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Delay in fruit ripening: a promising approach for reduction of spoilage and use of hazardous chemicals in Bangladesh

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Abstract

Food safety is a global concern and Bangladesh is no exception. In last few decades, fruit and fruit processing industries have grown rapidly in Bangladesh. To achieve maximum quality in terms of visual appearance, texture, flavor and nutritional value, fruits must be harvested at proper maturity. However, after harvesting, rapid ripening of fruits is responsible for short shelf life. This problem can be addressed either by using preservatives or ripening manipulation. Because of its low cost and availability, Formaldehyde has been widely used as preservatives in Bangladesh despite very hazardous health impacts. Other impure food ripening agents like commercial-grade Calcium carbide is also being used to make the harvesting faster for quicker revenue. These all attributes to very severe health concerns including cancer, male sterility and many more. Considering current situation in Bangladesh, artificially delaying fruit ripening seems to be a promising alternative to overcome the crisis and this is also being practiced in several countries. Fruit ripening process requires production of ethylene during the process and ripening of fruit can be delayed by inhibiting ethylene activity. There are several chemical compounds that can be used as inhibitors of ethylene activity without any significant change in quality and health concern. Here, we present a small review on ethylene inhibitors focusing on scope, prospects, safety and potential of using that in Bangladesh. Some of the promising ripening delaying agents and their effective application doses are also reported, which might be applicable in Bangladesh as an alternative to the hazardous Formaldehyde or carbide application.

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Introduction

Fruits play a vital role in nutrition and they are rich source of vitamins, minerals, dietary fibers, different important carotenoids (lycopene, beta-carotene, xanthophyll etc.), flavonoids, phenolic and other phytochemicals(Harborne, 1971, Liu, 2003, Schreiner and Huyskens-Keil, 2006). Owing to their anti-oxidant, anti-carcinogenic and anti-mutagenic activities, carotenoids and other phytochemicals provide protection against chronic disease states, different types of cancers, macular and cardiac vascular diseases and age related ailments (Blasa *et al.*, 2010, Bourn and Prescott, 2002, De la Rosa *et al.*, 2009, Kader, 2008, Vicente *et al.*, 2009). Apart from regular consumption, different types of fruits have varying processing approaches for different applications. Fleshy fruits like apple, peach, pear, pineapple, watermelon and mango are commercially valuable as human food, eaten both fresh and as jams, marmalade and other preserves. Fruits are also used in manufactured foods like cookies, muffins, yogurt, ketchup, puree, sauces, soup, salad, ice cream, cakes and many more. Bangladesh is a tropical country with plenty of fruit varieties all around the year. Unfortunately, consumption of fruits is not as high as it is supposed to be because of unavailability during off season and lack of proper post-harvest preservation. World Health Organization (WHO) recommend daily per capita consumption of fruits and vegetable is a total of 400g for a healthy person. However, in Bangladesh, the per capita consumption is as low as 126 g of fruits and vegetables including only 14g of fruits (Chu *et al.*, 2010).

Fruits are generally expensive in Bangladesh because of the post-harvest spoilage of fruits in supply cycle and costly preservation procedure. People pertinent to the fruit business are not familiar with effective methods or techniques of food preservation that can contribute towards better post-harvest management and less spoilage. Approximately 3362 thousand Metric tons of fruits are produced annually in Bangladesh (2012) and post-harvest losses of fruits and vegetables ranges from 18-40% in different levels of supply cycle. These spoilage costs about Tk 3000-3500 crore per year (BSS, 2010, Hassan, 2010). To overcome this problem various chemicals are used unofficially and illegally, however, most of these chemicals are very harmful to human health. This scenario therefore emphasizes the requirement of a safe, suitable, cost-effective and consumer acceptable techniques that can reduce the spoilage by preserving the food quality or by delaying the ripening of harvested semi-ripen fruits. Availability of such a technique will extend the shelf life or storability of fruits and in turn, assist in effectively minimizing the direct financial loss and relevant health issues.

Current Scenario in Bangladesh

Bangladesh is predominantly an agricultural country. The climate and soil is suitable for a wide range of horticultural cultivation. High and medium high lands are mostly suitable for fruits and vegetables. More than 100 vegetables, 70 fruits and 60 spices are produced every year (2014). Some major vegetables are cucurbits, yard long bean, okra, radish, cauliflower, cabbage, tomato, beans, aroids, carrot, leafy vegetables etc.; fruits namely various kinds of citrus, jackfruit, mango, pine apple, papaya, guava, banana, melon, water melon, litchi, hog plum etc. and spices namely onion, garlic, ginger, turmeric, green chili and coriander etc. About 100 types of fruits and vegetables are exported from Bangladesh to more than 40 different countries in the world (2014). Export of fresh fruits and vegetables from Bangladesh also increased significantly from 50.71 million USD in FY2008-09 to 182.23 million USD in FY2012-13 (2014). However, it is still insignificant compared to other countries of the world. In FY2012-13, fresh fruits export market was dominated by India (93.94%), Middle East countries (4.3%), EU region (0.42%) and other countries 1.34% (2014). Fresh fruits and vegetables export values from FY2008-09 to FY2012-13 are shown in Table 1.

In recent years, Bangladesh is growing in terms of food processing and agro-based industries and export from these sectors is rising rapidly. These sectors have great potentials to be key players in the economy of Bangladesh in the near future. However, post-

harvest losses of fruits and vegetables is the main hurdle that needs to be addressed. In order to decrease the losses, the local farmer and distributer often uses some unauthorized chemicals, and Formalin is one of the most common examples. Formalin, a 37% water solution of formaldehyde, is very poisonous and can cause terminal diseases such as cancer (2001, Fischer, 1905).

Table 1. Export growth of Fresh Fruits and Vegetables [Export Promotion Bureau (EPB) and data analysis by Hortex Foundation 2013].

Fiscal Year	Quantity Exported (MT)	Export Value (in Million US$)	Export Growth (%)
2008-09	24670	50.71	-
2009-10	29370	64.21	(+) 26.62
2010-11	48428	109.41	(+) 70.39
2011-12	59573	134.59	(+) 23.01
2012-13	80660	182.23	(+) 35.39

Traders often use this chemical as a preservative to make fruits and vegetables look fresh for longer period (2010, Dhareshwar and Stella, 2008, Gatesoupe, 2002, Tang *et al.*, 2009). In 2013, the environmental group Paribesh Bachao Andolan (PABA) had reported horrific findings about the use of formalin on various food items in Dhaka. The group found 100% of vermicelli and 90% of noodles were contaminated with formalin and other harmful chemical preservatives. Apart from that 100% citrus fruits, 95% of grapes, 91% of bananas, 82% of mangoes, 77% of dates, 75% of tomatoes, 60% of eggplant, 59% of apples and 20% of cucumbers were also found to have some extent of formalin or other chemicals during random sampling (2013). This alarming situation is getting even worse for the fruit farmers and traders, as they have no other techniques to reduce the spoilage or preserve the unsold product. This can either be addressed with healthy preservation techniques and manipulating ripening time of the fruits so that farmers and traders can have control over the shelf life of the fruits. Current healthy preservation options such as FDA approved methods are not cheap enough or sometimes not accessible by the local farmers and traders. Research is still going on to develop cost effective techniques of preservation and delay in fruit ripening seems a promising alternative is and being used in different countries (Madrid, 2011, Watkins, 2008). Here we review some of the potential chemicals that are used to delay fruit ripening in different countries without any negative health impact. Some of these might be applicable for Bangladesh in terms of fruit types and requirements. This can certainly improve the current crisis of unauthorized application of hazardous chemicals in fruits.

Concept of delaying fruit ripening

Ripening is a natural process that brings a series of biochemical changes which are responsible for the change of color, pigment formation, starch breakdown, textural changes, volatile and aroma development and finally abscission of fruits (Brecht, 2002). Ethylene is a natural plant growth hormone having numerous effects on plant growth and development besides the regulatory role in ripening process of climacteric fruits (Atta-Aly *et al.*, 2000, Bapat *et al.*, 2010, Barry and Giovannoni, 2007, Burg and Burg, 1962). Plant cells contain ethylene binding receptors that has an ethylene binding site, which gets activated by ethylene and triggers ripening action of fruits (Ayoub *et al.*, 1989). Receptor-bound Ethylene molecules initiate series of interactions by propagating chemical signals inside the fruits' cells (Blankenship and Dole, 2003, Choi and Huber, 2008). These molecular interactions result in the ripening of the fruits by changing the color, flavor, aroma, and composition of fruit (water content, starch content, sugar content etc.). However, Ethylene was also reported to act as a rheostat rather than as a trigger for climacteric fruits ripening which implies that ethylene must be present continuously in

order to maintain the transcription of necessary genes required for fruit ripening (Theologis, 2015). To slow down the ripening process of fresh fruits to increase the shelf life of climacteric fruits, it is needed to inhibit or slow down the action of ethylene gas (Ponce *et al.*, 2009, Watkins *et al.*, 2000). Some chemicals were found to block the response of basal level of ethylene in fruits and thus delayed the natural ripening process significantly (Grichko *et al.*, 2006, Kandungan *et al.*, 2013, Looney *et al.*, 1992, Osorio *et al.*, 2013, Paul *et al.*, 2012, Sisler, 2006, Yalpani *et al.*, 1994). These ethylene inhibitors reacts with the ethylene receptor and inhibits the action of ethylene. Therefore, signals are not propagated for the downstream interaction and thus the ripening process is delayed. Nevertheless, interaction between Ethylene and receptors is a dynamic process and the inhibitors cannot bind the receptor sites permanently. When all the ethylene inhibitor molecules are used up, new receptor sites forms and ethylene regains its sensitivity for them and ripening begins (Blankenship and Dole, 2003, Choi and Huber, 2008). Here we have reviewed the performance and applicability of few potential chemical compounds that can be very promising for Bangladesh in current context.

Methylcyclopropene

1-Methylcyclopropene (1-MCP) was reported to inhibit the ethylene action more effectively (Grichko *et al.*, 2006, Paul *et al.*, 2012, Sisler, 2006) and it can be used to delay the ripening process of various climacteric fruits. The ability of 1-MCP to delay ripening of papaya was demonstrated widely (Ergun and Huber, 2004, Hofman *et al.*, 2001, Shiga *et al.*, 2009). 1-MCP delayed ripening of 'Tainung-1' papaya fruit effectively without changing the quality of papaya (Pereira *et al.*, 2007). It was found to delay the softening process of papaya quite well; and the storage of fruits at low temperature after treatment was found to extend the post-harvest life effectively maintaining the quality of the fruit (Ahmad *et al.*, 2013). However, papaya is not recommended to be treated with 1-MCP at the color break stage as it makes the fruit firmer with little 'rubbery' texture at the ripe stage. It was suggested that more than 25% ripen fruits could be treated with 1-MCP successfully without any alteration of properties (Manenoi *et al.*, 2007). 1-MCP showed an effective role in delaying ripening of guava too. 'Pedro Sato' guava treated with 1-MCP at 900 nL/L for 6 or 12 hours, was much more effective than the other concentration of 1-MCP to delay the ripening of guava (Bassetto *et al.*, 2005). 1-MCP was recommended to extend the shelf life of climacteric bananas as well (Golding *et al.*, 1998, Sisler and Serek, 1997, Watkins, 2006). However, contradictory and inconsistent results on Banana was also reported (Pelayo *et al.*, 2003). Interestingly, it was found that the efficacy of 1-MCP had no significant influence on immersion duration for banana. Moreover, post-harvest immersion of mature-green banana in aqueous solution of 1-MCP was found to extend the storage life up to 35 days while keeping into 1% perforated low density polyethylene bag without changing the fruit quality significantly and it can be suggested as a feasible alternative way for long distance transportation and marketing for banana to reduce losses (Rahman *et al.*, 2014).

1-MCP can also be used on vegetables like tomato to increase shelf life by delaying ripening at various stages of ripeness (Hoeberichts *et al.*, 2002, Mir *et al.*, 2004, Su and Gubler, 2012). However, the efficiency of 1-MCP in delaying ripening of tomato depends on concentration. Tomatoes treated with 250, 500 and 1000 µL/L of 1-MCP, was found to delay ripening by 8 to 11, 11 to 13 and 15 to 17 days, respectively (Moretti *et al.*, 2002). Therefore, it is very important to apply an effective concentration of 1-MCP to treat tomato. In another study, 0.3 µL/L of 1-MCP for 24 hour treatment was reported to be the most effective for tomato maintaining the quality of tomato (Paul *et al.*, 2010). 1-MCP treatment delays ripening of apple, as well (Watkins and Nock, 2012), and this has altered the Washington state apple industry (Mattheis, 2008) and apple storage in New York (Watkins, 2008). 1-MCP has been legally used for commercial purposes in many countries such as Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Costa Rica, France, Guatemala

and Honduras, Germany, Israel, Korea, Mexico, Nicaragua, The Netherlands, New Zealand, South Africa, Switzerland, Turkey, UK and USA for number of commodities including various climacteric fruits, vegetables and flowers and the registered crop often specific to country depending on weather (Madrid, 2011, Watkins, 2008). Recently, 1-MCP has also been approved for its use by European Union. Several other countries are amending their regulations to allow 1-MCP for a range of horticultural products.

Salicylic Acid

Salicylic acid (SA) is a ubiquitous plant phenolic compound that regulates a number of processes in plants and it is an important component in the signal transduction pathway (Raskin, 1992). SA is also involved in local and systemic resistance to different pathogens (Kang *et al.*, 2003, Yalpani *et al.*, 1994). SA was found to inhibit the ethylene action on different climacteric fruits (Leslie and Romani, 1988, Shafiee *et al.*, 2010). It was reported to delay banana fruit ripening effectively. The major enzymatic antioxidants namely, catalase and peroxidase, was also found to be reduced in presence of SA during the ripening process of banana (Srivastava and Dwivedi, 2000). SA was also found to delay ripening of strawberry effectively maintaining the quality of the fruit. The pre-harvest and post-harvest application of SA was reported to maintain the quality of strawberry fruit during post-harvest storage and thus increased post-harvest life of strawberry (Lolaei *et al.*, 2012). SA and $KMnO_4$ treatments, individually or in combination, were found to be a very effective method in extending the shelf life of kiwifruit during storage. 1 mM SA and then $KMnO_4$ was found effective without noticeable change of kiwifruit quality during the long storage period (Bal and Celik, 2010). It was also suggested that kiwifruit can be stored in polyethylene bags (LDPE-low density polyethylene, 13 µm thicknesses) at 0°C and 85-95% relative humidity for 200 days without losing much of its quality after treatment (Bal and Celik, 2010). SA is being used in many countries on a number of commodities including various climacteric fruits, vegetables and flowers (Bal and Celik, 2010).

Gibberellic Acid

Gibberellic acid (GA_3) is a naturally-occurring plant growth hormone found in most plant tissues. It is involved in physiological processes such as flowering, seed set and fruit development, and is used in selected horticultural crops to manipulate flowering and fruit development (Richards *et al.*, 2001). It was found that GA_3 delayed the anthocyanin synthesis and chlorophylls degradation (Martinez *et al.*, 1994). Post-harvest treatment of GA_3 increased the quality of different climacteric fruits (Kandungan *et al.*, 2013, Looney *et al.*, 1992, Southwick *et al.*, 1995). Peach treated with GA_3 maintained a higher firmness during storage at 2°C and the respiration rate and ethylene emission was also reduced significantly (Omero *et al.*, 2000). Therefore, GA_3 treatment is seems to be effective in reducing the susceptibility of the fruits under unexpected mechanical damages. GA_3 treatment was found to delay the ripening of tomato as it retards ethylene action (Dostal and Leopold, 1967). GA_3 is also suitable for banana. Dipping of whole banana fruit in aqueous solutions of GA_3 at concentrations from 10^{-5} to10^{-2} M was reported to delay ripening of banana fruit effectively maintaining the quality of the fruit and thus increase shelf life (Vendrell, 1970). Post-harvest treatment of GA_3 shows an effective role in delaying ripening of mango fruit as well. GA_3 treatment on 'Alphonso' mango inhibited the ripening significantly during storage at 28°C. The low Brix/acid ratio and high firmness was observed in mango fruits treated with GA_3, which is suitable for long distance transportation of mango (Murthy and Rao, 1982). GA_3 is being used in many countries and it was approved by The United States Environmental Protection Agency (EAP) (1995).

Alternative Options

Many other chemicals also inhibit the ethylene action and can be used to delay the ripening process of various climacteric fruits. Post-harvest treatment of ethanol vapor to retard ripening can be a useful technique to extend the post-harvest life of tomato (Saltveit and Sharaf, 1992). Sodium dehydroacetate (Na-DHA) was found effective in extending the shelf life of strawberry by slowing down various stages of

ripening and subsequently extended the duration of marketability (Watada, 1971). Indole-3-acetic acid can be considered as an effective chemical to delay ripening of different fruits. Ripening of tomato was found to be delayed significantly by using moderate levels of Indole-3-acetic acid (Cohen, 1996). It was reported that at the low concentration (1 and 10 μM), Indole-3-acetic acid delayed ripening of Avocado fruits and inhibits the climacteric respiration and ethylene production (Tingwa and Young, 1975).

Coating is considered as one of the most popular techniques to prolong the post-harvest life of fruits. Beeswax-coated mango was found to have the longest shelf life with good quality as beeswax is an antioxidant with antimicrobial property. However, the taste, color, aroma and flavor were found to be the best for starch coated fruits (Bibi and Baloch, 2014). Apples treated with hot air at 38°C for 4 days and then coated with 1% chitosan before storage at 0°C for 8 weeks, followed by further commercial shelf storage at 20°C for 7 days is considered as an effective method to maintain the quality of Gala apples (Shao *et al.*, 2012). Chitosan coating was found to delay fruit senescence and fungal decay of strawberry stored at 10°C and 70 ± 5% relative humidity. Calcium gluconate contributed to extend the shelf life of strawberries by inhibiting fungal decay and maintaining fruit firmness when used in combination with a low concentration of chitosan (Hernández-Muñoz *et al.*, 2008).

Conclusion

Bangladesh has achieved significant progress in production of various climacteric fruits during the last decade. But at the same time it is also true that the post-harvest management opportunities have not been increased at the same proportion. On the other hand, any suitable and safe local technology has not yet developed to delay the fruit ripening. Therefore, the country continues to face a huge post-harvest losses (ranging from 25 to 40 %) (BSS, 2010, Hassan, 2010). Beside the adverse impact of this situation on the farmers, stockiest, suppliers and traders, consumers are also affected due to the sudden and wide fluctuations in availability and prices of fruits. It has become a burning issue to identify a potential solution to decrease the post-harvest losses. Delay ripening technique offers flexibility and convenience, thus can be an attractive alternatives to hazardous chemicals currently being in use without authorization. It is very important to consider the benefits and effectiveness of ethylene inhibitors in delaying the ripening and ripening-related changes in fruits and vegetables which has been reported by many researchers. Delay ripening technique therefore has the tremendous potential and scope in improving the current problem associated with post-harvest management of fruits in Bangladesh.

One of the ethylene inhibitors, 1-MCP has already been adopted by Washington state apple industries (Mattheis, 2008) and apple storage facilities in New York (Watkins, 2008). The use of 1-MCP, at concentration up to 1.0 μL/L (=1.0 ppm) has been approved in USA for many fruits like tomato, apple, plum, apricot, avocado, banana, broccoli, mango, melon, papaya, peach, pear, persimmon, kiwifruit and nectarines. Apart from USA, this has already been applied for its use in many countries (Madrid, 2011, Watkins, 2008). The use of GA_3 at concentration up 0.5 ppm has been approved by The United States Environmental Protection Agency (EAP) (1995). Ethanol is generally recognized as safe (GRAS) and has been successfully applied as preservative as well (Saltveit and Sharaf, 1992).

In terms of quality, it is very important to find out large number of additional information before using ethylene inhibitors widely. In the coming years, delay ripening technique will get commercial importance as a feasible alternative for long distance transportation and marketing for general consumption and also a major faction of food processing industries will adopt delay ripening technique to decrease the post-harvest losses. However, prior to this, it is highly important to clarify all the possible safety and health concerns regarding the use of ethylene inhibitors in delaying the ripening and ripening-related changes of specific types of fruits available in Bangladesh. Inexpensive

treatment methods without any health issues could change the fruit production and processing industries to a new level, socially and commercially.

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