Study regarding the process of ripening have fascinated plant physiologists and biochemists in a number of ways. Some considered it as a workable system to understand the process of senescence and its regulation, while others considered it in terms of hormonal and chemical control of ripening. To the laymen consumer, its importance lies in the quality of fruits. This quality includes appearance, texture, flavour and nutritive value. An understanding of the process of ripening is required, so as to develop new technologies for the improvement of the quality of fruits and prevent wastage due to improper handling, transportation and microbial spoilage.

The botanical role of fruits can be attributed to the dispersal of seeds, striking colors, sweet and juicy flesh and the distinctive aroma. The edible fleshy tissue of the commercially important fruits is derived from diverse tissues of inflorescence (1).

A fruit passes through several phases during its life span such as growth, maturation and senescence. The beginning of cell division and enlargement marks the fruit growth and later leads to its maturation (2). The final stage in the ontogeny of fruits is 'senescence' during which a series of irreversible events occur which leads to cellular breakdown and death (3). The process of ripening is the controlling phase in the ontogeny of fruit.

The ripening of fruits involve a series of changes during their early stages of senescence, where in the structure and composition of the unripe fruit gets altered (4). The 'ripe'
stage is subjectively determined condition in the continuous series of changes from the initiation of ripening to cell death.

Due to diversity in the origin of cells which forms the edible part of the fruit, various patterns of development have been observed in the ripening of a variety of fruits (4).

The early contribution in the study of ripening patterns of various fruits was made by Kidd and West (5). Based on the autocatalytic production of ethylene and the respiratory behaviour, fruits have been classified into two classes—Climacteric and Non-climacteric. In the climacteric class of fruits which includes mango, papaya, apple, banana, tomato etc., the upsurge in the rate of respiration was observed after the fruit had been harvested. It is termed as 'respiratory climacteric' or 'climacteric peak'. The rate of respiration declines thereafter. The autocatalytic production of ethylene follows the same pattern. On the other hand, in non-climacteric class of fruits such as grapes, cucumber, oranges, lemon etc., a gradual decline in the respiration was observed after harvest. There is virtually no or very little production of ethylene in non-climacteric fruits.

Thus, the upsurge in the respiratory rate of climacteric fruits is one of the major changes occurring during their ripening. Rhodes (6) defined climacteric as a period in the ontogeny of certain fruits during which a series of biochemical changes are initiated by the autocatalytic production of ethylene, marking the changes from growth to senescence and involving an increase in respiration and leading to ripening.
BIOCHEMICAL CHANGES DURING RIPENING:

Ripening of a fruit is a complex phenomenon involving co-ordination of a variety of synthetic and degradative processes. Some of these processes are listed below.

**DEGRADATIVE**
- Destruction of chloroplast
- Breakdown of chlorophyll
- Hydrolysis of starch
- Destruction of major acids
- Oxidation of substrates
- Inactivation of phenolic compounds
- Solubilization of pectins
- Activation of hydrolytic enzymes
- Initiation of membrane leakage
- Increased cell wall softening

**SYNTHETIC**
- Maintenance of mitochondrial structure
- Formation of carotenoids and other pigments
- Interconversion of sugars
- Increased TCA cycle activity
- Increased ATP generation
- Synthesis of flavour volatiles
- Increased amino acid incorporation
- Increased transcription and translation
- Preservation of selective membrane
- Functioning of ethylene production pathway

Table from ref. (7)

The major factor responsible for the change in color during fruit ripening is the transition of chloroplast rich in green pigment chlorophyll to chromoplast containing red or yellow carotenoid pigment. The change in color marks the onset of
The major precursors of ripening in climacteric fruits, carotenoid biosynthesis viz. gernyl and mevalonic acid were found to increase as ripening proceeds (10). A seven fold increase in the β-carotene content was also observed during ripening of mangoes (11). Anthocyanins are the largest group of water soluble pigments responsible for color in many fruits (4).

One of the major ultrastructural changes during ripening occurs in the plastids. The mature, green tomatoes contain chloroplast with small grana and one or two vacuoles bearing starch. At the onset of ripening there is appearance of electron dense region in the granal and intergranal membranes which represents initial stage of lycopene deposition. Later, the intergranal membrane swells and the grana enlarges with the appearance of a new structure called thylakoid plexes. This marks the conversion of chloroplast to chromoplast (8). In contrast to chloroplast, mitochondria retain their ultrastructure until late in senescence, when degradation has started in all other cell organelles (9).

As ripening proceeds, the texture of the fruit undergoes alterations. The change in texture result from the changes in the structure and composition of the cell wall constituents. The major constituents of the cell wall include pectic substances, cellulose and hemicellulose in addition to other polymers such as rhamnogalacturon (12). The enzymes involved in cell wall softening are pectin methyl esterase, polygalacturonase, β-glycosidase (13,14) and to some extent cellulase and amylase (14,15,16). The changes in the
ultrastructure of tomato cell wall have been reported to occur in correlation with the appearance of a polygalacturonase isoenzyme during ripening of tomato fruit (17).

A fruit possesses characteristic aroma during its ripening process. The production of volatile compounds is low in pre-climacteric and unripe fruits, but it rises later during ripening. There are two major groups of precursors for volatile compounds - the long chain amino acids like leucine, isoleucine and valine and unsaturated fatty acids (18). Bandyopadhyay and Gholap (19,20) correlated aroma and flavour of the mangoes with the glyceride content and fatty acid composition of the fruit. The glyceride content was found to increase with the process of ripening and at the same time level of saturated fatty acids decreased and those of unsaturated fatty acids increased. They conclude that the ratio of palmitic to palmitoic acid could be taken as an index for measuring aroma.

In addition to glyceride and fatty acid composition of the fruit, sugars too are important constituents contributing to the appealing flavour. The appropriate levels of sugar and acids play an important role in the taste of the ripe fruit (4). As fruit ripens, the level of acid decrease with a corresponding increase in the sugar content. During ripening of mangoes, starch gets hydrolysed to form sucrose (10,21). There is also an increase in the level of pentose along with an increase in glucose and fructose content (10). Citric acid and malic acid are the major organic acids in most of the fruits with an exception of grapes, in which tartaric acid predominates (31).
The changes in in vivo activity of enzymes involved in various processes were reflected by the changes in these metabolites. One of the most significant changes in climacteric fruit ripening is change in the activity of hydrolytic enzymes such as amylase from mangoes and tomatoes (16), cellulase from tomatoes (22) and ribonuclease from banana and apple peel (3,23) which were found to increase with the process of ripening. An increase in acid phosphatase activity has been suggested to control carotenogenesis in mangoes (25). During ripening of alphonso mangoes levels of oxidative enzymes viz. catalase and peroxidase also increased significantly (21,25).

The activities of some of the carbohydrate metabolizing enzymes of glycolytic pathway eg. glucose-6-phosphate isomerase, phosphofructokinase and aldolase were also elevated during ripening of mangoes (21). The activity of Hexose monophosphate shunt (HMP) pathway enzyme such as glucose-6-phosphate dehydrogenase has been shown to increase with ripening in mangoes (10). During climacteric rise in bananas, a shift from HMP pathway to the glycolytic one has been observed (26). Subsequently, this observation was confirmed by Surendranathan and Nair (27). They observed that level of a HMP shunt enzyme, glucose-6-phosphate dehydrogenase decreased with ripening and this fall in enzyme activity is correlated with the increase in respiratory activity. Due to increased respiratory activity during climacteric rise in banana ripening, there is increased flux of carbon through glycolytic and gluconeogenic pathways (28). It was observed that the concentration of fructose-2,6-diphosphate and the activities
of three enzymes responsible for the reversible phosphorylation of fructose-6-phosphate to fructose-2,6-diphosphate such as fructose-2,6-diphosphatase (FDPase), ATP-phosphofructokinase (ATP-PFK) and PPi-phosphofructokinase (PPI-PFK) are controlling steps in maintaining the balanced carbon flux through glycolytic and gluconeogenic pathways (28).

The higher levels of malic enzyme and pyruvate carboxylase were observed during climacteric rise in apples which coincided with the increase in the respiratory quotient and an increased rate of oxidation of added malate (29). Surendranathan and Nair (30) observed the increase in activity of some of the gluconeogenic enzymes viz. fructose diphosphatase, PEP carboxylase and pyruvate carboxylase during ripening of bananas.

In the non-climacteric fruits such as grapes and pineapples, the major carbohydrates present are glucose, fructose and sucrose (31,32). The inception of ripening in the grape berry is called 'veraison' and marks the beginning of sugar accumulation, loss of acid, softening and skin coloring (33). Enzymes like pyruvate carboxylase and phosphopyruvate carboxylase were found to decrease in activity with the ripening in grapes (34,35). On the other hand, the activities of enzymes involved in sugar metabolism such as invertase, sucrose synthetase, sucrose phosphate synthetase and sucrose phosphatase were found to be elevated at the time of sugar accumulation (34). Mature grapes contain high levels of phosphopyruvate carboxylase and malic enzyme, which may be involved in the dark fixation of carbon dioxide (31). However, these enzymes may also be involved in the
The changes in the membrane permeability during the process of ripening is evident (36). It was reported that the organizational resistance was lost due to permeability changes and facilitate ready access between enzyme and substrates and thereby inducing enzyme activity (36). Such changes were reported in pears (37), apples (38), avocados (39) and bananas (40).

REGULATION OF RIPENING PROCESS:

The process of ripening can be regulated either by manipulating external or internal conditions. The variation in the internal conditions include changes at the hormonal level or changes at gene expression level at various stages of ripening. The regulation of ripening by external means include changes in the environmental conditions such as varying temperature, pressure etc.

A. HORMONAL CONTROL OF RIPENING:

Fruit ripening is known to be affected by plant growth regulators (15). Ethylene, abscisic acid, gibberellic acid, auxins and cytokinins are some of the important plant hormones which have received considerable attention during the past decade.

Ethylene is a unique plant hormone because of its gaseous nature and simplicity in structure. Increase in ethylene production is known to be associated with the ripening process of many fruits such cantaloupe (41), banana (42), tomato (43) and apples (44). The non-climacteric fruits showed low levels of ethylene at all stages of ripening (71). Methionine is a major
precursor for ethylene biosynthesis. S-adenosylmethionine (45) and 1-amino-cyclopropane-1-carboxylic acid (ACC) (46) are the intermediates in the conversion of methionine to ethylene. An enzyme capable of catalyzing this reaction (ACC synthase) has been purified from the tomato tissue (47). A non-enzymic system capable of producing ethylene has also been proposed by Liberman and Mapson (48). This system uses Cu as a catalyst and ascorbic acid as a reducing agent. Further confirmation of this was obtained by Mattoo and Modi (49). They showed that utilization of methionine by mango tissue slices increases in presence of Cu and ascorbic acid.

Beside methionine, ethylene can be produced from linoleic acid (50), propanol (51), methanol (51) and β-alanine (52). Evidence available suggests the involvement of superoxide radicals in formation of ethylene from ACC in etiolated pea seedlings (50,53). A fungal toxin—rhizbiotoxin—is known to inhibit ethylene production from methionine in apples (54), whereas in a fungal system Penicillium digitatum, ethylene production is not affected by rhizbiotoxin. Burg and Thimann (55) further observed basic metabolic difference in ethylene production in apple slices and P. digitatum. The apple tissue readily synthesize ethylene from carbons 1 and 2 of acetate while P. digitatum synthesize it from carbon 3 and 4 of pyruvate, suggesting an alternate metabolic pathway for ethylene synthesis in the fungal system.

The study of elevation in ethylene concentration during the ripening process is a matter of great interest. Two hypotheses
were put forward to explain this. According to one, upon treatment with ethylene, there is an autocatalytic production of ethylene, probably triggered by two isoenzyme of peroxidase (56). This enzyme is suppose to play a role in ethylene biosynthesis. The second hypothesis states that with ripening, membrane permeability changes take place which enables easy access of substrates and enzymes involved in ethylene biosynthesis and thereby inducing ethylene production (57).

Ethylene is known to trigger the ripening process in many fruits (58, 59). The process of ripening in bananas was completely inhibited when stored at low oxygen (1-5%) concentrations. It was reinitiated when ethylene was administered under the same conditions (60). Bananas stored under hypobaric condition also reduce ethylene evolution and thereby delay ripening (61). The presence of proteinic inhibitors in the unripe fruit was detected earlier by Mattoo and Modi (62, 63), which affect the activities of enzymes like peroxidase, catalase and amylase. The treatment of unripe fruits with ethylene, inactivated the inhibitor and thereby led to increase in the activity of all the enzymes. Similar effects might also be occurring in vivo and thereby stimulating the levels of various enzymes. Recently, Christoffersen and Laties (64) observed that treatment of carrot roots with ethylene stimulates respiration and polysome content. The increased levels of polysomes indicate higher rate of protein synthesis. The poly(A) RNA fraction showed presence of new mRNA species which on in vitro translation yields new proteins. This study gave an idea of regulation of ethylene action at gene
expression level (64).

Beside ethylene, abscisic acid (ABA) is another plant growth regulator playing an important role in stimulating the ripening process. Unlike ethylene, the level of ABA is higher in non-climacteric fruits. Externally applied ABA triggers ripening in climacteric fruits such as tomatoes (65) and apples (66), and in non-climacteric fruits such as grapes (67), citrus fruits (68) and cherry (69). The level of ABA increases during ripening of some of the climacteric (65,66,70) and non-climacteric fruits (67,68,69) and varies according to the storage conditions. The treatments which hasten or delay the ripening process made corresponding changes in the ABA level. For instance, cold treatment, which has been shown to promote ripening in pears, showed elevated ABA level (71), whereas the control atmosphere conditions which delays the ripening process, yielded lower ABA levels. Similar observations were made by Coombe and Hale (72) during ripening of grapes.

Assante et al. (73) observed that a fungus Cercospora rosicola produces large amount of abscisic acid. This microbial system was exploited to study the biosynthesis of ABA, and it was found that terpenoid precursors, acetate (74), mevalonate (75) and farnesyl pyrophosphate (76) get converted to ABA. It has been observed that inhibitors of gibberlic acid biosynthesis such as (2-chloroethyl)-trimethylammonium chloride (CCC), ancymidol and decymidazole (77,78,79) and cytokinins inhibit ABA biosynthesis in C. rosicola. Since ABA and GA both have opposite physiological effects and both arises via isoprenoid pathway with mevalonate as
a common precursor, the inhibition of ABA biosynthesis by inhibitors of GA biosynthesis indicates the need for further studies in plants for the mode of action of these compounds (80).

ABA plays an important regulatory role in climacteric and non-climacteric fruits. Evidence available leads to the following conclusions: a) endogenous ABA increase preceding or attending the onset of fruit ripening, b) treatment which hastens the onset of senescence causes an increase in endogenous ABA, c) exogenous treatment with ABA accelerates the onset of fruit ripening. These observations reveal that ABA exerts similar effect in both climacteric and non-climacteric fruits and it might be a predominant ripening promoter in some non-climacteric fruits.

In contrast to ethylene and abscisic acid which stimulate the ripening process, the nature of the factors that antagonize promotion of ripening, is a matter of speculation (4). Very little information is available on the role of cytokinins, gibberellins and indole acetic acid which delay the ripening process (4). Coggins and Hield (81) for the first time demonstrated the retardation of chlorophyll in naval oranges by Gibberlic acid (GA). Subsequently, it was shown that it delays rind softening and accumulation of carotenoids (82,83). Ultrastructural studies revealed that this regreening may be due to the conversion of chromoplasts to chloroplasts.

The major senescence retarding effect of GA is predominantly on the color change of peel. For instance, GA will delay the loss of green color from citrus fruits and the appearance of red pigment lycopene during ripening of tomatoes.
Similarly, Vendrell (86) showed that GA applied either to whole green banana or to slices of unripe banana delayed the yellowing of the skin. Cytokin-in-kinetin also retard the degreening of the banana peel (87). Other than having senescence retarding effect, GA is also a good promoter of growth and development of plants. GA application promote substrate mobilization in barley (88), normalizes growth habit in genetic or physiological dwarfs in plants (89), germination of photodormant seeds (90) and growth of dormant buds (91).

The action of GA and ABA are antagonist to each other. As ripening proceeds, the endogenous ABA level increases with corresponding decrease in GA content (92). When applied exogenously GA probably maintains its endogenous level and thereby delays the ripening process (15). The knowledge regarding the action of exogenously applied growth regulators revealed the fact that they might be acting by affecting endogenous balance of the hormone.

B. BIOCHEMICAL CONTROL:

Though extensive studies have been carried out to understand the process of ripening in both climacteric and non-climacteric fruits, the question as to how the ripening events are co-ordinated and regulated is a matter of speculation. Two theories were put forward to explain the underlying biochemical control of the levels of enzyme activity. According to one, the process is regulated at the level of transcription/translation, indicating involvement of de novo synthesis of a group of specific enzymes. The alternative theory suggests, that all key enzymes
responsible for the triggering of various ripening processes are present and needs only to be activated.

Evidence for the first theory was obtained when Hulme (93) observed that protein nitrogen content of detached apples increased during ripening. Increased incorporation of amino acid into proteins was also observed during ripening of some of the climacteric fruits (94,95). Further confirmation of the involvement of protein synthesis during ripening was obtained by use of protein synthesis inhibitors. Cycloheximide, a protein synthesis inhibitor, when infiltrated into pre-climacteric pears (96) and bananas (97), inhibited all processes of ripening except respiration. These suggest that protein synthesis plays a vital role during ripening. Since the specificity of cycloheximide is doubted, this statement may not necessarily be true (98). The new mRNA species have also been observed during ripening of avocados (99) and tomatoes (100).

The evidence for the second hypothesis was obtained from the Blackman and Parija's hypothesis of 'organizational resistance' during ripening, which states that with the onset of ripening, permeability changes take place which makes various enzymes and substrates accessible to each other and thereby activating various enzyme reactions (36).

No conclusive evidence for either theory has been advanced, but both types of changes can operate in various ripening processes at the same time (4,92).

It seems likely that ripening is a differentiation process which is determined at the genome level. The process by
which this control is expressed is unknown. The increase in enzyme activity may be due to the de novo synthesis, activation or release of enzymes from membrane bound form, although all three processes may be involved at the same time (4).

C. EXTERNAL CONTROL OF RIPENING:

In addition to the use of plant growth regulators to control the process of ripening, various other technologies have also been developed to control the same. These include low temperature storage, control atmosphere storage, storage in plastic films and wax coating of fruits.

Most fruits ripen normally in a very narrow range of temperature (4). The disadvantage of low temperature storage is susceptibility of the fruits to a physiological disorder called 'chilling injury'. The 'chill injury' is marked by skin discoloration and inability of fruits to ripen normally when brought back to the room temperature later (101). Bananas get chill injured at 10°C, while mangoes develop this disorder at 5°C (102). Toraskar and Modi (103) observed that during chilling injury of unripe bananas, level of peroxidase decreased, suggesting that low temperature storage affects the enzyme level. Thomas (104) made an interesting observation that adoption of alphonso mangoes at 10°C by step wise exposure to declining temperature made the fruits withstand storage at lower temperature for longer time and develop better flesh color and organoleptic qualities on ripening. These studies can be extrapolated on a larger scale for the storage and transport of mangoes.
Another method of storage, which can be widely applied, is storage under modified atmospheric conditions. In such experiments, concentration of oxygen and carbon dioxide plays an important role (105).

Low levels of oxygen (1-5%) at ambient temperature completely inhibit ripening of bananas by preventing ethylene production and respiratory climacteric (60). This effect could be reversed by administering ethylene in low oxygen atmosphere. Similarly, storage of mature green tomatoes and apples in 3% oxygen completely prevented the onset of ripening and this effect could not be reversed even by inclusion of relatively high amount of ethylene, suggesting that oxygen concentration of more than 3% is required for initiation of ripening after storage (106). On the other hand, oxygen tension greater than normal atmospheric values promotes ethylene biosynthesis and initiate ripening in many fruits (107). Citrus fruits kept in 34 to 99% oxygen showed normal climacteric rise and produces high level of ethylene.

Reduction in the atmospheric pressure brings about delay in the ripening process. The ripening of bananas was completely inhibited when stored at one-fifth atmospheric pressure in pure oxygen (61). This effect could be reversed by the inclusion of small amount of ethylene in the atmosphere. The principle involved in the hypobaric storage system is that, an increase in diffusion of ethylene due to reduction in the pressure which leads to delay in the ripening of fruits. Salunkhe and Wu (108) showed that mature green tomatoes could be stored for 100 days at 102 mm Hg at 55 F and they ripened normally upon returning.
to atmospheric pressure. Avocados could be stored for 70 days at 60 °C at 60 mm Hg and ripened normally when brought to atmospheric pressure (109).

Increasing carbon dioxide concentration in the atmosphere around fruits delay the onset of ripening. CO₂ concentration of 3 to 10% is effective but further increase in concentration leads to a physiological disorder (110). CO₂ acts as competitive inhibitor of ethylene, probably by competing with the attachment site (111). Recently, Chaves and Thomas (112) observed that exposing apples with 20% CO₂ for 2 hours inhibits ethylene production and respiratory climacteric. 1-aminoacyclopropane-1-carboxylic acid (ACC) content also increases upon CO₂ treatment. They suggested that the action of CO₂ is directed towards the enzymes responsible for the conversion of ACC into ethylene.

Though very advantageous and successful, controlled atmospheric storage is uneconomical and advocated only in cases of distinct financial gains.

Recently, Ben-Yehoshua et al. (113) developed a technique which involves sealing of individual fruit in high density polyethylene film. Seal-packaging effect was due to the water saturated atmosphere in the sealed enclosure around fruits. Sealing inhibited softening as well as changes in cell wall pectines and also delayed disintegration of membranes. This technique was successfully applied to lemon and bell-pepper fruits. Sealing of individual climacteric fruits such as tomato, avocado, mango, peach and persimmon delayed softening but to a lesser extent. Ripening process superseded and softening proceeded
even in sealed fruits, though at a slower rate.

MICROBIAL SPOILAGE OF FRUITS AND ITS CONTROL:

Post-harvest disease is a major factor responsible for the loss of fruits. Diseases affect the quality of the fruits. They decrease the plant stand or vigour and thereby the yield size and eating quality. They blemish the surface resulting in low market value. Increased water loss due to infection decreases the keeping quality in the store, resulting in increased wastage. It was estimated that about 40% of the unconsumed produce of the world is lost due to the post-harvest decay (114). The economic loss associated with deterioration increases as the commodity is transported from the plantation to the consumer (114).

Disease of fruits and vegetables developed because of either infestation of the product during development or by infection through wounds created during harvesting operation or other means and through physiological damage resulting from inadequate storage atmosphere (115). The factors which influence the disease development include water status of the tissue, pH, biochemical status of the host tissue, temperature and humidity (115). These may be related to the degree of ripeness of the fruit.

Among causative agents, fungal pathogens play a vital role in the spoilage of fruits and vegetables (116). Some of the genera most commonly involved are *Penicillium*, *Colletotrichum*, *Aspergillus*, *Geotrichum*, *Alternaria*, *Rhizopus* and *Fusarium* (115,116). These pathogens are capable of proliferating rapidly under favourable conditions and may invade the host tissue by
dissolving parts of the cell wall. On the other hand, causative agent for "brown rot" in many fruits such as Monilinia fructicola in stone fruits, Gloeosporium spp. in apples, Diplodia natalensis, Phomopsis citri and Alternaria citri in the stem ends of citrus fruits do not spread rapidly at the time of storage and shipment, but may cause problems at the time of harvest (117, 118).

The principle cause for the post-harvest decay of mangoes during ripening is fungal infection. The stem-end rot caused by Gloeosporium mangiferae, anthracnose by powdery mildew Oidium mangiferae and black spot symptoms is caused by Erwinia mangiferae (115). Among bacteria, various species of Bacillus are also responsible for the formation of "spongy tissue" (121).

Several methods have been employed to combat pre and post-harvest diseases by maintaining natural resistance of the host (114). Low temperature and treatment with growth regulators which delay senescence, reduce possibility of diseases to some extent. However, these may not adequately protect the crop from microbial attack during prolong storage and transport.

Use of chemicals to protect post-harvest losses of fruits have increased in recent years (108). These methods have been used successfully to protect bananas, citrus fruits and grapes (108). Eckert (122) tried a wide range of chemicals such as benzimidazole, nitrogen trichlorides, formaldehyde, phenols to control post-harvest diseases of the fruits. Fungicides like benomyl and thiabendazole have been used successfully to eradicate pathogens (123).
A new formulation of extending post-harvest life of certain fresh fruits and vegetables and thereby preventing infection was developed by Lowings and Cutts (124). This product is trade marketed by Tate and Lyle Chemicals (U.K.) as "TAL-PROLONG". It is a coating material consisting of mixture of sucrose esters of fatty acids and polysaccharides. When applied to fruits, it alters the permeability of the skin to gases in such a way that the permeability to oxygen is reduced while that of carbon dioxide is little affected. The coating is effective in fruits such as bananas, apples, pear, plum, avocado and mangoes, but had little effect on grapes, tomatoes and strawberries (125).

The use of ionizing radiation for the control of established infection has not proved to be very beneficial (126). Cold storage of fruits may result in the delay of onset of infection (127). However, low temperature does not eradicate the pathogen and generally only retard its development (108).

PRESENT INVESTIGATION:

Extensive studies have been carried out earlier to understand the biochemical changes taking place during ripening of mangoes (25,49,102,114). The rate of respiration increases with the onset of ripening, attains a peak and then declines (128). Increase in the activity of hydrolytic enzymes like cellulase, amylase and invertase was observed (129) and their substrates viz. cellulose, starch and sucrose decreased with a concomitant increase in the hexoses and pentoses. A 2-fold increase in the activity of pectin methyl esterase was also observed (129). The concentration of citric acid, a predominant acid of mango,
decreases with the corresponding increase in the activities of citrate cleaving enzymes (130). The activities of NADP-linked malate dehydrogenase, glucose-6-phosphate and 6-phosphogluconic dehydrogenase were also found to increase with the onset of ripening (10).

The process of gluconeogenesis has been established in ripening mangoes (131). Cell-free extracts have been reported to convert organic acids to sugars, suggesting an operative gluconeogenic pathway (131). Both acidic and alkaline fructose-1,6-diphosphatase have been isolated and partially purified from the ripening mangoes (131).

The process of ripening is known to be affected by the treatment with plant growth regulators (15). Ethylene and abscisic acid enhances ripening, whereas gibberellic acid, indole acetic acid and kinetin delays it (15). The mechanism by which these hormones exert their effect is still unclear.

The present investigation was undertaken to study the effect of one such hormone, Abscisic acid (ABA), on the ripening of a climacteric fruit (mango) and a non-climacteric fruit (grape).

The process of gluconeogenesis i.e. conversion of acids to sugars was taken as a parameter to study the ripening of mango. The activities of various enzymes responsible for the conversion of acids to sugars were estimated. The rate of respiration, as determined by the amount of carbon dioxide evolved, was monitored during ripening of mango and was correlated with the other aspects of ripening. The structural changes taking place during
softening of the mango and the involvement of protein synthesis during ripening were among the other parameters studied. The effect of ABA on the mentioned parameters was also studied.

The ultrastructural changes taking place during ripening of mangoes were observed. The transformation of chloroplast rich in chlorophyll to chromoplast containing red or yellow carotenoid pigment, changes in the cell wall of cells of peel and pulp, structural integrity of mitochondria and abundance of ribosomes were observed during ripening of untreated control and ABA treated mangoes.

The effect of Abscisic acid was also observed on the ripening of seeded grapes. The factors responsible for lowering metabolic activities in the seeded grapes were studied and possible role of ABA in overcoming the inhibition was examined.

Prolong storage and ripening of mango leads to microbial spoilage of fruits which results into wastage and economic loss. Several causative agents for microbial decay have been isolated from this laboratory, few examples being Rhizoctonia bataticola, Penicillium cyclopium, Aspergillus spp., Bacillus megaterium, B. cereus (132-135).

Penicillium purpurogenum Stoll was isolated for the present study from a naturally spoiled, ripe alphonso mangoes. To study the epidemiology of this organism, the degree of infection during various stages of ripening was examined. Various biochemical changes were observed from both healthy and infected tissues. Bavistin (a fungicide) and aureofungin (an antifungal
antibiotic) were used to combat the post-harvest spoilage of mangoes by this isolate.
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