Review of Literature
REVIEW OF LITERATURE

The literature on the studies on the physical and biochemical composition of the banana fruit and its composition during developmental and in post-harvest stages has been dealt with in this section under three major heads.

I. Physico-chemical composition of fruits of different banana cultivars.

II. Studies on developmental physiology.

III. Studies on post-harvest physiology.

The relevant and available information on the above noted three aspects are briefly discussed hereunder.

I. PHYSICO-CHEMICAL COMPOSITION OF FRUITS OF DIFFERENT BANANA CULTIVARS.

Physico-chemical composition of fruits is important from the view point of edibility and nutritional value. The
different cultivars of banana differ widely in this respect.

Von Loesecke (1949) stated that the moisture content of four different cultivars varied from 70 to 75.9%. Jacob (1952) also reported that the moisture content of Nendran, the dual purpose cultivar was 64.2% and the moisture content of few other cultivars varied from 73.75 to 78.16%.

Jacob (1952) presented the analysis report on the acidity of different banana cultivars which varied from 1.0 to 1.22% while Nendran contained only 0.4% acidity. Von Loesecke (1949) recorded the interesting observation that titratable acidity in the ripe pulp of the plantain was nearly twice as high as in the ripe pulp of four dessert types.

Miller and Bazore (1945) estimated the content of vitamin C and vitamin A in Gros Michel and Cavendish and observed a poor source of vitamin C and a negligible amount of vitamin A and thiamine. Von Loesecke also reported on the vitamin C content of 20 other cultivars which varied from 2.1 to 24 mg per 100 g fresh pulp.
The ripe fruit is a rich source of carbohydrates. Analysis of the flesh of 59 types of the ripe bananas from Madras gave the values of reducing and non-reducing sugars as 2.0 to 14.6%. Von Loesecke (1949) studied the content of reducing and non-reducing sugars of four different cultivars of banana where he observed the variation of percentage of reducing sugars from 4.1 to 7.3% and non-reducing sugars from 6.13 to 16.08%. Jacob (1952) also analysed the different cultivars amongst which Nendran, Ney Poovan and Basrai were important. Nendran contained by far the greatest amount of sugars 26.42% while the popular Basrai was lowest with 15.04%. The range of other cultivars in the case of reducing sugar varied from 10.02 to 19.76% and in case of non-reducing sugar from 0.12 to 5.02%. Several of the less important cultivars contained 25% or more of sugar, the Ney Poovan having 17.7%. Cheema et al. (1954) studied seven cultivars in which total sugars ranged from 15.07 to 22.44%. Lulla and Johar (1955) analysed different sugars by paper chromatography and identified maltose, sucrose, glucose and fructose in ripe banana.

Lulla and Johar (1954) stated that all the ripe bananas contained malic and citric acid. Wolf (1958) noted that in large-fruited cultivars malic acid predominated and in other small bananas citric acid was present in greater quantities.
The protein content is also an important criterion for evaluating the quality of the banana. Jacob (1952) studied the protein content of seven cultivars, amongst which Rashtheli contained the highest value. Hulme (1955) and Bhagavan and Rajagopalan (1956) studied the nitrogenous compounds of bananas and identified 17 amino acids from alcoholic extracts of fruits. Usually large amounts of histidine were present although the acid hydrolysate of the protein contained only very small amount of histidine. The principal basic amino acid in the protein was lysine.

Garcia (1962) observed the presence of invertase with an optimum pH of 4.15 and optimum temperature of 44.4°C. Haard and Tobin (1971) observed the pattern of soluble peroxidases in ripening fruit. Deacon and Marsh (1971) studied the properties of an enzyme from banana (Musa sapientum) which hydroxylates tyrosine to dopamine. Singh and Singh (1973) isolated an allosteric glucan-phosphorylase from banana fruits. Singh and Sanwal (1975) also studied the characteristics of multiple forms of glucan phosphorylase from Musa paradisiaca. Three forms of glucan phosphorylase from mature banana fruit pulp differed in sensitivity to the phenolics extracted from immature and mature banana pulp. Only two forms of enzyme were detected in the immature pulp.
Knapp and Nicholas (1969) determined the sterols and triterpenes of banana peel. The sterols and triterpenes identified were sitosterol, stigmas-terols, campesterol, cyclosterol and other 24-methylene cycloartenal, 24-methyl cyclosterol palmitate and unidentified triterpene ketones were the major constituents.

Banana is a fair source of calcium and iron, a rich source of potassium, magnesium and phosphorus. Von Loesecke (1949) stated the following values for minerals: 401.0 mg/100 g pulp potassium, 31.0 mg/100 g phosphorus, 9 mg/100 g calcium, 31 mg/100 g magnesium, 0.6 mg/100 g iron and 23.8 mg/100 g silicon.

II. STUDIES ON DEVELOPMENTAL PHYSIOLOGY

There is a close relation between the stages of maturity and the taste and palatability of fruit and the time required for ripening. Gane (1936), Barnell (1943, 1944), Von Loesecke (1944), Khalifah (1966), Sanchez et al. (1968), Gottreich et al. (1969), Wally et al. (1969) studied the different aspects of developmental physiology of banana. In this country, Nayar et al. (1958) and Lodh et al. (1971) also worked on that line.
Nayar et al. (1958) made a preliminary study of banana fruit development by measuring length, girth, volume and weight of Poovan and Monthan banana from August to December and concluded that they should not be harvested earlier than 15 weeks from the date of emergence. Sanchez et al. (1968) also investigated the preharvest changes in the physical characteristics of Gueyamono and Maricongo bananas and noted a significant correlation between age and the pulp/peel ratio and a highly significant correlation between age and texture; the fruit became softer as it matured. Wally et al. (1969) studied the changes occurring during growth and development of Hindi banana fruits and recorded significant increases in weight of fruit, pulp and pulp peel/ratio. This type of study was also conducted by Lodh et al. (1971) who noted increases in length, whole fruit weight, pulp weight and pulp peel ratio of Dwarf Cavendish banana. In Gros Michel banana, the pulp/peel ratio had been found to range between 1.2 to 1.6 in the green fruit and between 2.2 to 2.4 at advanced ripening stages (Barnell et al., 1941; Wardlaw et al., 1939). Lal et al. (1974) also studied the changes in pulp/peel ratio and expressed the same view.

The biochemical aspects were studied by a number of workers. Lodh et al. (1971) determined the dry matter percentage of pulp of Dwarf Cavendish which rose steadily to about 33 percent in 100 days and slightly dropped thereafter. While
studying the fruit biochemistry of Gros Michel, Barnell (1941) made similar observations. Wally et al. (1969) observed the changes in acidity during the development of fruit and noted a low content of acidity in the initial stages of development. In Dwarf Cavendish, Lodh et al. (1971) noted an increase of vitamin C up to 55 days which, however, decreased at the ripening stage. Starch increased up to 70 days and sharply decreased during the ripening stage.

Von Loesecke (1949) studied the protein content of Gros Michel banana fruit during development and ripening but could observe no appreciable changes. Similar observations were also made by Lodh et al. (1971) in Dwarf Cavendish. But Lal et al. (1974) noted a decreasing tendency during developmental stages of Musa cavendishieca. Sanmugavelu and Rangaswami (1962) isolated twelve amino acids including tryptophane from the ovaries of the cultivar, Monthan. He also opened a new line of approach by investigating the growth factors responsible for the development of the fruit. He isolated hormone like compounds from the ovaries of the aforesaid cultivar and it was suggested that they might be involved in fruit development. Khalifah (1966) also isolated IAA from the developing banana fruit, which occurred at a concentration of 0.06 ppm. He also isolated gibberellin-like substances from the developing banana fruit.
III. STUDIES ON POST-HARVEST PHYSIOLOGY

The studies on physico-chemical changes during ripening and post-ripening stages are of great fundamental and practical importance.

No appreciable changes were observed in length and diameter of fruits of Dwarf Cavendish but major changes were observed in weight of the fruit and peel and pulp/peel ratio by Lodh et al. (1971) who also recorded a decreasing trend in the weight of pulp and peel of the fruits. Barnell (1941) observed that the dry matter content of Gros Michel banana decreased with the advance of ripening. While studying the fruit biochemistry of Dwarf Cavendish, Lodh et al. (1971) also made similar observations.

Acidity of the pulp increased to a maximum value at or soon after the climacteric and then showed a slight fall as ripening progressed (Barnell and Barnell, 1945; Lodh et al., 1971).

The predominant carbohydrate of green banana was starch, which was largely replaced by sucrose, glucose and fructose in the ripe fruit (Gane, 1936; Poland et al., 1938; Wardlaw et al., 1939, Barnell, 1941; 1943 a, b; Von Loesecke, 1949). Yang and Ho, (1958) studied the changes in carbohydrate metabolism and ripening and indicated the existence of a transition stage between maturation and
senescence in which there was a marked rise of respiration accompanied by physiological and chemical changes. Starch was converted into sucrose and in the post-climacteric stage into glucose and fructose; phosphorylase being the chief enzyme involved. The respiration rate of the pre-climacteric but not of the climacteric banana flesh was limited by the capacity of the phosphate transfer system. Adenine triphosphate developed during ripening and was apparently a factor responsible for increase in respiration in the climacteric stages. Yoshioka (1973) also investigated the changes in glucogenesis in injured banana by chilling. Mann (1959) observed the CO₂ production and sugar formation in the ripening banana and further noticed that the respiratory intensity of an unripe banana at 68°F in 1:1000 ethylene rose rapidly from a pre-climacteric value of 21 to the peak value of 140 mg CO₂/kg/hour. For spontaneously ripened fruit, the peak value was about 120 mg/kg/hour. The elevation in sugar content generally lagged behind the rise in respiration intensity. At fairly advanced stages of ripening, maximum sugar contents of 18-20% (fresh weight basis) were noted in pulp, which contained fructose, glucose and sucrose. They were uniform in both the ethylene stimulated and naturally ripened fruits. Two other sugars were observed in the pulp, one of which showed the same chromatographic properties as maltose and appeared only during the early stages of ethylene ripening, the other compound appeared during the later stages of ripening with and without ethylene. Lal et al. (1974) noticed a pronounced decrease in starch with the onset of ripening.
Gottreich et al. (1969) determined the stage of ripeness of bananas colorimetrically and according to him the content of reducing sugar and respiration rate in banana fruit could serve as an indicator of its state of ripeness. He further reported that there was a correlation between reducing sugar and respiration in banana at the ripening stage.

Wyman and Palmer (1963) determined the nonvolatile organic acids of banana pulp at various stages of ripening and stated that green fruits contained 4-5 meq. of total organic acidity per 100 g fresh weight of which oxalic acid accounted for about 50%, malic acid 35% and citric acid 10%. During ripening both the malic and citric acid contents decreased to half their original values. The result was a doubling of organic acidity of the ripe fruit with malic acid comprising about 65% of the total; the values of citric acid and oxalic acid being 20 and 10% respectively. A number of other acids, namely, aspartic, glutaric, quinic, glyceric and glycolic, in trace quantities, were noted at all stages of ripeness. Ripe fruits also contained low concentrations of keto acids.

Gane (1937) estimated ethylene production of preclimacteric Gros Michel at 50°F as 0.1 mg/kg/day and the amount roughly doubled as the fruit ripened; the trend of production was then similar to that of CO₂.

Biale et al. (1954) got much the same result and concluded that ethylene though undoubtedly
stimulative, was a product of climacteric metabolism rather than the primary cause of ripening. McCarthy and Palmer (1962) investigated the production of volatile compounds by the banana fruit during ripening. They identified 20 volatile compounds, in addition to CO\textsubscript{2} and ethylene, and correlated the appearance of these compounds to the typical climacteric respiratory curve. Burg and Burg (1965) also observed a relationship between ethylene production and ripening of banana.

Askar (1973) studied the production of amino acids in banana and noted that the fruits were rich in arginine, serine, valine, leucine and particularly high content of histidine. But during ripening, these five amino acids increased whereas aspartic acid and glutamic acid contents declined.

A number of enzymes participate actively in the ripening of the banana fruit. Tager and Biale (1977) studied the carboxylase and aldolase activity during ripening. They noted that the enzymes carboxylase and aldolase appeared to be absent from the pulp of the pre-climacteric banana fruit; both enzymes made their appearance during the climacteric and an increased activity was noted until several days after the climacteric peak had been reached. Hultin and Levine (1965) noted that during the post-ripening stages the activity of pectin methylesterase increased as the banana skin began to change from green to yellow. Lal et al. (1974) studied the activities
of glutamate-oxalacetate transaminase (G.O.T.), glutamate-pyruvate transaminase (G.P.T.) and aldolase at developing and ripening stages of *Musa cavendishii*. The enzymes exhibited maximum activity at a stage corresponding to the initiation of the climacteric. G.P.T. level, at this stage was higher than that of G.O.T. Weaver and Charley (1974) studied the enzymatic browning during ripening of banana and measured the activity of polyphenol oxidases and concentration of 3, 4-dihydroxyphenylethyl amine (dopamine) and vitamin C in banana as they ripened. A decrease in the concentration of dopamine correlated best with the increase in browning but the activity of polyphenol oxidase was not significantly correlated with browning. Both the increase in browning and fall in dopamine were associated with a fall in vitamin C content.