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Biochemical changes during ripening of banana: A review

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Abstract
In fruit ripening fruits undergo different biochemical and physical changes and those changes are characteristic to different fruits. Studying the nature of those changes may beneficial for postharvest handling of particular fruits. The aim of this review is to study biochemical changes occur during ripening process in banana. During ripening process softening of fruit flesh occur mainly due to degradation starch and insoluble polysaccharides. As well sugar content is increased from 2% to 20% during ripening. Colour changes of banana peel occur due to degradation of chlorophylls. Malic acid content in flesh is said to increase during ripening process. Astringency, occur due to tannin is decreasing during ripening. Volatile profile undergoes different changes in different changes of the ripening process.

Keywords: banana, ripening, biochemical changes

1. Introduction

Banana belongs to the genus Musa of the family *Musaceae*. The genus *Musa* contains four sections, *Eumusa*, *Rhodochlamys*, *Australimusa*, and *Callimusa*. *Rhodochlamys* and *Callimusa* are of ornamental interest only. *Australimusa* species are utilized across a large area of the Pacific as a cooked vegetable. However, *Eumusa* is the largest and most widespread geographically and contains the all the major edible species of banana. Most edible bananas are delivered from two members of the sect of *Eumusa*: *Musa acuminate* and *Musa balbisiana* [1]. Most of the edible bananas are either derived solely from the *Musa acuminate* or are hybrid between two wild diploid species, *Musa acuminate Colla* and *Musa balbisiana Colla;* which contributed to A and B genomes respectively [2].

There are 300 -500 cultivars which are naturally occurring banana hybrids which can be grouped according to their genome constitutions, as AA, AAA, AB, AAB, ABB and ABBB. Tetraploid AAAA cultivars have only been produced through breeding program. Nevertheless triploid and tetraploid B cultivars have not been identified yet [3]. Three most common species of banana which are mostly grown in the world are *Musa cavendishi*, *Musa paradisiaca* and *Musa sapientum* [4].

It is one of top most fruit in the world in production and as well as in consumption. Bananas are climacteric fruits which are artificially ripened regularly. Ripening process of banana can be divided into three distinct phases namely the pre-climacteric or 'green life' stage, the climacteric and ripening stage and finally eat-ripe and senescence stage [5]. During ripening process banana undergoes different physiological, biochemical, and organoleptic changes that lead to a soft and edible ripe fruit [6]. This review paper investigates the changes occur during banana ripening.

2. Bio chemical changes during ripening

Fruit ripening is a genetically programmed, highly coordinated process of organ transformation from unripe to ripe stage, to yield an attractive edible fruit with an optimum blend of colour, taste, aroma and texture. A set of biochemical and physical changes occur in banana during ripening which makes it an edible fruit. These changes involves several biochemical pathways like degradation of starch to sugar, change in the peel and pulp colour, cell wall changes, change in the concentration of volatiles and acids [6].

2.1Tissue softening

Softening is a very important aspect of the ripening syndrome. Loss of turgor, degradation of starch and enzyme catalyzed changes to wall structure and composition are the mechanisms which leads fruit softening. According to Finney [7] textural change in banana fruit during ripening is predominantly due to the changes in chemical structure of starch grains. Many researchers have shown that starch content in the pulp of banana decreases drastically during the short period of ripening and then starch is no longer detected [8, 9, 10]. However Kojima [11] suggests that banana pulp softening process is due to the associated process whereby the contents of pectic and hemicellulosic polysaccharides and starch decrease during ripening. According to ALI [12] 50% firmness loss was occurred in 3 days during ripening in Mas banana (*Musa acuminata*, AA group).

2.2 Carbohydrates

During ripening process starch is converted in to simple sugars through enzymatic browning process [13]. Starch forms about 20 to 25% of the fresh weight of the pulp of unripe bananas. Sugars are present in the green fruit only about 1 to 2% in the fresh pulp which rises up to 15 to 20% at ripeness [14]. The soluble sugars detected in ripened banana are mainly sucrose, glucose and fructose [15]. According to Adao and Gloria [15] the mean level of starch content in 'Prata' banana was reduced from 15.7 g/100 g to 3.40 g/100 g during ripening. As well total soluble sugar content was increased from 1.26g/100g to 14.3g/100g. Adewale [16] reported that unripe banana (*Musa sapientum)* had highest amylase activity (3900 ± 310 Units/mg protein) and decreased rapidly to a very low value (100 ±15 Units/mg protein) when it was fully ripened.

2.3 Pigments
The peel colour changes from green to yellow during ripening of banana fruit. The most important compounds responsible for the change in peel color are chlorophylls and carotenoids [17]. Chlorophyll content decreases become absent in ripe fruit [18, 19, 20]. The level of total carotenoids decreased to half the level at the colour break and subsequently again reached a level similar to that in green fruit [18]. According [21] the major pattern of pulp carotenoids is α - carotene (31%), ß- carotene (28°/o) and lutein (33°/o) of total carotenoids. Banana peel contained 3-4 µg/g carotenoids content as lutein equivalent and ingredients were lutein, ß- carotene, α – carotene, violaxanthin, auroxanthin, neoxanthin, isolutein, ß-cryptoxanthin and α- cryptoxanthin.

2.4 Pectin
The inter-lamella layer in higher plants composed of polysaccharides mainly pectin [22]. The nature of the pectic component in cell wall is associated with fruit softening [5]. Pectin is a linear chain of α- (1→4)-linked D-galacturonic acid which are methyl esterified. The great strength of green fruit is due to the protopectin or water insoluble pectic which is partially esterified polygalacturonic acid [23]. Increased solubility of pectic polysaccharides is one of the identified changes happens during fruit ripening. Pectic enzymes are related with the softening of fruits along with the increase in soluble pectins. The mainly enzymes involved in pectin degradation are Polygalacturonase (PG) and pectin methylesterase (PME). According to Tapre and Jain [24] pectin content in banana (*Musa sp.* var 'Robusta') pulp increased from 0.37-0.66% significantly which was measured as calcium pectate. According to Robinson and Sauco [5] reported ripe pulp in banana contains 0.5-0.7% pectin content. Whereas several studies have been done to characterize pectin degrading enzymes and their activity. Smith [25] and Markovic [26] reported the presence PG in banana tissue. Nagel and Patterson [27] identified that PME activity appears as the fruit ripens and continues to increase exponentially. However Patil and Magar [28] reported that PME activity is highest at colour stage 4 (greenish yellow) and fell down sharply in the advanced stages of ripening.

2.5 Organic acids
Vonloesecke [29] reported the presence of malic, citric, oxalic, and tartaric acids in the banana fruit, with malic acid being the principal acid. Malic and Citric acids are responsible for tartness in the unripe banana while oxalic acid is contributed to astringent taste of the fruit [19]. According to von loesecke [29] titratable acidity of the pulp increases to a peak during ripening in the case of some varieties, and then declines. Further it has reported that malic acid concentration has been reported to vary between 0.8 and 7.5 meq/100g and it is increasing three to sevenfold during ripening [29]. The controversial results with Vonloesecke [29] were reported in Soltani [30] where titratable acidity decreased gradually until the fruit reaches to full-ripe (stage-6) then increased at stage-7. In Malakar [31] and Kulkarni [32], titratable acidity was decreased during the ripening period.
According to Wyman and Palmer [33] malic acid content was 1.36 meq/100g at the pre climacteric stage and it increased up to 5.37 at the climacteric stage and 6.2 meq/100g at the post climacteric stage while oxalic acid content was decreased from 2.33 to 1.37 meq/100g at pre climacteric stage to post climacteric stage. However total organic acidity was increased during ripening.

2.6 Astringency
Most fruits and vegetables are astringent in unripe stage and during ripening process astringency is reduced. Similarly banana which tastes astringent in unripe stage becomes palatable in the eating ripe stage. Astringency is claimed to be related to tannins which causes drying, roughing and puckering of the mouth epithelia giving astringency in oral sensation [34]. Unripe fruit contained considerable level of tannin which reduces as ripening proceeds [29, 35]. However some earlier researches reported that tannin remained unchanged during ripening. The confusion of reduction of astringency and constant value of tannin content was well explained by Barnell and Barnell [34]. According to Von loesecke [29] there are many types of tannin and during ripening soluble tannin becomes insoluble. Barnell and Barnell [34] explained that there are two types of tannin containing elements, latex vessels in both the pulp and peel and small scattered cells in the peel. Further Barnell and Barnell [34] explained that nature of tannin in latex vessels undergo changes while tannin content of the small scattered cells of the skin appears to undergo little or no change.

2.7 Volatile constituents
Very few researches have been published on aroma compounds and their changes during ripening. The unique aroma of bananas arises from set of volatile constituents including esters, alcohols, ketones, aldehydes and phenol esters [19]. According to Pino and Febles [36]. The composition of banana (Musa spp., AAA group) fruit volatiles included 75 esters, 18 ketones, 14 phenols and derivatives, 7 aldehydes, 13 alcohols, 7 acids, and 12 miscellaneous compounds. As well isoamyl and isobutyl esters together with 2-pentanone are the major compounds found in banana volatile profile [37]. Mccarthy [38] reported that characteristic banana flavour is due to the amyl esters of acetic, propionic and butyric acids. Jordan [37] studied aromatic profile of fresh banana fruit paste and identified 26 volatile compounds including *E*-2-hexenal and hexanal as major aldehydes and 3-hydroxy-2-butanone, 3-methyl-1-butanol, 2-pentanol, isoamyl acetate, isoamyl isobutyrate, and eugenol were also presented in high concentrations.

3. Conclusion
Ripening is a process consists of a set of biochemical and

physical changes which gives an edible fruit. Banana is one of mostly consumed fruit in the world and it has been studied for its biochemical and physical changes for years. Softening of the texture, yellowing of peel, reduction of astringency and increase of sweetness are major organoleptic changes which can be noted in banana ripening. These changes occur as a result of series of biochemical changes in peel and flesh of banana fruit.

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