Agri Articles

(e-Magazine for Agricultural Articles)

Volume: 03, Issue: 03 (MAY-JUNE, 2023)

Available online at http://www.agriarticles.com

Role of Ethylene in Fruit Ripening

(*Preeti Yadav, S.K. Dhankhar, RamMehar and Sandeep Dagar)

CCS Haryana Agricultural University, Hisar-125004, Haryana, India

*Corresponding Author's email: yadavpreeti77413@gmail.com

Abstract

Ripening is the process by which fruits attain their desirable flavour, quality, colour, palatable nature and other textural properties. Fruits are of two types based on ripening behaviour *viz.*, climacteric and non-climacteric fruits. Fruits show a dramatic increase in the rate of respiration during ripening and well respond to exogenous ethylene for ripening are climacteric fruits while Fruits do not show an increase in Respiration and ethylene production rate during ripening and do not respond to ethylene for ripening are non-climacteric. Several changes occur during ripening which includes an increase in rate of respiration, change in colour, chlorophyll degradation, hydrolysis of starch into sugar, cell wall degradation, textural softening, reduction in organic acids and production of volatile aromatic compounds. Tomato is a model plant for ripening as a demonstration of the requirement for ethylene in fruit ripening came from the analysis of the never-ripe mutation in tomato. This mutation completely blocks the ripening of tomato fruit. Molecular analysis revealed that never-ripe was due to a mutation in an ethylene receptor that rendered it unable to bind ethylene. These experiments provided unequivocal proof of the role of ethylene in fruit ripening. Hormones interact with each other to perform a physiological process like auxin inhibits ethylene-mediated ripening while ABA and cytokinin promote ripening.

Keywords: Ethylene, ripening, climacteric, respiration rate, model plant

Introduction

Fruit is the ripened ovary enclosing seeds inside it. Ripening is the process by which fruits attain their desirable flavour, quality, colour, palatable nature and other textural properties. It makes fruit acceptable for consumption. The fruit becomes sweeter and softer on ripening. The ripening of fruits is a unique coordination of various biochemical and developmental pathways regulated mainly by ethylene**.** Ripening is associated with conversion of starch to sugar, change in colour, shape, size and odour. Fruits are of two types based on ripening behaviour *viz.*, climacteric and non-climacteric fruits.

1. **Climacteric Fruits-** Fruits show dramatic increase in the rate of respiration during ripening and well respond to exogenous ethylene for ripening. *eg*. Tomato, Brinjal, Muskmelon, Apple, Banana, Mango, etc.
2. **Non - Climacteric Fruits-** Fruits do not show an increase

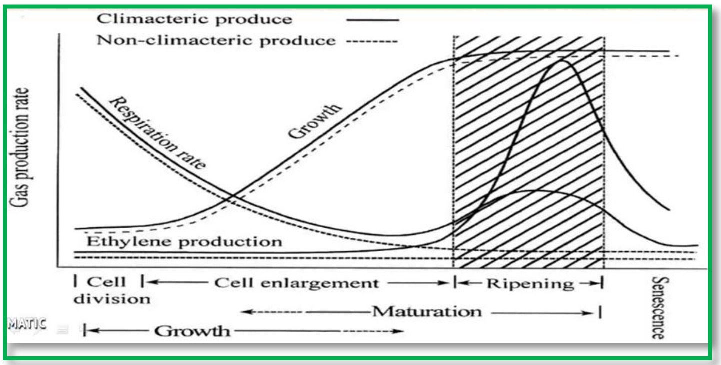
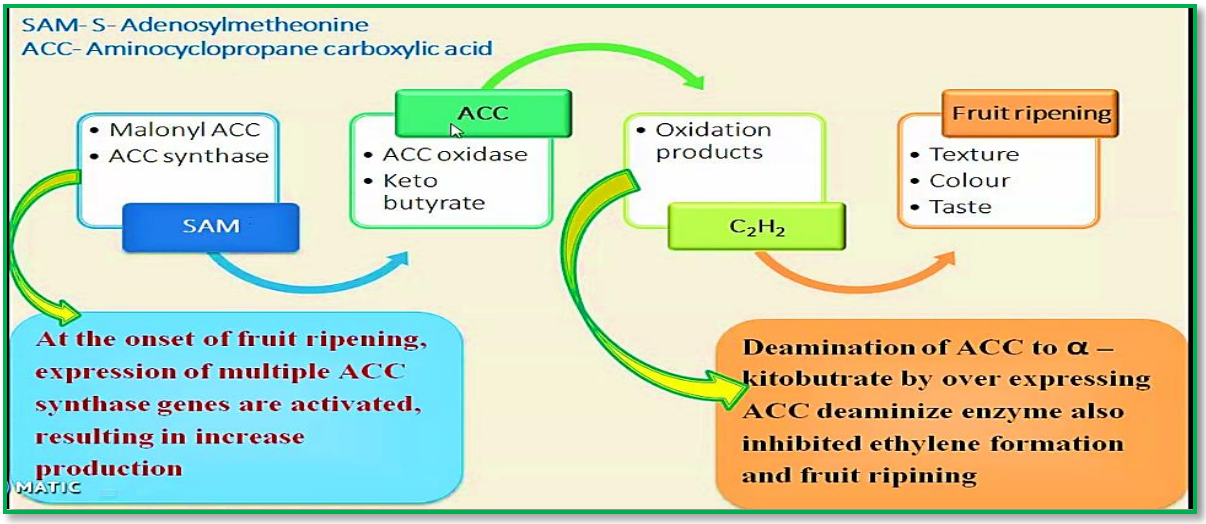


Fig-1 Ripening Graph of Climacteric and Non-Climacteric Fruits

in Respiration and ethylene production rate during ripening and do not respond to ethylene for ripening. *eg*. Watermelon, Cucumber, Pumpkin, Citrus, Grapes, Pineapple, etc.

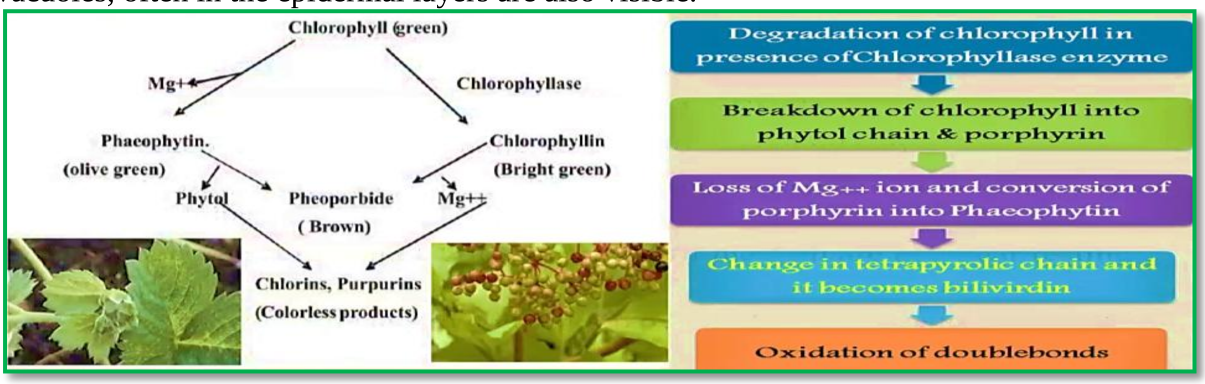
Mechanism of Ripening



Changes occur during Ripening

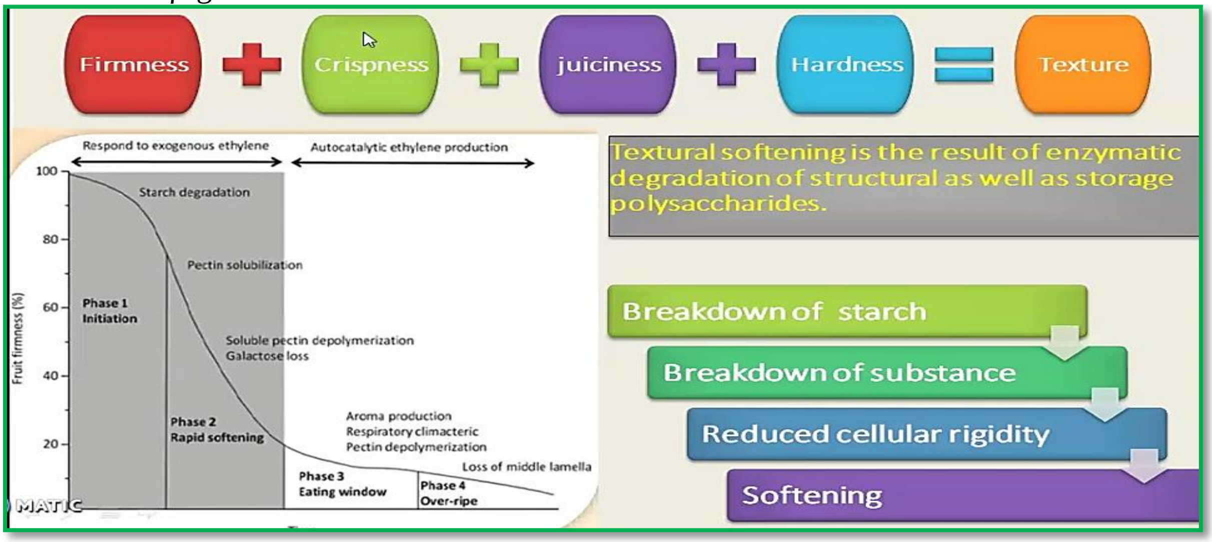
Increase in rate of respiration: Respiration declines gradually throughout the season until several weeks before the fruit ripens. Just before ripening metabolic functions of the fruit are in the near-resting stage. Movement of fructose from the vacuole to the cytoplasm and conversion of stored organic materials convert to simple end products + energy (carbohydrates, proteins, fats) take place during ripening. Glycolysis and Pentose phosphate pathway are the two pathways for the conversion of starch or sucrose to glucose-6-P. When unripe climacteric fruits are treated with exogenous ethylene, the onset of the climacteric rise is hastened accompanied by an increase in oxygen uptake. When non-climacteric fruits are treated in the same way, the magnitude of the respiratory rise increases as a function of the ethylene concentration, but the treatment does not trigger the production of endogenous ethylene and does not accelerate ripening.

Colour Change and degradation of chlorophyll: Pigments, responsible for skin & flesh colours, undergo changes during fruit ripening. Carotenoids may be synthesized during the developmental stages of the plant, but they are masked by the presence of chlorophyll. Degradation of chlorophyll makes the carotenoid pigments visible. Anthocyanins, water soluble pigments, provide many of the red- purple colour of fruits, found mainly in the cell vacuoles, often in the epidermal layers are also visible.

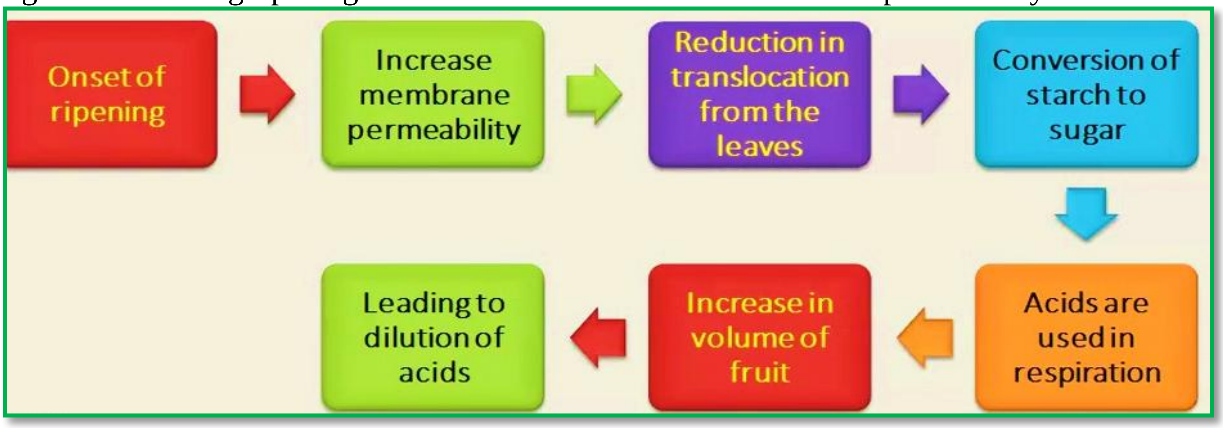


Hydrolysis of starch to sugar: During ripening, starch is hydrolyzed to simple sugars. Starch is broken down to sucrose by the action of sucrose phosphate synthetase. Sucrose is then converted into non-reducing sugars by acid hydrolysis. This conversion affects both the taste & the texture of the produce. During the early part of fruit ripening, sucrose is the predominant sugar, but in later stages, glucose & fructose predominate.

Cell wall degradation and textural softening: Plant cell wall are composed of complex polysaccharides, proteins, cellulose, hemicellulose and pectin substances. Due to the activation of certain enzymes soluble pectin increases which results in a decrease in firmness and wall degradation. Cell wall degradation involved depolymerization and de-esterification. Enzymes responsible for cell wall are hydrolases, pectin esterase, polygalacturonase, cellulase and β-galactosidase.



Production of Aroma Volatiles and reduction in organic acid content: Aroma volatiles includes esters of aliphatic alcohols and short-chain fatty acids. In fruits, major volatile compounds are isoamyl acetate, aldehydes and terpenoid compounds. Volatiles originate from proteins carbohydrates, lipids and vitamins. Taste is provided by many non-volatile components, including sugar and acids present in fruits. Short-chain unsaturated aldehydes and alcohols (C3-C6) and esters are important contributors to the aroma**.** The total organic acid (malic + citric + quinic) decreases with ripening of fruits. The decline in the content of organic acid during ripening is the result of an increase in membrane permeability.



Tomato: A Model Plant for ethylene-mediated fruit ripening

Several biochemical changes occur during the transition from unripe to ripe fruit, including ethylene biosynthesis and perception. The trials in which ethylene biosynthesis was suppressed by expression of an antisense version of either ACC synthase or ACC oxidase in transgenic tomatoes provided the final confirmation that ethylene is essential for fruit ripening. The absence of ethylene production in these transgenic tomatoes fully prevented fruit ripening, which was restored by the addition of exogenous ethylene. The investigation of the tomato never-ripe mutant provided additional evidence of the need for ethylene in fruit ripening. This mutation, as the name says, completely prevents tomato fruit from ripening. Molecular investigation found that never-ripe was caused by a mutation in an ethylene receptor, rendering it unable to bind ethylene. These trials proved unequivocally that ethylene plays a function in fruit ripening. Tomato ethylene receptors, LeETR4 or LeETR6, were significant regulators of fruit ripening. At least two separate mechanisms influence gene expression during ripening:

1.) An **ethylene-dependent pathway** includes genes involved in lycopene and aroma biosynthesis, respiratory metabolism, and ACC synthase. Unripe fruits give off low quantity ethylene and are unaffected by external ethylene. As a result, ethylene treatments do not promote fruit ripening. Fruits are classified as system 1 when they produce little ethylene and their tissues are unaffected by exogenous ethylene. ACS6 and ACS1 genes control ethylene production at this stage.

2.) A developmental, **ethylene-independent pathway** includes genes encoding ACC oxidase and chlorophyllase. At the start of ripening, ethylene production rises, causing an increase in autocatalytic biosynthesis. When exposed to exogenous ethylene, these fruits show a burst of ethylene production and mature faster. These two mechanisms are hypothesised to explain ethylene's auto-inhibitory action during vegetative development and ethylene's auto-stimulatory effect during ripening.

Interaction between Ethylene and Other Hormones during fruit ripening

Ethylene and Auxin: Auxins are involved in fruit development and inhibit ripening. The exogenous application of auxins in different fruits delayed the senescence and ripening. AUXIN RESPONSE FACTOR 2A (ARF2A) has been recognized as an auxin signalling component and able to control ripening.

Ethylene and Cytokinin: The exogenous application of cytokinin or compounds with cytokinin-like activity increased the sugar content of fruits and induced earlier ripening. Spray application of using N-(2-chloro-4-pyridyl)-N'-phenyl urea (CPPU), a diphenyl urea derivative cytokinin, increased the starch content and induced faster fruit development in many fruits.

Ethylene and Abscisic acid: ABA can be a trigger for ethylene production and influence fruit ripening. The exogenous application of ABA increases ethylene biosynthesis. ABA application increases all hydrolases, which can enhance the softening, except polygalacturonase activity. Recently, it has been reported that an ABA Stress Ripening (ASR) transcription factor acts as a downstream component of a common transduction pathway for ABA and sucrose signals during fruit ripening.

Conclusion

Ethylene a gaseous plant hormone has an important role in fruit ripening by which fruits attain their desirable flavour, quality, colour, palatable nature and other textural properties. Ethylene is produced in tissue undergoing conversion from vegetative to reproductive and senescence stage. Its mode of action is autocatalytic. Ethylene stimulates fruit ripening by the breakdown of chlorophyll and synthesis of other pigments, softening of cell wall and hydrolysis of starch into sugar. In fruits such as tomato there is a sharp rise in respiration known as respiratory climacteric whereas non climacteric fruit are insensitive to ethylene. Tomato is a model plant for ripening as a demonstration of the requirement for ethylene in fruit ripening came from the analysis of the never-ripe mutation in tomato. Ethylene interacts with other hormones during ripening, auxin inhibit ripening while ABA and cytokinin promotes ethylene mediated fruit ripening.