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A Critical Analysis of Artificial Fruit Ripening: Scientific, Legislative and Socio-Economic Aspects

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Abstract

Fruit ripening is a natural process which also can be stimulated using different artificial fruit ripening agents. In the recent years, the effect of artificial ripening has become questionable because of various health related issues. There are direct and indirect health hazards associated with artificial ripening agents and their impurities, which require qualitative and quantitative analysis of chemical toxicity and their impact on fruit quality. To understand the possible health hazards, it is important to analyze chemicals present within artificially-ripened fruits, and to analyze any change in food value. This article sheds light on the usages of different chemical compounds as artificial fruit ripening agents, their mechanisms, their effects on fruit quality, and possible health impacts. The existing laws and legislations practiced in different countries are also reported here. The paper gives an overview of different aspects of artificial ripening, and the key factors which should be borne in mind while choosing right fruits. The key objective of the paper is to address the problems associated with artificial ripening and bring them to the notice of the scientific and non-scientific communities.

Keyword: Artificial fruit ripening; ethylene; calcium carbide; ethephon; health hazards; legislations.

1. INTRODUCTION

Fruit ripening is a natural process in which the fruit goes through various chemical changes and gradually becomes sweet, colored, and gets soft and palatable [1-5].With the advancement of science and technology, various artificial methods of fruit ripening has been observed mostly to meet consumers' demand and other economic factors. However, in the recent years, artificial fruit ripening has been considered a matter of concern and the effect of artificial ripening has become questionable because of various health related issues [6-9].

The need of artificial fruit ripening is often encountered when the fruit-sellers offer fruits to the customers before due season. It is easier to identify artificially-ripened fruit during off season. However, it is harder to find physical differences between artificially ripened fruits and naturally ripened fruits during the actual season of ripening. Fruit-sellers artificially ripen green fruits even during the due season to meet the high demand and make high profit of seasonal fruits. They also ripen fruits artificially to deal with the transportation and distribution issues. Transporting and distributing fruits from the farmers' orchards to consumers' baskets can take several days. In the distribution process fruits are collected from farmers to the local storage points. From local storages (or collection points), fruits are transported to the warehouses of the major cities and also to the remote parts of the country, from where the retailers collect fruits and sell to household customers. Besides, a wide range of fruits are also exported to different parts of the world. Therefore, it may take several days from plucking fruit from the tree to reaching it to consumer's basket considering the transportation

route and the availability of warehouses or cold storage. During this time the naturally ripened fruits can become over ripe and inedible. A part of naturally ripened fruits can also be damaged during harsh condition of transportation. It is an economic loss for the fruit-sellers and therefore, to minimize the loss, fruit-sellers sometimes prefer collecting fruits before they are fully ripe, and artificially ripen fruits before selling to the consumers.

Though the demands of the consumers is met to a great extent with the help of these ripening agents, it is important to investigate any possible health hazards that are associated with them. Most of the ripening agents are toxic and their consumption can cause serious health problems, such as heart disease, skin disease, lung failure and kidney failure [6, 9-12]. Scientists have also reported that regular consumption of artificial-ripened fruits may cause dizziness, weakness, skin ulcer and heart related diseases [6, 7, 13-15]. In addition, these ripening agents may contain different chemicals as impurities which are also toxic for human health. To address the increasing health related concerns, different countries have issued and implemented different acts and laws to control or to prohibit the production, sell and distribution of artificial fruit ripening [11, 16-22]. It is important to perform qualitative and quantitative analysis of the presence of ripening agents within the fruit-skin and flesh to understand the relevant health hazard. The presence of artificial ripening agents is usually encountered on the fruit skin. It is also important to quantify the presence of chemicals within fruit-flesh and to analyze the chemical impact on the food value of artificially ripened fruits [12].

The purpose of this study is to address the legislative, scientific and health related issues associated with artificial ripening, to report current research findings on the food value assessment of artificially ripened fruits, and to make people aware of choosing the right fruit. In order to perform the study on artificial fruit ripening our research explored different concerned places in Bangladesh for information regarding the manufacturing, distribution and application of artificial ripening agents. Measures for qualitative and quantitative analysis shall be taken up in future to proceed with the study further.

2. ORIGIN OF FRUIT RIPENING

Unripe fruits often contain various types of organic acids, namely citric acid, malic acid, ascorbic acid, formic acid, tartaric acid etc [5]. These acids are held responsible for the sour taste of fruits. After certain chemical changes these acids are transformed into sugars and the fruits turn sweet [5]. In fruit ripening process, Chlorophyll is produced and at the same time decomposed. Starch is induced by Amylase usually produces sugar. Pectin converts into pectinase and decomposition of pectin, in this case unglues the fruit cells. The cells being able to slip past one another makes the fruit further soft [4].

Since many years people have been adopting several ways to ripen fruits. Ancient Egyptian harvesters used to cut figs in order to stimulate the ripening process, while Chinese farmers used to leave pears in confined chambers with added heating [5]. Later on Researches showed that treating of fruits with high temperature also triggers fruit ripening [2].

In 1901 Russian scientist Dimitry Neljubow observed that Ethylene gas emerging from larger pipes influences ripening process of fruits [5]. After almost three decades, researchers [5] observed that the plants not only respond to ethylene but also they produce ethylene all by themselves and hence ripening process is accelerated in injured fruits or at a temperature usually higher than the normal. As the gas (ethylene) can diffuse and travel spontaneously from cell to cell at a high pace in the fruits which are cut than those which are uncut, the rate of ripening accelerates [5].

3. CHEMICAL AGENTS USED FOR ARTIFICIAL RIPENING

Ethylene is the major ripening agent produced naturally within the fruits which initiates the process of ripening [15]. There are multifarious uses of many ripening agents to release ethylene in order to speed up the ripening process. Chemicals like ethanol, methanol, ethylene glycol, Ethephon, calcium carbide are used to ripen fruits and vegetables artificially [13, 15, 23]. The use of calcium carbide is much widespread in many regions of south Asia including India, Bangladesh, Nepal and so forth for its cheaper market price

despite its ban due to its harmful feats [4, 9, 20, 21, 24].

Ethylene: A very small concentration (1 ppm) of ethylene in air is sufficient to promote the fruit ripening process [3]. Externally applied Ethylene is likely to trigger or initiate the natural ripening process of apple, avocado, banana, mango, papaya, pineapple and guava, and therefore, can be marketed before the predicted time.

Calcium Carbide: Calcium Carbide is widely used in different parts of the world [10]. Once applied on the fruits Calcium Carbide comes into the contact of the moisture and releases acetylene, which has fruit ripening characteristics similar to ethylene.

The reaction is [24]:

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2$$

Industrial grade calcium carbide contains traces of arsenic and phosphorus hydride, which are hazardous for human health in direct contact [24].

Ethephon: Ethephon is another agent which is used to artificially ripen fruits [25, 26]. Ethephon is often considered better than calcium carbide because pineapple, banana and tomato treated with 1000 ppm of ethephon required less time for ripening (48, 32 and 50 h, respectively) than other treated fruits as well as compared with the non-treated fruits. The fruits ripened with ethephone have more acceptable colour than naturally ripened fruits [31] and have longer shelf life than fruits ripened with CaC_2 [32]. Ethephon is decomposed into ethylene, bi-phosphate ion and chloride ion in aqueous solution [25]. The released ethylene further fastens up the ripening process.

4. Possible Health Hazards

Calcium Carbide releases acetylene which almost works like ethylene in terms of speeding up the ripening process. Direct consumption of acetylene has been found to be detrimental as it reduces oxygen supply to the brain and can further cause prolonged hypoxia [6].

Calcium Carbide is alkaline in nature and irritates the mucosal tissue in the abdominal region. Cases of stomach upset after eating carbide-ripened mangoes has been reported recently [9]. Even though eating the carbide-ripened fruit does not lead to any allergic reaction instantly, seizure headache, sleepiness may be faced while applying these chemicals on the fruits. Impurities like arsenic and phosphorus found in industrial grade calcium carbide may cause serious health hazards when workers are in direct contact with these chemicals while applying the ripening agents. This may cause dizziness, frequent thirst, irritation in mouth and nose, weakness, permanent skin damage difficulty in swallowing, vomiting, skin ulcer, and so forth [9]. Higher exposure may cause undesired fluid build-up in lungs (pulmonary edema) [11].

5. NATIONAL AND INTERNATIONAL LAWS AND LEGISLATIVES

To address the growing health related concerns, developing and developed countries have issued and implemented different acts and laws controlling the usage of artificial fruit ripening agents. In Bangladesh, the agencies and organizations responsible ensuring the proper practice of inspecting, examining and controlling harvesting, ripening and marketing fruits are: Bangladesh Ministry of Agriculture, Customs, Mobile court, Ministry of health, Ministry of Science. These agencies implement the following laws and acts in order to maintain the quality of the home grown and imported fruits: Pesticide law 2007, Pure food rules and act 1967 and 2005, Quarantine rules 1968, Mobil court act 2009, and Penal code 1860 [20, 21]. The above laws and acts prohibit using any chemicals (such as calcium carbide, ethephon, etc.) to ripen fruits and penalize any person who is mixing, selling and/or using illegally ripened fruits.

In Sri Lanka, under the Food Act No 26, 1980, no person can manufacture, sell or distribute any food that contains any added detrimental substance, which turns out to be injurious to human health [18]. In India, the usage of calcium carbide for fruit ripening is prohibited under Rule 44 AA of the Prevention of Food Adulteration Rules 1955 [16]. In Nepal, the Nepal Food Regulation-2017 (Part 7, rule no 19(d)) has strongly prohibited the use of calcium carbide in ripening of fruits [9].

In USA, the United States' NOSB recommends the use of ethylene for post-harvest ripening of tropical fruit and degreening of citrus, which is stated in the 'Formal Recommendation by the National Organic Standard Board (NOSB) to the Organic Program (NOP)' [22]. The United Kingdom's Soil Association allows the use of ethylene to ripen bananas and kiwi [Soil Association Organic Standards, rev 16.4,

June 2011] [27]. Besides, the International Federation of Organic Agriculture Movements' (IFOAM) also enlists ethylene gas as 'Only for ripening fruits' in IFOAM Indicative List of Substances for Organic Production and Processing.

6. Critical Analysis on Fruit Quality and Nutrition Values

Researchers from different disciplines are working to assess the health hazards associated with fruit ripening agents [1, 2, 9, 12, 13, 15, 23]. To evaluate the relevant health hazard it is critical to quantify the toxic concentration within the chemically-ripened fruit-skin and flesh. In different studies, sample fruits are collected from local market rinsed in water and analyzed rinsed water to identify the presence of ripening agent(s) on the fruit skin; this methodology may not confirm or quantify the presence of chemicals within fruit-flesh. There are few studies reported the presence of chemicals within fruit-flesh and have addressed the changes of biochemical and nutritional properties of fruits because of treating with fruit ripening agents [9, 12, 28]. Wills et al (2007) have reported the ethylene concentration in a wide range of artificially ripened fruits: apple, pear, peach, avocado, banana, lemon, pineapple, orange, and lime [28]. Hakim et al (2012) have collected Pineapple and Banana samples from different Bangladeshi local markets and compared to the naturally ripened and lab treated (using Ethephone) Pineapples and Bananas. They have found that chemically ripened Pineapples and Bananas have higher sugar content than non-treated samples; other fruit nutrition values like Vitamin C and β-carotene are higher in naturally ripened fruits (Table 1). They also have reported the presence of Lead (Pb) in chemically ripened (market and lab treated) pineapples and bananas, and Arsenic (As) in pineapples collected from market) [12]. The daily permissible intakes of Pb and As for adults are 600 µg/day and 16.7-129 µg/day, respectively [33, 34]. The average daily consumption of fruits for an adult is in between 100 to 150 gm [35]. Therefore, the possible daily intake of Pb and As from fruits would be 12-50 and 2.5-3.75 µg/day respectively, which is within the acceptable limit for an adult. Nonetheless, further studies must be conducted regarding the effects of long term consumption of such elements in fruits.

Besides, in many developing countries, the potential sources of chemical contamination of fruits and vegetables include the usage of pesticides during harvesting process, preservatives at post-harvesting process [29]. Therefore, to correctly assess the health hazards related with ripening agents, it is not only essential to consider their effects on the fruit's quality, but also the qualitative and quantitative analysis of the impurities associated with ripening agents, other possible sources of chemical adulteration, and their aftereffects on the nutrition value, taste and shelf-life.

Table 1: Properties of Pineapple and Banana at different conditions [12]

Name of Sample		Total Mineral	Total Fat	Total Protein	Total Sugar	Vitamin C	β-carotene	Arsenic (As)	Lead (Pb)
		(g/100 g)				(mg/100 g)	(µg/100 g)	ppm (µg/g)	
Pineapple	Naturally Ripened	0.61	0.02	1.24	9.25	15	78	Nil	Nil
	Treated with Ethephone at Laboratory Condition	0.95	0.03	0.91	9.30	14	63	Nil	0.12
	Collected from Market	0.85	0.03	0.85	9.85	10	31	0.025	0.15
Banana	Naturally Ripened	0.93	0.02	1.37	11.2	13	54	Nil	0.12
	Treated with Ethephone at Laboratory Condition	0.94	0.03	1.33	12.3	9	47	Nil	0.31
	Collected from Market	0.97	0.03	1.01	13.7	7	38	Nil	0.24

7. Choosing the Right Fruits to Consume

The external color and the texture are usually taken under consideration when it comes to choose right fruits. The naturally ripened fruits are often uneven in color. It is advisable to choose fruits during the season when it turns ripe naturally, since a ripe fruit during off season may artificially ripen unless it is genetically ripen [9]. For instance, in Bangladesh,

June and July is the ideal period when naturally ripened mangoes occupy the market. However, ripening also induce the taste of the fruits and also contributes to their weight loss.

8. Discussion

Ethylene is the major ripening agent produced naturally within the fruits to instigate ripening process. However, chemicals agents like ethephon and calcium carbide are frequently used in developing countries to activate fruit ripening process due to cheaper price. Working with such chemical agents without using appropriate protective gears can be hazardous for the workers. On the other hand, the consumers suffer from the indirect consumption of ripening agents and their contaminants. Researchers from Bangladesh reported that the nutrition values like the protein content, vitamin-C and beta-carotene decrease in artificially ripened Pineapples and Bananas [12]; the critical finding was the presence of Arsenic (As) and Lead (Pb) within artificially ripened Pineapples and Bananas. The concentration of As and Pb were within the daily permissible intake limit for an adult, however, regular consumption of such fruits can cause serious health hazards to human beings like cancer, skin irritation, diarrhea, liver disease, kidney disease, gastrointestinal irritation with nausea, vomiting, diarrhea, cardiac disturbances, central nervous system depression and cardiac abnormalities etc. [12]. Ideally artificial ripening agents release ethylene or acetylene to instigate fruit ripening and should not contain metal or metalloid. But practically industrial grade calcium carbide and ethephon may contain a high percentage of As, Pb and Phosphorus compounds which are toxic for human health and can contaminate artificially ripened fruits. Usage of high grade ripening agents requires low dosing rate and any metal/metalloid contamination must be avoided.

It is interesting to note that the developed countries like USA and UK allow using ethylene for post-harvest ripening of selective fruits following specific dosing protocols. In contrast, most of the developing countries, including Bangladesh, India, Pakistan and Sri Lanka, demonstrate zero tolerance in preparing, selling or distributing artificially ripened fruits. However, it is reported that in spite of the strict laws and acts, fruit-sellers in developing countries often use different fruit ripening agents because of different socio-economic factors, such as: high profit, high demand, offsetting transportation and distribution issues, etc. The law enforcement agencies also take actions against artificial fruit ripening [10]. Contrariwise, the fruit-sellers seek guidelines to the government agencies for the safer use of artificial ripening agents [30]. Most of the ripening agents used by the fruit-sellers are of industrial grade, collected from unauthorized sources, and may contain a high percentage of toxic impurities. These chemical impurities also cause serious health hazard. To compensate the transportation and distribution issues in developing countries, Government or local authorities can help fruit-sellers and farmers facilitating convenient transportation and adequate cold storage especially for the seasonal fruits. In addition, the government agencies and scientific communities can investigate to develop safer, low concentration and economically viable dosing protocols and guidelines for fruit ripening. The consumers can also play an important role in terms of selecting the right fruit by keenly observing the variation of color and buying seasonal fruits.

9. Conclusion

In recent years, different ripening agents are used to artificially ripen fruits. These ripening agents along with their chemical impurities are health hazardous. To understand their health effect better, it is important to study their chemical criteria, mechanisms, effects on fruit quality and nutrition value. In this article, different fruit ripening agents are discussed along with their ripening mechanisms and possible health hazard. The national and international laws and regulations available to prohibit or control artificial fruit ripening are also reported. The socio-economic issues of artificial fruit ripening were also addressed. Artificial fruit ripening is a complex issue especially in developing countries like Bangladesh and requires the combined involvement of the government agencies, policymakers, fruit-sellers, farmers, scientists and consumers for an effective solution to this matter. Instead of generalizing the issue, it is important to assess different aspects of artificial fruit ripening, investigate standard practices and carry out extensive scientific studies to improve the situation.

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