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Empowering Import Regulation through Consumer Education: An Example of Mango Fruit Ripening and Calcium Carbide

Madhavi Venkatesan*

Bridgewater State University, United States
*Corresponding author: mvenkatesan@bridgew.edu

Abstract Fruit ripening has fostered the growth of a large-scale global industry in agricultural products. As a result of ripening techniques, fruits can be harvested while green, to be eventually sold with the appearance of full maturity in countries far from their point of origin. Given the size of the import market for fruits and vegetables in the United States, nearly fifty percent of all fruits and vegetables are imported. Arguably, consumers are highly dependent on the actions of regulatory authorities to ensure the food safety of imports. This paper will explore the use of calcium carbide in fruit ripening, specifically addressing the application of the chemical in the ripening of mangoes. After providing an overview of fruit and mango imports to the U.S., the paper will evaluate the known risks to human health from calcium carbide ripening. Following will be a discussion of current domestic regulatory protections specific to calcium carbide. The paper concludes with an evaluation of emerging risks and opportunities, promoting consumer education as a regulatory policing and risk mitigation strategy.

Keywords: *food risk, regulation, imports, calcium carbide, fruit ripening*

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1. Significance of Imports on Domestic Food Supply

In 2014, U.S. imports of food exceeded $109.4 billion. Four countries supplied nearly $51.2 billion, nearly half of U.S. food imports for that year: Canada, Mexico, China and India [31]. As noted in Table 1, the growth rate in imports from China and India was significant over the 2000-2014 period, representing average annual growth in excess of 13% on a currency value basis.

Table 1. Top four food exporters to U.S.

Country	Rank by Currency ($) Value of Imports	Currency ($) Value of 2014 Imports	Average Annual % Growth Rate in Imports 2000-2014
Canada	1	20,607.3	6.7
Mexico	2	17,314.3	9.5
China	3	5,647.6	13.4
India	4	4,110.9	13.8

Source [31].

According to data available from the United States Department of Agriculture (USDA), fruit imports represented more than 10.0% of the value of all food imports on an annual basis over the 2004 to 2013 period [31]. In 2004, the dollar value of U.S. fruit imports totaled in excess of $5.9 billion. By 2013, the value of U.S. fruit imports more than doubled to $13.6 billion, representing an average annual increase of 9.5%. Adjusting for the impact of world prices, from a weight (metric tons) perspective, fruit imports have increased at an average annual rate of 3.5% over the same period. The growth rate represents an increase in the volume of imports from 8.8 million metric tons in 2004 to more than 12.3 million metric tons in 2013. The proportion of fruits on a tonnage basis relative to all other imported food remained fairly steady, representing approximately 18.5% on an average annual basis [31].

1.1. Importation of Mangoes

Specific to mangoes, India is by far the single largest global producer of mangoes; however, much of the country’s production is focused on domestic consumption. Of the 15.2 million metric tons produced in 2014, only 229.2 thousand metric tons were exported [32]. Interestingly, Mexico with an attributed production of 1.8 million metric tons was the single largest exporter of mangoes selling 287.2 thousand metric tons to primarily U.S. importers [32]. In large part the trading relationship represented is attributable to the North Atlantic Free Trade Agreement (NAFTA), which promotes trade between U.S., Canada and Mexico. Mexico presently has the most favorable import tariff rate available for mangoes [32]. Further, limitations on Indian mangoes are specific to import requirements and the product's relatively recent reintroduction into the U.S. market [23].

Indian mangoes, banned from importation in the 1980's and approved for reintroduction in 2007, are the first fruit to be irradiated in a foreign country and approved for importation into the United States [3]. The irradiation, which takes place in the presence of a U.S. inspector [23], prior to export from India, is the FDA approved standard for the elimination of Indian fruit flies and mango seed weevils [23]. Due to the cost of irradiation facilities and the limited number of existing locations, at present there are not sufficient numbers of irradiation centers to promote large-scale exportation to the U.S. [23]. In contrast, Mexican mangoes do not have seed weevil infestation, but due to the prevalence of fruit flies, are required to undergo a water dip prior to U.S. importation (see ***Present regulatory oversight of imports***).

1.2. Present Regulatory Oversight of Imports

Under U.S. law, as provided in the U.S. Federal Food, Drug and Cosmetic Act, importers are responsible for ensuring that food products are "safe, sanitary, and labeled according to U. S. requirements" [11] Imported food products are subject to FDA inspection at U.S. ports of entry and FDA has discretion to detain and or refuse shipments that are deemed to be non-compliant with U.S. regulations [11]. In compliance with Food Safety Modernization Act (FDA, 2015), FDA works with a number of federal agencies to ensure holistic oversight. These agencies include: Centers for Disease Control, U.S. Department of Agriculture, Food Safety and Inspection Service (FSIS), U.S. Department of Agriculture, Agricultural Marketing Service (AMS), U.S. Department of Agriculture, Foreign Agricultural Service (FAS), U.S. Department of Agriculture, Food and Nutrition Service (FNS), and the Environmental Protection Agency (EPA). However, due to resource limitations in combination with growth in facilities (foreign and domestic) requiring oversight, regulatory enforcement has lagged, defaulting to both importer compliance (as referenced above) and sample statistics.

According to the most recent FDA data available, prior to October 22, 2012, there were 172,969 active registered domestic food and feed facilities and 285,977 active registered foreign food and feed facilities, for a total of 458,946. FSMA's amendments to section 415 of the FD&C Act had not been fully implemented in FY 2012. In FY 2012, FDA and the states under contract with FDA inspected (or attempted to inspect) 24,462 domestic food facilities and FDA inspected 1,342 foreign food facilities (FDA, 2015). The total number of food import lines for FY 2012 was 11,136,599 of these 1.9 percent, or 207,839, of the food import lines were physically examined by the FDA [14,21,28]. In an effort to enhance regulatory compliance with U.S. safety standards, the FDA established permanent inspection facilities in foreign countries, citing the significance of imports in domestic consumption as the rationale: "food imports constitute approximately 10 percent of the U.S. food supply and 50 percent of domestically available fresh fruits" [12].

As of May 2013, FDA has established a total of 12 foreign posts. The posts have 30 U.S. direct hires (USDH) and 16 locally employed staff (LES) and are fully operational [12]. Given to largess of exports under the direct supervision of the foreign posts, the oversight, though an improvement, appears to be lean.

Table 2. U.S. FDA foreign posts

Foreign Post Established	USDH	LES
Beijing, China	4	2
Shanghai, China	2	2
Guangzhou, China	2	1
New Delhi, India	7	2
Mumbai, India	4	1
San Jose, Costa Rica	3	2
Santiago, Chile	1	2
Mexico City, Mexico	2	2
Brussels, Belgium	2	0
London, England, UK	1	0
Parma, Italy	0	0
Pretoria, South Africa	1	1
Amman, Jordan	1	1
Totals	30	16

Source [12].

1.3. Import Requirements for Mangoes

Depending upon the country of export, imported mangoes to the U.S. may be subject to a variety of pre-import treatments, which currently include [32]:

- Fumigation– Fumigation with methyl bromide gas. This treatment takes 0.5 to 4 hours.
- Water Dip – Immersion of the commodity in hot or soapy water. Treatment time varies by pest, but is less than 110 minutes in all.
- Hot Air – Exposure to forced hot air, similar to vapor heat but differing in the humidity of the air involved. Typically requires 1.5 to 4 hours.
- Methyl Bromide – Fumigation with methyl bromide gas. This treatment takes 0.5 to 2 hours and is similar in nature to Fumigation treatments.
- Irradiation – Exposure of commodity to radiant energy (x-rays or gamma rays).
- Vapor Heat – Exposure to vapor heat, similar to hot air similar to forced hot air but differing in the humidity of the air involved.
- Cold Treatment – Prolonged exposure (typically 2 weeks) to cold, though not freezing, temperatures.
- Fumigation then Cold Treatment – A combination of fumigation and cold-treatments.
- Cold Treatment then Fumigation – A combination of fumigation and cold-treatments.
- Quick Freeze – Exposure to freezing temperatures for a several day period.

As stated earlier, imported Mexican mangoes are required to undergo water treatment due to prevalence of fruit flies. At this time there is no appearance of mango seed weevils in Mexican mangoes, eliminating the need for irradiation. Also as noted above, Indian mangoes require irradiation prior to export. Of significance to note is that the pre-importation of Mexican mangoes does impact the topical "skin" of the mango, where as, the treatment of Indian mangoes is focused on eliminating pests within the fruit and does not cleanse the topical layer of the fruit.

Neither the water treatment nor irradiation has been found to harm the mango fruit. However, the water treatment through the heat distribution over the fruit may act as a ripening agent and also enhance the uniformity of color in treated mangoes [1].

2. Risks Associated with Foreign Production of Mangoes

Ripening is the process by which fruits attain their flavor, attributed color, and other physical properties. Ripening is associated with a change in the composition of a fruit, specifically the conversion of fruit starch to sugar [26]. On the basis of ripening behavior, fruits are classified as climacteric and non-climacteric fruits. Mangoes are climacteric fruits.

Climacteric fruits are defined as fruits that continue to ripen after harvest. During the ripening process the fruits exhibit an increased rate of respiration and emit ethylene. Ethylene promotes the conversion of fruit starch to sugar and thereby regulates the ripening process. Ripe fruits are soft and delicate and generally cannot withstand rigors of transport and repeated handling. As a result climacteric fruits destined for sale are typically harvested prior to ripening. These fruits are separated from their trees when they are still hard and green. They are processed through exposure to a ripening agent during the transportation stage to induce ripening and ultimately, due to artificial ripening have an aesthetically pleasing, uniform coloration consistent with visible maturity for consumption [4].

2.1. Ethylene Ripening

Ethylene is a naturally occurring plant hormone, referred to as a phytohormone. The process by which ethylene promotes ripening is still being researched; however, what is apparent is that climacteric fruit in the presence of ethylene is stimulated to ripen [16] For this reason, post-harvest application of ethylene is used to promote ripening in green climacteric fruit [16]. Commercial application of ethylene occurs through the use of the chemical ethephon, which metabolizes into ethylene within the fruit. Regulation of ethephon is jointly held between the EPA and FDA. EPA has regulatory oversight of application during harvest under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and FDA has oversight of residue on food product under the Federal Food, Drug, and Cosmetics Act (FFDCA) [7]. However, ethephon is not considered a toxic substance and there is no set tolerance stated for use on mangoes [10]. Additionally, ethephon is generally recognized as safe (GRAS) by the FDA. "If used for the purposes indicated, in accordance with good manufacturing practice, ethephon exhibits no observable adverse consequences" [29].

2.2. Calcium Carbide Ripening

Green harvested mangoes can be ripened quickly through the use of calcium carbide, an inexpensive, easily accessible industrial chemical. The ripening process requires only that the green fruit be in proximal distance to calcium carbide. Essentially, small packets or containers of calcium carbide are placed in the crate or truck transporting unripened mangoes. As the calcium carbide reacts with the moisture in its surrounding environment, it produces acetylene gas, which is similar to ethylene but much more toxic. The acetylene gas acts as a ripening agent in much the same manner as ethylene but the residue of its use has significant adverse health impacts. Acetylene is believed to affect the nervous system by reducing oxygen supply to the brain [26,29]. Additionally, industrial-grade calcium carbide contains arsenic and phosphorus, both of which are toxic, compounds. Arsenic is a listed toxin with the World Health Organization [34] and the FDA has noted prolonged exposure to arsenic can result in cancer [30,34] Phosphorous associated with industrial-grade calcium carbide is white phosphorous, which is a highly toxic substance. EPA describes white phosphorous as "extremely toxic to humans" [13] and notes that short-term exposure to white phosphorous can lead to "rapid decline in condition with gastrointestinal effects, plus severe effects on the kidneys, liver, cardiovascular system, and central nervous system" [9].

Consumption of fruits ripened with calcium carbide have been documented to cause stomach upset, induce prolonged hypoxia which in turn causes headache, dizziness, sleepiness, mental confusion, memory loss, cerebral edema (swelling of the brain caused by excessive fluids) and seizure [25]. At the present time, irrespective of legality of usage, calcium carbide is used in the ripening of mangoes in Brazil, Costa Rica, India, Malaysia, Pakistan, Philippines, Senegal, and South Africa [24].

2.3. Indian Regulation of Calcium Carbide

Legislative protections have been enacted in some countries. For example, the Indian Food Safety and Standards Act, 2006 and Food Safety and Standards Regulations, 2011 makes the manufacture, sale, distribution or use of calcium carbide in conjunction with fruit ripening a crime punishable by imprisonment and fines [33] In spite of this, due to limited policing, lack of consumer awareness of the hazards, and the ease and inexpensiveness of procuring calcium carbide, the chemical remains in use [27]. However, the government of India along with the media have launched consumer education programs focused on raising awareness of the use and risk associated with calcium carbide ripening.

The Food Safety and Standards Authority of India provides the following listing, which the media has disseminated routinely in stories specific to calcium carbide and fruit ripening [16,24].

The following steps that can be followed at home to reduce the level of contamination:

- Wash fruits and vegetables thoroughly with water, preferably running potable water, before eating and cooking.
- Purchase fruits and vegetables from known dealers.
- Peeling of fruits before consumption and vegetables before cooking will reduce exposure to pesticide.
- Do not buy and consume cut fruits from open market.

- Ensure the quality of fruits and vegetables by sending them to voluntary testing laboratories

2.4. U.S. Regulation of Calcium Carbide

In India use of calcium carbide is strictly banned by government regulation; however, U.S. importation screens remain focused on policing for pests (fruit fly and seed weevil) [20]. Instructions for export to the U.S. specify irradiation and fungicidal treatments but make no note of the use of ripening agents in general or use of calcium carbide, specifically [2,3].

Presently, the U.S. FDA does not regulate calcium carbide specific to threshold dose and domestic regulations do not regulate the use of the product in food. The EPA does provide an information sheet on the chemical but no tolerances or toxicity detail is provided [8]. Therefore, by default, regulation of calcium carbide in exporting countries follows the country specific standard given the lack of prevailing domestic policy (FDA, n.d.(d)).

3. The Consumer's Role in the Mitigation of Emerging Importation-led Risks

The demand for mangoes in the U.S. has been primarily limited to the small but growing ethnic minority populations and as a result has been concentrated in specific geographic areas. However, since 2003 with the establishment of the National Mango Board (Board), there is a marketing-led catalyst for demand growth. The organization recognizes that the most significant growth driver for U.S. mango consumption lies within the untapped 66% of predominantly white, non-ethnic households in the U.S. [33].

The Board, which is comprised of importers, wholesalers/retailers, as well as domestic and foreign producers working to increase the consumption of mangoes in the United States, is one of the nine Research and Promotion Programs of the USDA. The board members who implement the programs are appointed by the U.S. Secretary of Agriculture from industry nominations and the Board's connection to the USDA is limited to compliance with the USDA requirements of Research and Promotion Programs [33].

At the present time, the dominant source of U.S. imports of mangoes is Mexico. However, given the potential shortfalls related to droughts [18], fruit fly infestation [19]. and even Salmonella triggered recalls within the last two years [17], there is ample opportunity for other geographies to enter the U.S. mango market and capture the anticipated expansion in demand

3.1. Significance of Consumer Awareness

Imports from other global production leaders such as India and Pakistan could enhance variety but could also increase health risk. Specific to the latter the use of calcium carbide in both countries remains a health threat. In the case of India the threat is being addressed through domestic regulation, while mitigation is being fostered through direct to consumer educational campaigns. Arguably, India's own domestic policy provides protection to foreign importers due to the legally established standard or duty of care. However, in Pakistan, the same is not the case. There is no governmental intervention and the ban on use of calcium carbide is non-existent [22].

Further, given the FDA's focus on invasive pests, without Pakistani regulatory involvement in the policing of calcium carbide, calcium carbide ripened mangoes may be undetected prior to export. The risk from Pakistan imports is real and significant as the United States is likely to implement zero duty on import of Pakistani mangoes in the upcoming Generalized System of Preferences (GSP) [5]. Limited consumer-focused communication related to risks from calcium carbide ripening preempts domestic consumer capacity to self-police risk in the same manner that the Indian government is actively promoting among its citizens.

Given limited sampling and personnel resources on the part of the FDA, the risks related to calcium carbide ripening underscore the significance of establishing active consumer education and promotion of consumer due diligence with respect to cleaning and preparing foods. Credibility for the need for transparent and timely information flow between the FDA and consumers is further strengthened given that FDA research has noted a recurrence in food safety issues overtime with the same trading partners. Further, recurring violations have been concentrated within the three food industry groups: vegetables (20.6 percent of total violations), fishery and seafood (20.1 percent), and fruits (11.7 percent) [5].

The Centers for Disease Control (CDC) "estimates that each year roughly 1 in 6 Americans (or 48 million people) get sick, 128,000 are hospitalized, and 3,000 die of foodborne diseases". The CDC characterizes foodborne illness as a common, costly and preventable public health problem and estimates that reducing foodborne illness by 10 percent would keep five million Americans from getting sick each year [6].

The example of calcium carbide provided, highlights the unique attributes of food risk. As noted specific to the mango, ethnic difference and individual specific food preferences can increase food risk to some members of a society relative to others. Routine communications conveying potential risks, as well as recurring risks through multiple channels can enhance consumer awareness and promote proactive food sanitation and other due diligence activities. The latter can allow a partnership role between consumers and regulatory agents that may enable the prevention alluded to by the CDC.

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