artificially ripened fruit would present a yellow outer skin, but the tissue inside would not be ripe or itself remains green and raw (Rahman *et al.,* 2008). Rahman *et al.* (2008) also reported that when CaC_2 is used on raw fruit, the amount of the chemical needed to ripen the fruit has to be increased resulting in the fruit becoming even more tasteless and possibly toxic. Although the cosmetic quality of such artificially ripened fruits was found to improve, the organoleptic quality was impaired especially when harvested fruits were subjected to treatment without considering their maturity status (Medlicott *et al*., 1988; Rahman *et al*., 2008). Considering these facts, in Sri Lanka, CaC_2 was banned to be used as a fruit-ripening agent by the gazette notification No. 788/7 dated 1993.10.14, issued under the Food Act No. 26 of 1980.

<u>Ethephon</u>

Ethephon is another artificial ripening agent (commercial names – Ethrel, Florel, Cepa), which makes an acidic solution in water and liberates ethylene in neutral to basic medium generally above pH 5 (Siddiqui and Dhua, 2010). In the presence of moisture and at neutral pH, ethephon is decomposed into ethylene gas, biphosphate ion, and chloride ions. Even though ethephon is not a food grade chemical many countries practiced dipping of fruits in ethephon solution to hasten the ripening process. It has been reported that exogenous application of ethylene in the form of Ethrel accelerates ripening, increases colour and eating quality with reduced spoilage in different varieties of mango (Saltveit, 1999; Singh and Janes, 2001).

As recommended, the fruit sellers have to either dip the fruits in a solution of this mixture or pass fumes of this chemical through the fruits (Siddiqui and Dhua, 2009; Kulkarni *et al*., 2004). Warner and Leopold (1969) reported that ethephon is absorbed into the plant tissue and subsequently ethylene generation occurs at intra-cellular level due to the higher pH within the plant cells. Maintaining a solution pH between 4.0 and 4.5 is critical when applying an ethephon spray to plants. As the solution pH increases, the rate at which ethephon evolves to ethylene also increases (Warner and Leopold, 1969).

The fruits ripened with Ethrel have more acceptable colour than naturally ripened fruits and have more shelf life than fruits ripened with CaC_2 (Siddiqui, 2008). A mixture of water (5 litres), ethephon 39% (10 ml) and sodium hydroxide (2 g), kept in a bucket close to the mangoes heaped in an airtight chamber would release ethylene gas, which naturally facilitates the ripening of fruits without any harmful effects (Sudhakar, 2006). The Industrial Technology Institute (ITI) of Sri Lanka, recommended the safe use of ethephon by exposing the fruits to the gas emitted (natural ethylene) at the basic pH level, which is achieved by addition of NaOH (Recommended dose – 1 ml of ethephon in 1 L of water). Fruits should be placed in an enclosed chamber with the solution of ethephon-NaOH mixture in a beaker for 24 hours and placed outside the chamber to support ripening.

Reported improvement in sensory quality with Ethrel treatments may be due to the role of ethylene in promoting changes such as softening of texture, production of more sugars, and release of volatile compounds during the ripening period, which are important for the flavour quality, and formation of aroma volatiles in the climacteric fruit (Mahajan *et al*., 2008). Ethrel-treated banana fruits during ripening shows an upsurge in respiration rate leading to faster and uniform ripening compared to untreated fruits (Kulkarni *et al*., 2011).

The degradation of chlorophyll pigments in fruit peel in Ethrel-treated fruits is more rapid than in untreated fruits (Terai *et al*., 1973). In untreated fruits, there was less chlorophyll degradation in the peel tissues in the absence of exogenous ethylene treatment, and such relatively low levels of pigment degradation would probably depend on ethylene produced by the pulp (Vendrell and McGlasson 1971). There are many different opinions about the toxicity of ethephon that have made users worried (Nguyen *et al*., 1999). For instance, ethephon is an irritant to the human skin or the eyes. Ethaphon was not a carcinogen and is classified by the International Agency for Research on Cancer (IARC) as group D (not carcinogenic to humans) substance and the Food and Agriculture Organization (FAO) of the United Nations has reported the maximum allowable daily intake for ethephon to be 0.05 mg/kg body weight/day (Bui, 2007). However, ethephon treatment has shown better result in terms of fruit quality, shelf life and marketability of ripened bananas (Mebratie *et al.,* 2015) and proved to be safe if fruits were exposed only to ethylene gas liberated at a basic medium.

Health Effects of Artificial Ripening

Fruits form an important food item in the human diet rich in nutrients. The role of fruits is well established and known for protecting against major diseases and disorders of the cardiovascular, digestive and endocrine system. Food security was used to be the primary concern of countries and individuals alike. However, as agricultural research became in alleviating the effect of diseases and adverse climate, food security is generally not perceived as a problem any longer; instead concern over quantity has been replaced by preoccupation with quality (Chow, 1979). It is difficult to ensure that whether the food is safe as nowadays, rarely any food item is spared from the malicious practice of food adulteration with chemicals, such as calcium carbide (CaC_2), ethephon (2-chloroethylphosphonic acid) and other non- recommended pesticides for the ripening of immature fruits rapidly with attractive colour (Hakim *et al.*, 2012).

Toxic ripening agents are commonly used in developing countries. Artificial ripening agents accelerates ripening, but they may affect the nutritional quality of the fruits (Sogo-Temi *et al*., 2014). The use of toxic ripening agents is of great concern as they are said to contribute to exposure of food materials to heavy metal contamination (Orisakwe *et al*., 2012). These toxic chemicals are indiscriminately used to achieve faster and more uniform ripening characteristics with better consumer acceptance and facilitating better marketing (Siddiqui and Dhua, 2010). The adverse potential of calcium carbide as a ripening agent has been established (Singal *et al.*, 2012).

Hakim *et al.* (2012) found that chemically ripened pineapples and bananas have higher sugar content than non-treated samples; other fruit nutrition values like vitamin C and carotene are higher in naturally ripened fruits. They also have reported that lead (Pb) is found in chemically ripened (market and lab-treated) pineapples and bananas, and arsenic (As) in pineapples collected from market. According to WHO (1987), the daily permissible intakes of Pb and As for adults are 600 μg/day and 16.7 - 129 μg/day, respectively. An average person consumes 100 to 150 grams of fruits a day (Agudo, 2005). Hence, the possible daily intake of Pb and As from fruits would be 12-50 and 2.53.75 μg/day respectively, which falls within the acceptable limit for an adult. However, further studies must be conducted regarding the effects of long term consumption of such elements in fruits (MehnazMursalat and Rony, 2013). The wholesalers often dip banana fruits in the calcium carbide solution for quick ripening and attractive color. Besides using ripening agents, they drop the banana again in the formalin to protect from rottening (Bhuiyan *et al*., 2009).

Some of these chemicals may change nutritional properties of fruits and vegetables as well as lead serious health hazards to human beings like cancer, skin irritation, diarrhea, liver disease, kidney disease, and gastrointestinal irritation with nausea, vomiting, diarrhea, cardiac disturbances, central nervous system depression and cardiac abnormalities.

Hakim *et al*. (2012) reported that chemical ripening agents like ethephon, Ethrel and ethylene glycol are also hazardous to health and they have to be used within recommended safe limits. However, some scientists state that the concentration of ethephon residues in fruits will decrease over preservation time as ethephon could be hygroscopic and release ethylene (Tran, 2000). Scientists have also reported that regular consumption of artificial ripened fruits may cause dizziness, weakness, skin ulcer and heart related diseases (Jayan, 2011; Hakim *et al*., 2012).

As the ripening agents along with their chemical impurities are health hazardous, it is important to understand their health effect better by studying their chemical criteria, mechanisms, effects on fruit quality and nutrition value (MehnazMursalat and Rony, 2013). Although the presence of residues of artificial ripening agents is usually encountered on the fruit skin, it is vital to quantify any presence of chemicals within fruit-flesh and to analyze the chemical impact on the food value of artificially ripened fruits (Hakim *et al*., 2012). Many countries have specific laws and regulations regarding the usage of these chemical ripening agents. Even-though the terms and conditions of the corresponding legislations vary from country to country, the major objective to enact such laws is to control or prohibit the usage of the chemicals as ripening agents. There is little information as to what extent the local methods of ripening could

influence the postharvest quality and shelf life of banana (Mebratie *et al*., 2015).
Recent research conducted in Sri Lanka by Premaseela *et al*. (2019) reported the presence of ethephon residues on both peel and flesh of ethephon spray and dip treated banana fruits even after three days of storage at ambient temperature (28 °C ± 2). The ethephon residues found in flesh of spray treatment was 4 times higher than the maximum residue level of ethephon (0.05 mg/kg) recommended for banana in the EU Pesticides database. Smoke-treated banana fruits were detected with Polyaromatic Hydrocarbons (PAH) on the peel out of which 3.94 µg/kg was benzo (a) pyrene, 5.04 µg/kg benzo [a] anthracene and 3.23 µg/kg Benzo (b) fluoranthene, which are carcinogens and some of them were persistent even after three days of storage.

Conclusion

Fruit ripening under natural process results in no harm to the consumers due to the natural source of ethylene being the cause. Physicochemical attributes are also satisfactory under these normal conditions with its slow action and metabolic reactions. However, different ripening agents are used on fruits for commercial ripening to fasten the ripening process to cater to the market demand. These may cause problems in safe consumption of fruits. Artificial ripening accelerates ripening, however, affects the nutritional quality and safety of the fruits if not properly used. Various researchers are working to assess the health hazards associated with fruit ripening agents. It is critical to quantify the toxic concentration within the chemically ripened fruit-skin and flesh in order to evaluate the relevant health hazard. Further, the qualitative and quantitative analysis of the impurities associated with ripening agents and other possible sources of chemical adulteration, and their aftereffects on the nutrition value, taste and shelf life need to be analyzed.

References

Abeles, F.B., Morgan, P.W. and Saltveit, M.E. (1992). Ethylene in Plant Biology. San Diego Academic Press, San Diego. 414 p.

Agudo, A. (2005). Measuring Intake of Fruit and Vegetables. World Health Organization, Kobe, Japan. 40 p.

Bartley, I.M., Knee, M. and Casimir, M.A. (1982). Fruit softening. I. Changes in cell wall composition and endo-polygalacturonase in ripening pears*. Journal of Experimental Botany*. 33: 1248-1255.

Ben-Arie, R., Kisler, N. and Frenkel, C. (1979). Ultrastructural changes in the cell walls of ripening apple and pear fruit. *Plant Physiology*. 64: 197-202.

Bhuiyan, M.H., Ali, M.S. and Molla, M.M. (2009). Effects of using chemicals and hormones for cultivation and marketing of vegetables and banana. Final Report CF # 14/07. National Food Policy Capacity Strengthening Programme. USAID.

Bouzayen, M., Latché, A., Nath, P. and Pech, J.C. (2010). Mechanism of fruit ripening: In: Plant developmental biology–biotechnological perspectives (E.C. Pua and M.R. Davey, Eds). Springer.

Brady, C.J. (1987). Fruit ripening*. Annual Review of Plant Physiology and Plant Molecular Biology*. 38 (1): 155-178.

Burg, S.P. and Burg, E.A. (1967). Molecular requirement for the biological activity of ethylene. *Plant Physiology*. 42 (1): 144-152.

Chan, H-T. Jr., Hibbard, K.L., Goo, T. and Akamine, E.K. (1979). Sugar composition of papayas during fruit development. *Horticultural Science*. 4: 140-145.

Chow, M. (1979). The preoccupation with food safety. In: Critical Food Issues for the Eighties (Chow, M. and Harmon Jr, T.D.P. Eds), pp 14-42. Pergamon Press, New York.

De Arriola, M. C., Calzada, J. F., Menchu, J. F., Rob, C. and Garcia, R. (1980). Papaya. Tropical and subtropical fruits (S. Nagay and RE. Shaw, Eds). pp 316-340. AVI Pubishing Inc. West Conn.

Eduardo, K. (2012). Banana and Plantain. Dole Fresh Fruit International, Ltd., San Jose, Costa Rica. www.ba.ars.usda.gov/hb66/banana.pdf

Fan X., Belankenship S.M. and Mattheis J.P. (1999). 1-Methylcyclopropene inhibits apple ripening. *Journal of the American Society of Horticultural Science*. 124:690-695.

Fattah, S.A. and Ali, M.Y. (2011). Carbide Ripened Fruits-A Recent Health Hazard. *Faridpur Medical College Journal*. 5: 37.

Ghanta, P.K., Dhua, R.S. and Mitra, S.K. (1994). Studies on fruit growth & development of Papaya. *Indian Journal of Horticulture*, 51: 246-250.

Gray, J., Picton, S., Shabbeer, J., Schuch, W. and Grierson, D. (1992). Molecular biology of fruit ripening and its manipulation with antisense genes. *Plant Molecular Biology*,19: 69-87.

Gross, S. and Wallner, S.J. (1979). Degradation of cell wall polysaccharides during tomato fruit ripening. *Plant Physiology*, 63: 117-120.

Hakim, M.A., Hakim, M.A., Obidul Huq, A.K., Alam, M.A., Khatib, A., Saha, B.K., Haque, K.M.F and Zaidul, I.S.M. (2012). Role of health hazardous ethephon in nutritive values of selected pineapple, banana and tomato. *Journal Food Agriculture and Environment,* 10(2): 247-251.

Hartshorn, R. (1931). Some effects of acetylene on the ripening processes of bananas. *Plant physiology*, *6*(3): 467.

Hibler, M. and Hardy, D. (1994). Breeding a better banana. *IDRC Report*. 22(1): 16-18.

Hossain, M.F., Akhtar, S. and Anwar, M. (2015). Health hazards posed by the consumption of artificially ripened fruits in Bangladesh. *International Food Research Journal*. 22 (5): 1755.

Islam, M.N., Mursalat, M. and Khan, M.S. (2016). A review on the legislative aspect of artificial fruit ripening. *Agriculture and Food Security. BioMed Central*. 5(1): 1–10.

Jayan, T.V. (2011). Beware of these fruits. The Telegraph, Calcutta, India.

Knee, M. and Bartley, L.M. (1981). Composition and metabolism of cell wall polysaccharides in ripening fruits. In: Recent Advances in the Biochemistry of Fruits and Vegetables (J. Friend and M.J.C. Rhodes, Eds), pp 133-148. Academic Press, London, New York, San Francisco.

Kulkarni, S.G., Kudachikar, V.B., Vasantha, M.S., Prakash, M.N.K., Prasad, B.A. and Ramana, K.V.R. (2004). Studies on effect of ethrel dip treatment on the ripening behaviour of mango (Mangifera indica L.) variety 'Neelum'. *Journal of Food Science and Technology*. 41 (2): 216–220.

Kulkarni, S. G., Kudachikar, V.B., and Keshava Prakash, M.N. (2011). Studies on physico-chemical during artificial ripening of banana (Musa sp) variety "Robusta." *Journal of Food Science and Technology*, 48(6): 730–734.

Kumar, S., Das, D.K., Singh, A.K. and Prasad, U.S. (1994). Sucrose metabolism during maturation and ripening of mango cultivars*. Plant Physiology and Biochemistry*. 21: 27-32.

Kumar, S. and Purohit, P. (1998). Plant Physiology Fundamentals and Applications*.* Agro-Botanical Publishers India.

Mahajan, B. V. C., Singh, G. and Dhat, A.S. (2008). Studies on ripening behavior and quality of winter guava with ethylene gas and ethephon treatment. *Journal of Food Science and Technol*ogy. 45(1): 81-84.

Mebratie, M.A., Woldetsadik, K., Ayalew, A. and Haji, J. (2015). Comparative study of different banana ripening methods. *Science, Technology and Arts Research Journal*, 4(2):32-38.

Medlicott, A. P., Reynolds, S. B., New, S. W. and Thompson, A. K. (1988). Harvest maturity effects on mango fruit ripening. *Tropical Agriculture*. 65: 153–157.

MehnazMursalat and Rony, A.H. (2013). A Critical Analysis of Artifical Fruit Ripening. *Chemical Engineering & Science Magazine*, 4(1): 1–7.

Mohapatra, A., Bhosale Yuvraj, K. and Shanmugasundaram, S. (2016). Physicochemical changes during ripening of Red banana. *International Journal of Science, Environment and Technology*. 5(3): 1340-1348.

Mohapatra D., Sabayasachi M. and Namrata S. (2010). Banana and its by-products utilisation: an overview. *Journal of Scientific and Industrial Research.* 69: 323-329.

Mursalat, M., Rony, A.H., Rahman, A.H.M.S., Islam, M.N., Khan, M.S. (2013). A critical analysis of artificial fruit ripening: Scientific, Legislative and Socio-Economic Aspects. *CHE THOUGHTS - Chemical Engineering and Science Magazine*. 4(1): 6-12.

Nguyen, Q.T., Nguyen, M.K. and Tran, H.P. (1999). Ethylene and its applications. In: Agriculture. Agricultural Publishing House, Vietnam.

Orisakwe, O., Nduka, J., Amadi, C., Dike, D. and Bede, O. (2012). Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. *Chemistry Central Journal*. 6(1): 77.

Palmer, J.K. (1971). The banana. In: Food Science and Technology-A Series of Monographs (A.C. Hulme, Ed), pp 65-105. Academic Press, London and NY.

Paull, R.E. (1993). Pineapple & Papaya. In:Biochemistry of Fruit Ripening. (G.B. Seymour, J.E.Taylor and G.A.Tucker, Eds), pp 291-323. Publisher Chapman & Hall, London.

Pech, J.C., Latché, A. and Balagué, C. (1992). Cellular and molecular aspects of the plant hormone ethylene. Kluwer Academic Publishers, Netherlands, 385 p.

Premaseela, H.D.S.R, Perera, M.G.D.S, Hewajulige, I.G.N, Gunasekera, M.M.N.P, Madage, S.S.K., Weerasekara, R.A.D.S.M.R, Ganege, and Don, K.K. (2019). Effect of commonly used artificial fruit ripening methods on ripening behaviour, quality and safety of banana. 5th IFSTSL Annual Research Session of Institute of Food Science & Technology Sri Lanka. pp 35-40.

Rahim, M.A. (2012). Indiscriminate use of chemical in fruits and their health effects. In: Proceedings of the First AFSSA Conference on Food Safety and Food Security held at Osaka Prefecture University, Osaka, Japan, pp 17-25.

Rahman, A.U., Chowdhury, F. R. and Alam, M. B. (2008). Artificial ripening: what we are eating. *Journal of Medicine.* 9: 42-44.

Ram, H.B., Singh, S.K., Singh, R.V., Surjeetsingh (1979). Effect of ethrel and smoking treatment on ripening and storage of banana cultivar. *Himachal Prog Horticulture*, 11(3): 69–75.

Ried, M.S. (1992). Ethylene in postharvest biology. In: Postharvest Technology and Horticultural Crops. (A. Kader, Ed)). University of California Division of Agriculture and Natural Resources.

Robinson, J.C., Sauco, V.G. (2010). Bananas and Plantains. 2nd ed. CAB International, UK, MPG Books. pp 259-263.

Saltveit, M.E. (1999). Effect of ethylene on quality of fresh fruits and vegetables. *Postharvest Biology and Technology*. 15(3): 279-292.

Sawamura, M., Knegt, E. and Bruinsma. J. (1978). Levels of endogenous ethylene, carbon dioxide, and soluble pectin, and activities of pectin methylesterase and polygalacturonase in ripening tomato fruits. *Plant and Cell Physiology*. 19: 1061-1069.

Selamat, M.K. (1993). Effects of modified atmosphere and storage temperature on ripening of papaya. MSc Thesis, University of Kebangsan Malaysia.

Selvaraj, Y., Pal, D.K., Subramanyam, M.D. and Iyer, C.P.A. (1982). Fruit set and the developmental pattern of fruits of five papaya varieties. *Indian Journal of Horticulture*. 39: 50-56.

Seymour, G. (1993). Banana. In: Biochemistry of Fruit Ripening. (G. Seymour, J. Taylor and G. Tucker, Eds) pp 83-106. Chapman and Hall, London.

Shimokawa, P. and Kasai, A.(1968). Ribosomes as a target. In: Plant Physiology Fundementals and Applications (A. Kumar and S.S. Purohit, Eds.). Agro Botanical Publications, India, 435 p.

Siddiqui, M.W. and Dhua, R.S. (2009). Standardization of ethrel treatment for inducing ripening of mango var. 'Himsagar'. In: Proceedings of International Conference on Horticulture (ICH-2009), Bangalore. pp 1641–1648.

Siddiqui, W. and Dhua, R.S. (2010). Eating artificially ripened fruits is harmful. *Current Science*, 99(12): 1664–1668.

Siddiqui, M.W. (2008). Studies on some aspects of mango ripening. Thesis submitted to Department of Post-Harvest Technology of Horticultural Crops, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, India.

Singal, S., Kumud, M. and Thakral, S. (2012). Application of apple as ripening agent for banana. *Indian Journal of Natural Products and Resources*. 3(1): 61-64.

Singh, Zora and Janes, J. (2001). Effects of postharvest application of ethephon on fruit ripening, quality and shelf life of mango under modified atmosphere packaging. *Acta Horticulturae.* 553(1): 599-602.

Soares, A.L. and Mello-Farias, P.C. de (2006). Ethylene and fruit ripening: from illumination gas to the control of gene expression, more than a century of discoveries*. Genetics and Molecular Biology*, 29(3): 508–515.

Sogo M -Temi, C & A Idowu, O and Idowu, Ebenezer (2014). Effect of biological and chemical ripening Agents on the nutritional and metal composition of banana (*Musa spp*). *Journal of Applied Sciences and Environmental Management*. 18(1): 243.

Subbaiah, K.V., Jagadeesh, S.J., Thammaiah, N. and Chavan, M.L. (2013). Changes in physico-chemical and sensory characteristics of banana fruit cv. Grand Naine during ripening. Karnataka. *Journal of Agricultural Sciences*. 26(1): 111-114.

Subbaiah, K.V., Jagadeesh, S.L., Manjula, R. and Kumar, Y.L. (2014). Effect of Ethrel Dip and Smoke Treatments on the Ripening Behavior of Banana Fruits cv. Grand Naine. *Research Journal of Agricultural Sciences*, *5*(6): 1294-1298.

Sudhakar, P. (2006). A solution to ripen mango the right way. The Hindu, Tamil Nadu, 18 May, 2006.

Tapre, A.R. and Jain, R.K. (2012). Study of advanced maturity stages of banana. *International Journal of Advanced Engineering Research Studies.* 1(3): 272-274.

Terai, H., Ueda, Y. and Ogata, K. (1973). Studies on the mechanism of ethylene action for fruits ripening *Journal of the Japanese Society for Horticultural Science*. 42(1): 75-80.

Tran, H.P. (2000). Initial results of Ethrel application in agriculture. Research Collection of Science and Technology, Vietnam.

Ur-Rahman, A., Chowdhury, F.R. and Alam, M.B. (2008). Artificial ripening: what we are eating. *Journal of Medicine*. 9(1): 42-44.

Vendrell, M. and Mcglasson, W. (1971). Inhibition of ethylene production in banana fruit tissue by ethylene treatment. *Australian Journal of Biological Sciences*. 24 (4): 885.

Warner, H.L. and Leopold, A.C. (1969). Ethylene evolution from 2-chloroethylphosphonic acid. *Plant Physiology,* 44(1): 156–158.

WHO (1987). Lead (Evaluation of Health Risk to Infants and Children). In: Toxicological Evaluation of Certain Food Additives and Contaminants. WHO Press: Cambridge.

Wills, R.B.H., McGlassan B., Graham, D. and Joyce D. (1998). An Introduction to the Physiology and Handling of Fruit, Vegetables and Ornamentals. (4th ed.). Publisher UNSW. Press Australia.

Yonea, T., Nip, W.K., Wei, F.P.S. and Cai, T. (1990). Physico-chemical parameters of post harvest ripened mangoes from Hawaii. *Acta Horticulturae*. 269(1): 291-298.

Zegzouti, H. (1997). Isolement de noveaux gènes regulés par l'éthylène chez la tomate (*L. esculentum*) par criblage de cDNA issus du "Differential Display". PhD. Thesis, Institut National Polytechnique, Toulouse.