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# THE MATURITY AND RIPENESS PHENOMENON WITH REGARD TO THE PHYSIOLOGY OF FRUITS AND VEGETAGLES: A REVIEW

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**Abstract:** *Fruits and vegetables being highly perishable is, however a rich source of nutrients, they need extra care during handling, transportation and even during harvest. Maturity of the produce is that phase of organic product advancement, which guarantees fulfillment of greatest palatable quality toward the consummation of the ripening process because ripening is the phase of most extreme consumable quality accomplished by the natural product following harvest. Certain measures are opting for in order to delay ripening or to regulate this process such as chlorine, retardants, and hot water treatment. Also, various advanced techniques such as clod plasma and nanotechnology have been used to indicate maturity and its relation to fruit and vegetable physiology in the system. This review article summarizes the understanding of the concept of maturity and ripeness, their measurement, and it's the advanced techniques used in food processing.*

***Key words:*** *Harvest, Maturity, Maturity indices, ripening.*

## 1. Introduction

Fruits and vegetables (FV) are the supplier of fundamental nutrients. Being exceptionally perishable, 20-40% of the bulk of produce goes to waste ; from the season of gathering till they reach the customers. World production of vegetables added up to 486 million tons, while that of fruits achieved 392 million tons. Around 2% of this goes for analysis and processing, while more than 25% is ruined because of poor handling practices and storage, and the rest is consumed fresh. Mangoes, grapes, mushrooms are sent out to the United Kingdom, the Middle East, Singapore and Hong Kong.Onions, potatoes and green vegetables like okra, bitter gourd, and green chilies have an equally great export potential. Fruits and vegetable are those living life forms that keep on changing even after harvest. While some of these progressions are desirable, the rest are not, and may lead to undesirable changes. Cultivators must be aware of efficient measures to decrease unsatisfactory changes, and diminish postharvest damages. Fruits and vegetable are exceptionally perishable however they are

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the most most vital items for human eating routine because of their high nutritious value [2]. They are the cheapest source and often act as protective food supplied in fresh or processed form during the time for human utilization [20].

### 2.1. Role of Production Practices and Pre-harvest Practices

Processing and production practices tremendously affect fruits and vegetables on their harvest, post-harvest (PH) quality and shelf life. For instance, carrots cultivated on muck soils do not hold up as long as carrots developed on lighter, upland soils. Lettuce harvested during a rainy period does not behave well when shipped and there is an increase in losses [12]. Manure should not be applied to an area immediately adjacent to a field approach harvest maturity. Equipment that had been used to apply manure to one field should be cleaned before moving it to another field in production. Irrigation with a water body from a farm pond used by livestock should be avoided. As shown in a literature review, the dominant elements affecting the production and quality of vegetables are cultivars, soil plant systems and fertilizer practices, and also some other environmental factors i.e., light intensity, temperature, relative humidity and rainfall during production [21]. Higher concentrations of vitamin B are present in grown plants. The quality of carrots is perceived as decreasing because of the result of the extensive use of mineral fertilizer, but are not affected by measuring fertilizers, whereas an increased use of compost manure quality of carrots.

### 2.2. Post-Harvest Technology

Post-harvest technology plays an enormous part in the food industry like legitimate packaging, transportation and storage lessens the PH losses [7]. Preparing and conservation innovation ensures availability of overabundant foods grown from the ground amid the off season. It enforces the need to enhance the food safety and reinforce country's nourishment security. In addition, it supports fare of agricultural commodities as preserved and value added products [7]. Also pH affects the product detrimentally, for example, the dry matter content (energy supply) is diminished with time due to the continuation of biological processes within the product. Vitamin C content declines with time after harvest, little might be left in green leave a few days. Cooking partially obliterates vitamins C and B1. Peeling may cause noteworthy loss to food value, particularly in Irish potatoes and numerous other root crops where the protein and vitamin content is found promptly under the skin. Minerals, including exchange components are broken up out in cooking water, which is usually discarded resulting in loss of nutrients [5].

### 2.3. Maturity and Ripening

Fruit and vegetable, harvested too soon lack in flavor and may not age properly, while if they are harvested too late lead to no market return. Vegetables are harvested over an extensive variety of physiological stages, depending upon which part is consumed as food.The level of maturity really helps in determination of storage measures, estimation of shelf life till it remains usable usability, choice

of handling operations for value addition and so on. The maturity has been partitioned into two classifications, i.e. physiological maturity and horticulture maturity. Physiological maturity, is the phase when a natural product is able enough to develop and ripen when it is harvested i.e. for eating or handling [25] Horticulture maturity, it alludes to the phase of advancement when plant and plant part has the pre-necessities for use by shoppers for a specific reason i.e. ready to harvest.

Maturity index is utilized to distinguish the exact harvest time and to examine the connection amongst maturity and flavor quality. Guarantees a satisfactory postharvest shelf life and encourages planning of harvest and packaging operations. Maturity, is that phase of fruits and vegetable advancement, which guarantees fulfillment of greatest palatable quality toward the consummation of ripening process, though development is the formative procedure by which the natural product achieves development. It is the transient period of improvement from close consummation of physical development to achievement of physiological development. Ripe, is the state of most extreme consumable quality accomplished by the natural product following harvest [25]. Just fruits and vegetable which winds up plainly develop before harvest can end up plainly ripened.

Immaturity brings about inferior quality and higher opportunities to shivellage and mechanical harms [14]. Matured fruits and vegetables are grown to achieve their best quality just when permitted to ripen on plants. Muskmelons have next to no starch holds and their sugar content increments are less than (<15%) after collect. It is essential to gather melons, honeydews, and different muskmelons at a completely developed to partially ripe stage when enough sugars have collected in fruit. Ripening muskmelons mellow, change in color (loss of green color and appearance of yellow color), and increment in aroma intensity, and achieve great eating quality. Melons which are picked partially ripened produce enough ethylene to finish their ripening and PH ethylene treatment isn't required.

## 3. Maturity Indices and its Components

Maturity of fruits and vegetable can be evaluated by their final shape and size at the season of harvest. FV shape might be utilized as a part of a few occasions to choose maturity. The completion of cheeks nearby pedicel might be utilized as a manual for development of mango and some stone natural products [24]. The natural product shape might be utilized as a part of a few examples to choose development. Loss of green color of many natural products is an important manual for development. Target estimation of color is conceivable utilizing an assortment of reflectance or light transmittance spectrophotometer. Although, the human eye is considered as an evaluator for color, but results often vary considerably due to human differences in color observation and perception. Instrument that try to measure slight divergence in color precisely and can be automated in the packing line is popularly known as a Color Difference Meter [25]. Penetrometer is used to measure the firmness of fruits such as apple, pear, peach, plum, etc. This instrument measures the pressure that is

necessary to force a plunger of specified size into the pulp of the fruit. Such pressure is measured in pounds and kilograms force [24]. Apart from color and size changes, changes in specific gravity are also observed with change in maturity. Fruits and vegetable are in a tank of water; those that float will be considered as less matured than those that sink, as specific gravity increases with increase in maturity. Other chemical measurements such as total soluble solids (TSS) measured using a refractometer, acidity by titration using 0.1N NaOH, etc. also assessed.

The temperature of the juice is a basic factor for preciseness, since all materials expand when heated and turns out to be less dense. Good quality refractometers have an inbuilt temperature compensation capability. For enduring natural product crops developed in regular atmosphere which are pretty much uniform from year to year, calendar date for harvest is a reliable guide for commercial maturity. Such harvesting criteria can be produced by the cultivators depending on their experiences. Ripening includes a progression of changes happening amid beginning periods of senescence of fruits in which structure and composition of unripe fruits are altered to the point that it ends up noticeably satisfactory to eat. Ripening is a complex physiological process bringing about softening, coloring, sweetening and increment in smell mixes with the goal that aging natural products are prepared to eat or process [14]. The related physiological or biochemical changes are expanded rate of respiration and ethylene generation, loss of chlorophyll extension of cells and transformation of complex metabolites into basic particles. Senescence can be expressed as the last stage in the ontogeny of the plant organ amid which a progression of basically irreversible occasions happen which at last prompts cell breakdown and demise

### 3.1.1. Ripening Facilities

Fruits and vegetable are allowed to age in extraordinarily manufactured rooms normally called as ripening rooms that must be gas tight, have frameworks for controlling stickiness and groupings of $CO_2$, $C_2H_2$, and have hardware to control item temperature [14]. These rooms are normally protected, however they regularly work at temperature range 15-21˚ C. This procedure is constantly done at RH over 85%. Ripening is controlled on the premise of natural product mash temperature. It ought to be measured amid each cycle with a calibrated pulp thermometer. At the same time, room air temperature should likewise be consistently checked with adjusted pulp thermometer. The refrigeration framework must be outlined in such an approach to contain 85-95% RH. Air humidity beneath this range will prompt extreme product weight reduction. Humidifiers are expected to add moisture to the air in rooms. Air humidity ought to be occasionally observed with a wet and dry bulb psychrometer. Air flow is required to disseminate $C_2H_s$ gas to the product and to include or expel heat from the product amid ripening cycle.

### 3.1.2. Ethylene and its Function

Ethylene, assumes a part in the postharvest life of numerous agricultural harvests. It is a drab gas with a black out sweetish notice that is the normally delivered as ripening hormone of some

fruit. Fruits are classified further on basis of ethylene generation: climacteric and non-climateric fruits. Climacteric items, produce ethylene as they ripen, as well as an expansion in respiration is observed whereas non-climacteric items has no ethylene production as they mature.. The most widely recognized known utilization of ethylene is to trigger ripening is a few harvests, for example, bananas and avocados. The use of ethylene at a controlled rate implies that these items can be displayed to the client as "ready to eat". The concentration of ethylene required for the ripening of various items differs. The focus connected is inside the scope of 1 and 100 ppm. The time and temperature of treatment additionally impacts the rate of ripening with fruits being ripened at temperatures between 15 to 21˚C and relative humidity of 85 – 90 %. Albeit controlled ripening is the significant PH utilization of ethylene it can likewise be connected pre-harvest to advance postharvest benefits. The substance, Ethephon produces ethylene and is connected in the field [17]. The significant explanation behind the loss of shelf life is that ethylene exposure expands the rate the product ages. In green tissue such leafy vegetables and cucumbers ethylene animates the loss of chlorophyll or green color and furthermore elevates the susceptibility of the product to rots. Lettuce is likewise defenseless to ethylene. It experiences a distinctive issue, called russet spotting because of exposure to ethylene. The indications of russet spotting are dim darker spotting of the mid-ribs of lettuce clears out. Ethylene can likewise advance growing of potatoes and toughening of asparagus. Delicate/sensitive plants ought to be treated with an ethylene inhibitor, for example, silver thiosulfate that keep flower drop coming about because of ethylene introduction and extraordinary care ought to be brought to maintain a strategic distance from storage with ethylene producing products. Ethylene can likewise be evacuated by utilizing various compound procedures. The customary technique had been to utilize potassium permanganate or Purafil. Potassium permanganate responds with ethylene to deliver $CO_2$ and $H_2O$.

### 3.2. Measures to Delay Ripening

#### 3.2.1. Waxing

Visual parameters of fruits are an intense trademark for good economic growth of the business sector and numerous customers demands for shiny or glossy appearance which is the reason different sorts of waxes and eatable surface coatings are used. Waxing is prescribed just for good quality items since it doesn't enhance the nature of inferior ones. This is done to supplement regular wax on the surface of an item, which often gets evacuated during cleaning and packaging. Waxing means applying a thin layer of consumable wax to the external surface of the item. It provides with an enhanced appearance, less moisture loss and shriveling, decreased postharvest rot, and a longer shelf life. It discourage unwanted textural changes and firmness. Weight reduction of fruits and vegetables is considered unwanted from a financial point of view as farmers sell on weight basis which in turn will get less monetary come back with high rate of weight loss.

Waxing acts as a barrier against the passageway of parasitic and bacterial pathogens into the product as waxing

makes a hydrophobic (non-water compatible) surface which eliminates chances of pathogen. Fungicide can be added to the wax to give safety against rot. Waxing creates modified atmosphere altered environment inside the product itself in which oxygen content decreases and $CO_2$ level increases. This situation leads to decreased respiration rate and elevated post-harvest life. Waxing reduces chances of chill injury in storage of chill-injury sensitive commodities by marginally lowering temperature without causing harm.

Waxing can be carried out by roller brushing, dipping/submerging and manual rubbing. Additionally, waxing adds to the item cost and delays the product to enter the market. Inappropriate waxing may lead to surface burn to the item. Wax brightens the surface if subjected to high temperature and once in a while waxing stimulates anaerobic respiration as well.

### 3.2.2. Implementation of CA Storage and MAP

CA storage and MAP is removal or addition of gases resulting in an atmospheric composition different from that of normal air. Levels of $CO_2$, O2, $N_2$, ethylene, and metabolic volatiles in the atmosphere are manipulated in such a manner which benefits the intact product. CA storage basically refers to keeping the product at low $O_2$ and elevated $CO_2$ amounts with an appropriate levels of temperature and RH. MAP (modified atmospheric packaging) produce can be stated as a product which is enclosed in polymeric layered film that is allowed to generate its own atmosphere (passive MAP) or air of known composition which is flushed into the bag (active MAP). Characteristics of the film to be used in appropriate atmosphere depends on rate of gas / vapor transmission in order to prolong the shelf life of the produce.

### 3.2.3. Retardents and its Effectiveness

Retardants are those synthetic substances that are utilized to hinder, for a particular time period, the elongation of stem and shoots, without irreversibly obstructing the fundamental metabolic changes in plants. Retardants give taste, flavor, and color in a manner to enhance the quality and the cost estimation of the items. Such measures can impact the acidity, the sugar content, proteins, vitamins, minerals, etc. Retardants do not cause contamination and hinderence in availability of nutrient content of products as it is utilized as a part per million (ppm) [16].

The 2-chloroethylphosphonic acid (CEPA) is the most significant retardant, due to its wide activity region and effectiveness as plant ripening controller [23]. CEPA alters plant development and metabolism by releasing ethylene (a phytohormone) from root, bloom and other tissues. It can be utilized to anticipate holding up in oats, maize and flax, to accelerate pre-harvest ripening of soft fruit, tomatoes, sugar beet, grub beet, espresso and numerous different items, to encourage production of fruits and vegetables and to quicken post-harvest ripening. It is considered non-toxic to humans and animals.

### 3.2.4. Chlorination as a Disinfectant

Chlorine, inactivates pathogenic bacteria, fungi, viruses, cyst, and other microbes related with seed, cuttings, irrigation water, farm or horticulture

implements and equipment's, contact surfaces, and human contact with fresh produce. Chlorine is basically utilized as a part of the type of calcium or sodium hypochlorite. From recent years, chlorine was misused in high amount as it was expected no residues are left after its application [4], [19]. Chlorine, sometimes, does not completely oxidize by organic materials and create an unwanted result, for example, chloroform ($CHCl_3$) or different trihalomethanes are suspected to have cancer-causing potential at high doses [18]. At high pH, chlorine reacts with organic nitrogen-based materials to create mildly toxic chloramines. Agricultural chlorine is industrially accessible in three structures that have been affirmed for utilization by the U.S. Environmental Protection Agency (EPA) and by individual states, for example, California (California Department of Pesticide Registration). $Cl_2$ lessens the pH of water to below 6.5 [3]. Calcium hypochlorite, which is a typical source of chlorine is utilized for purification purposes and produce process water. It is accessible as a granulated powder, compressed tablets. Additionally, Calcium hypochlorite, apart from disinfection advantages, is accounted to enhance the shelf life [6] and disease resistance of FV by adding calcium to the cell wall. Sodium hypochlorite is largely favored for small scale businesses and is more costly than different types of chlorine due to the additional shipping cost of the water-based formulations. Chlorine dioxide is another yellow to red gas and has 2.5 times more oxidizing capability of chlorine gas [3]. Disinfecting power of chlorine dioxide is moderately constant within a pH range of 6 to 10. It is powerful against most microorganisms at concentrations of 3 to 5 ppm in clean water.

### 3.2.5. Degreening

Degreening is where the green chlorophyll colors in the peel are separated; yellow and orange xanthophyll; carotenoid colors are composed. In citrus fruits, this normal procedure is stimulated by exposing the FV to 10 to 20 parts per million (ppm) of ethylene gas under controlled conditions of temperature, ventilation and humidity, in specially designed degreening rooms, controlled by proficient administration. Degreening has been proved to be uneconomic unless and until large amounts of FV can be dealt with at one time.

### 3.2.6. Hot Water Treatment (HWT)

The utilization of synthetic chemicals on fresh harvested produce is becoming harder because of the concerns about human health risks related with the chemical deposits and residues especially in the diet of children. HWT is to control postharvest diseases of citrus fruits by maintaining a strategic distance from deposits and transfer material by chemical treatment [10]. The chances of fruits and vegetables to postharvest diseases elevates during prolong storage because of physiological changes that empower pathogens [8] in FV. Heat treatments influence the pathogen as well as can beneficially affect the FV. For instance, if citrus fruits are held at 35˚C out of a humid environment (95-99% RH), mould infection does not occur and prevents decay. Heat treatments as either moist hot air or heated water dips [8] are preferred. Significant favorable

advantages of hot water treatment is to control surface infections and also those infections that have penetrated the skin, without leaving any chemical residue on the product. The vital advantage of HWT (or air) is that they can kill the organisms on and beneath the FV surface. Hot water might be provided to FV from numerous points of view: by hot water dips, vapor heat, hot dry air or by hot water rinsing and brushing. Postharvest fungicides just kill surface pathogens. The heat may influence ripening process by lowing it, which could be bad or good [19].

Treatment with hot water has turned out to be progressively acknowledged commercially, and relevant changes have been made with the application of brushing [13]. It not just slows the ripening of climacteric FV to acquire longer shelf life yet in addition, decreases the affectability of subtropical fruits to low temperature [9]. Hot water immersion, high temperature forced air and vapor heat are powerful options in contrast to methyl bromide fumigation for FV which are susceptible to heat damage, especially tropical and subtropical commodities, with demonstrated viability against pests and diseases.

**4. Advance Techniques used in PHT**

Keeping in mind the end results to diminish PH losses, curing procedures and surface drying strategies are optimized. Curing is a characteristic process used in sweet potato and Irish potato that strengthens damaged regions by shaping a corky layer that protects against water losses and contamination by decay organisms. Products for example, onion and potato when set in long term storage in temperate countries, tend to sprout and eventually rot. Sprouting can be avoided by utilizing varieties with long dormancy periods [4], [9], [22], appropriate curing and the utilization of synthetic grow suppressants, for example, 'Tecnazene' (TNCB), 'Chlorpropham' (CIPC), or other restrictive chemicals.

The best cure is evasion by avoiding storage under high humidity, for example, in unventilated plastic sacks, and not exposed to light for a given periods. Fungi, a typically essential specialist in deterioration of fresh produce is conceivable by utilization of fungicides at dose rates which do not harm the produce or customers. If FV is to be marketed soon and consumed quickly just after harvest then fungicides may not be essential or their utilization might be uneconomic. Fungicides are aqueous solution or suspension that are washed off before packing. Washed fruits and vegetable are allowed to drain off abundance water before fungicide is applied else dilution may take place. Thus fungicide may not work appropriately, leading to money loss and time. Basic strategies for use of fungicides are spray or mist, drenching, dipping, etc. Ethanol being a volatile compound, normally delivered from plant tissues under anaerobic conditions [15], [24]. A few natural products are ordinarily ethanol producers under aerobic conditions. Ethanol is viewed as a successful inhibitor to ripening and gives slightest phyto-toxic effects [11]. In a contrary pattern to ethanol inhibitory effect on tomato fruit ripening, ethrel (2-chloroethan-phosphonic acid) is monetarily utilized for upgrading tomato fruit ripening [1].

### 4.1. Nanotechnology in PHT

Nanotechnology is expressed as an outline, portrayal, generation, and utilization of structures, gadgets, and frameworks by controlling the shape and size at the nanometer scale. *Botrytis cinerea* which causes grey mold disease which is considered as an imperative post-harvest pathogen all around the globe. It incites decay on an extensive number in economically essential fruits and vegetable during growing season and post-harvest storage. It is additionally a real hindrance to long distance transportation and storage. Fungicide treatments can be utilized to maintain a strategic distance from losses. Subsequently, in developing countries more consideration is gained by environmental friendly technologies for fresh fruits and vegetable industry. The utilization of nanoscale fillers is prompting the use of polymer nano-composites. Nano-composites offer additional advantages like low density, transparency, good flow, better surface properties and recyclability. Later a long time, nanomaterials have gained attention for their potential effect on an extensive variety of ventures and markets. Some application of nanobiosensors including: Virus recognition using antibody sensor arrays on self-assembled Nanoscale Block Copolymer Patterns, the Detection of Food-Borne Toxins with multifunctional nanoparticles; development and characterization of nanocomposite materials for the detection of pore-forming toxins; molecular imprinted polymers for plant and insect virus recognition.

### 4.2. Cold Plasma in PHT

Microorganisms and pathogens, a reason of spoilage are a noteworthy issue concerning the food processing industries as they unfavorably affect the health and economy. To kill different microorganisms, pathogens and spores, thermal inactivation procedures are practiced, for example, pasteurization, autoclaving, ohmic heating, canning and steam sterilization. All these methods are effective and efficient; however, they possess numerous side effects viz. nutritional loss, effect sensory properties and degrade functional properties of the food. In order to overcome the side effects, some novel cold processing technologies are introduced i.e., pulse electric field (PEF), high hydrostatic pressure (HPP), irradiation, ultrasound etc. Although, these processes acquires specialized equipment's, trained personnel and are relatively very expensive.

Cold plasma is one of the most novel technologies which is used for inactivation of microbes. Plasma gets produced when an inert gas comes in contact with electricity; reactive substance composed of charged particles, free radicals, photons and various radiations are formed. This whole formulation is known as plasma. Plasmas are produced at an ambient temperature that is referred to as cold plasma having a temperature of 30-60°C, which is generally preferred in the food processing industries.

Cold plasma technology (CPT) has become a successful study for effective inactivation of microbes like *E. coli* from fresh produce, *Aspergillus parasiticus* and *Penicillium* sp. From seeds of various

vegetables, legumes and cereals, *Erwiniacarotovora* in potatoes, *Listeria monocytogenes* from plastic trays, paper cups and aluminum foil, etc. Other than decontamination purpose, CPT works in various other phenomena such as effect on seed germination and retarding browning reaction.

CPT has also shown a great potential towards the novel processing fresh foods, processed food products and packaging. This technology helps in processing of heat liable foods while retaining the physico-chemical, textural and functional properties of the food. Cold plasma is used in minimal processing or acts as a chlorine replacer during washing to decontaminate fruits, vegetables and leafy vegetables from pathogens.

## 5. Conclusion

Post-harvest physiology of fruits and vegetable is generally dependent on ripening stage, which proceeds with their biological procedures after gathering them. Leafy foods being very perishable yet rich in nutritional supplements require additional care and handled precisely during transportation and even immediately after cutting from parent plant. Maturity indices, ethylene production, and ripening after parent plant growth are the important factors which are required to taken care of before fruits and vegetables processing. Waxing, CA storage and application of MAP on FV not only increase the shelf life, but also protect them from various physicochemical barriers. Chlorine disinfection, degreening and hot water treatment have different effect on ripening process of fruits and vegetable. Whereas advance technology such as cold plasma and nanotechnology can be used as indicators of maturity and ripeness. The above methods can be selected to defer aging or to control degradation process in fruits and vegetables and thus can enhance their shelf life.

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