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CHEMICAL INDUCED FRUIT RIPENING: PROCESSES, HEALTH IMPLICATIONS AND EMERGING SAFE TECHNOLOGIES.

Mrs. S. Vanitha [1*]., Ms.G.Gishmi [2]., Dr. G. Rathinavel [3]., Mr. K. V. Parthasarathi [4]., Ms. M. Madhumithra [5]

[1]Assistant Professor, Department of Pharmaceutical Chemistry, K.S.Rangasamy college of Pharmacy, KSR Kalvi nagar, Tiruchengode-637215.

[2]Assistant Professor, Department of Pharmaceutical Chemistry, K.S.Rangasamy college of Pharmacy, KSR Kalvi nagar, Tiruchengode-637215.

[3]Professor & Principal, Department of Pharmaceutical Chemistry, K.S.Rangasamy college of Pharmacy, KSR Kalvi nagar, Tiruchengode-637215.

[4]Associate Professor, Department of Pharmaceutical Chemistry, K.S.Rangasamy college of Pharmacy, KSR Kalvi nagar, Tiruchengode-637215.

[5]Assistant Professor, Department of Pharmaceutical Chemistry, K.S.Rangasamy college of Pharmacy, KSR Kalvi nagar, Tiruchengode-637215.

The Tamil Nadu Dr. MGR Medical University, Chennai-600032, Tamil Nadu, India.

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***Corresponding Author: Mrs. S. Vanitha**

Assistant Professor, Department of Pharmaceutical Chemistry, K.S.Rangasamy college of Pharmacy, KSR Kalvi nagar, Tiruchengode-637215.

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ABSTRACT

Artificial fruit ripening is widely practiced in modern agriculture and food supply chains to ensure uniform appearance, controlled marketing, and reduced post-harvest losses. Various chemical agents such as ethylene, ethephon, calcium carbide, and other synthetic ripening promoters are used to accelerate physiological ripening processes. While regulated agents mimic natural plant hormones, unsafe chemicals like calcium carbide remain used in some regions and may pose significant health hazards. This review summarizes the biochemical basis of fruit ripening, common artificial ripening procedures, chemicals employed, associated toxicological risks, advantages of controlled ripening, and emerging safer alternatives including biological ripening chambers and natural ethylene systems. The article consolidates evidence from toxicological and food-science literature to support safe and

regulated ripening practices and highlights future research directions for sustainable post-harvest management.

KEYWORDS: Artificial ripening; Ethylene; Calcium carbide; Ethephon; Fruit safety; Post-harvest technology; Food toxicology.

INTRODUCTION

Fruit ripening is a genetically regulated biochemical process involving respiration rise, starch hydrolysis, pigment development, softening, and aroma formation. Climacteric fruits such as mango, banana, papaya, and tomato continue ripening after harvest due to endogenous ethylene production.

To meet commercial demand, fruits are often harvested before full maturity and later ripened artificially to prevent transport damage and extend shelf life [1]. Artificial ripening technologies are therefore integral to global fruit supply systems. However, the misuse of hazardous chemicals has raised major food-safety concerns worldwide [2].

PHYSIOLOGY OF NATURAL RIPENING

Natural fruit ripening is a complex physiological process primarily regulated by the production of the plant hormone ethylene. During ripening, there is a marked increase in respiration rate accompanied by the enzymatic conversion of stored starch into soluble sugars, which enhances sweetness. Simultaneously, chlorophyll degrades while carotenoid and other pigments are synthesized, resulting in characteristic colour development. Structural modifications also occur in the cell wall, leading to tissue softening and improved palatability. Ethylene acts as the principal regulatory hormone in this process by activating gene expression responsible for fruit softening, aroma compound formation, and pigmentation changes, thereby coordinating the overall ripening sequence.[1].

CHEMICALS USED IN ARTIFICIAL RIPENING

Ethylene

Ethylene is a naturally occurring plant hormone that plays a central role in regulating fruit ripening. When applied at controlled concentrations, it is considered safe and is widely used in commercial ripening systems across the world. Because it mimics the natural physiological ripening signal in fruits, ethylene-based ripening methods are generally regarded as non-toxic and suitable for human consumption when used under proper regulatory control.[1].

Ethephon

- Ethylene-releasing compound
- Widely used in agriculture
- Controlled application required

Improper use may leave chemical residues affecting fruit quality [2].

Calcium Carbide

Cheap industrial chemical still used in some developing markets. Commercial carbide contains toxic impurities including:

- Arsenic
- Phosphorus

These contaminants are responsible for serious health risks [3].

Other Reported Agents

Additional chemicals reported in artificial ripening include:

- Ethylene glycol
- Smoke exposure
- Miscellaneous synthetic stimulants

Some of these may adversely affect human health depending on exposure level [1].

ARTIFICIAL RIPENING: PROCEDURES USED

Artificial ripening can be performed using several industrial methods.

Ethylene Gas Chamber Ripening

Commercial ripening chambers operate under carefully controlled environmental conditions to ensure uniform and safe fruit maturation. Typically, the temperature is maintained between 18 and 24 °C, while the relative humidity is regulated at approximately 85–95% to prevent moisture loss and maintain fruit quality. In addition, ethylene gas is introduced at controlled concentrations to stimulate the natural ripening process. By replicating the physiological conditions of natural ripening, this method promotes consistent colour development, texture softening, and flavour formation, and it is considered safe when implemented under proper regulatory standards and monitoring systems.[1].

Ethephon-Based Ripening

Ethephon is an ethylene-releasing compound that decomposes under neutral conditions to produce ethylene gas along with chloride ions and phosphate residues. Because the released ethylene acts as a plant hormone that accelerates physiological maturation, ethephon is widely applied either by spraying onto harvested fruits or by incorporation into controlled ripening systems to initiate and regulate the ripening process. [1].

Calcium Carbide Method (Illegal in Many Countries)

Industrial calcium carbide reacts with moisture to produce acetylene gas, which acts similarly to ethylene in triggering ripening [1]. This method is cheap but unsafe and banned in several regions.

HEALTH HAZARDS AND SIDE EFFECTS

Toxicity from Calcium Carbide

Calcium carbide exposure may cause:

- Reduced oxygen supply to brain
- Neurological symptoms
- Mucosal irritation
- Vomiting and abdominal disorders

These effects arise partly due to acetylene gas and toxic impurities [1][3].

Studies report both acute and chronic toxic consequences from carbide-ripened fruit consumption [3].

Respiratory and Gastrointestinal Effects

Consumption of improperly ripened fruits may lead to:

- Stomach irritation
- intestinal dysfunction
- neurological disturbances
- headaches and dizziness

Long-term exposure has also been linked with neurological complications [4]

Nutritional Quality Changes

Artificial ripening can influence:

- Sugar composition

- flavour development
- vitamin levels
- shelf stability

Poorly controlled ripening often results in inferior taste and shorter shelf life [2].

ADVANTAGES OF ARTIFICIAL RIPENING

Despite risks, controlled artificial ripening offers several benefits:

Reduced Post-Harvest Loss

Harvesting fruits before full ripeness reduces mechanical damage during transport [2].

Uniform Market Appearance

Artificial ripening ensures consistent colour and texture.

Supply Chain Control

Allows synchronized fruit availability throughout seasons.

Improved Economic Returns

Controlled ripening increases market value and reduces spoilage.

SAFER ALTERNATIVE RIPENING TECHNOLOGIES

Controlled Ethylene Ripening Systems

Modern ripening chambers provide:

- automatic gas regulation
- controlled temperature
- humidity monitoring

These systems replicate natural ripening safely.

Natural Ethylene-Producing Methods

Traditional techniques include:

- storing fruits with naturally ripe bananas
- enclosed straw storage

These release endogenous ethylene gradually.

Post-Harvest Biological Treatments

Emerging research includes:

- alginate-based coatings
- plant-derived oligosaccharide treatments
- non-destructive ripeness monitoring sensors

Such approaches aim to preserve fruit quality without toxic chemicals [5].

REGULATORY CONSIDERATIONS

Many countries restrict the use of calcium carbide due to safety concerns.

Regulatory agencies recommend:

- approved ethylene systems
- certified ripening chambers
- monitoring of chemical residues

Improper use of ripening agents remains a major food-safety challenge globally.

FUTURE PERSPECTIVES

Future research in artificial fruit ripening should concentrate on the development of smart ripening sensors capable of real-time monitoring of fruit maturity and environmental conditions, along with automated ethylene release systems that can precisely regulate gas exposure to ensure uniform ripening. Attention should also be given to designing biodegradable ripening regulators that minimize chemical residues and environmental impact, as well as implementing blockchain-based supply monitoring systems to enhance traceability and quality assurance throughout the distribution chain. The advancement of such safe and intelligent ripening technologies will be essential for building sustainable and reliable food systems.

CONCLUSION

Artificial fruit ripening is a critical post-harvest practice in global agriculture. While regulated ethylene-based technologies provide safe and efficient ripening, the continued misuse of hazardous chemicals such as calcium carbide presents significant health risks. Improved regulatory enforcement, adoption of controlled ripening chambers, and development of biological alternatives are essential to ensure consumer safety and maintain fruit quality.

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