Discussion
DISCUSSION

Physico-chemical composition of important banana cultivars

The varietal classification of edible bananas has been based primarily on the origin and ploidy level of the genome.

The cultivars grown in West Bengal may be placed under four groups: the Cavendish group, represented by Kabuli, Giant Governor and Lacatan; the Martaman group represented by local and Madrasi Martaman; the Kanthali group with Jurmony Kanthali, Deshi Kanthali and Kalibow as the important members and lastly, the miscellaneous group which is represented by Champa, Amritsagar, Anupam, Agniswar and Bichakala.
The bananas of the Cavendish group are large and heavy with high to medium sugar content, moderate protein content and medium concentrations of phosphorus, potassium, calcium and magnesium, coupled with low acidity and moderate vitamin C contents.

The fruits of Martaman group are medium-sized with high pulp/peel ratio and medium sugar, acidity and vitamin C concentrations. The protein content is high as also the minerals. Texture, flavour and palatability of fruits are very good.

The Kanthali bananas are small to medium sized with medium to high sugar contents, acidity and vitamin C. Proteins and minerals are present in moderate concentrations. Texture of the pulp is not good with some amount of stickiness and faint flavour.

The miscellaneous group is a rather heterogenous one, characterized by cultivars like Bichakala and Amritsagar with very large fruit size and Champa with very small fruits. The physico-chemical characters are also widely different with high to low sugar, acidity and minerals. The wide differences between the members of this indigenous group of bananas would suggest that they
should be subdivided into a number of sub-groups viz. Champa which is quite different from all other bananas grown in this State and is the most widely grown (over 70% of the banana area is covered by Champa) banana of West Bengal; Anupam-Agniswar group with medium-sized fruits of good quality; Amritsagar group with large fruits of excellent quality and a close rival of Martaman and lastly, Bichakala-large sized seeded fruits with high sugar content but poor texture and flavour.

It would appear that the genomic classification does not adequately account for the differences in physico-chemical and edibility characters of the bananas grown in this State. Of course, that was not the purpose of the genomic classification. Based on the physiological and edibility characters,

Classification based on Physico-chemical and edibility characters.

the bananas grown in West Bengal could, therefore, be grouped as follows: i) Martaman group

ii) Amritsagar-Anupam group

iii) Cavendish group iv) Champa group

and v) Miscellaneous group comprising of Kanthali-Kalibow and Bichakala. In this grouping of cultivars, the local Martaman fruits are adjudged the best, followed closely by the Martaman of Madras.
The physico-chemical composition of banana is greatly affected by the season of maturity of the fruit. The two cultivars Champa and Kabuli showed differential interactions with the season of development and maturity of the fruit. The physico-chemical composition of Champa fruits was much better in summer-matured fruits than in those matured in winter. The reverse was true for Kabuli, in which the physico-chemical and edibility characters of the fruit were much superior in winter in comparison to summer. The underlying reasons for this differential behaviour of the two cultivars possibly lie in their respective origins. Champa which is grown here for centuries is very well adapted to tropical climate. Because of its tolerance to the hot climate and poor soil conditions, it has become the most important banana clone of the tropics. On the other hand, Kabuli which belongs to the Cavendish group, originated in the relatively cool subtropical areas of China (Simmonds, 1965), performs better in the cooler climate. The fruits maturing in winter greatly excel those maturing in summer as regards morpho-physico-chemical characters and palatability. This study has great practical significance in the banana cultivation of West Bengal. Presently, little attention is given to the question of fruit bearing pattern of orchards. It would be better to organize planting and other cultural operations in the orchard in such a way that most of the Champa fruits mature in summer while Kabuli fruits would get the cooler winter months for development and maturity.
Developmental Physiology

The development of Champa and Kabuli fruits was very rapid initially and continued till the colour of the skin started to change. The pattern of growth was similar to those noted by earlier workers (Nayar et al., 1958; Wally et al., 1969 and Lodh et al., 1971). The pulp/peel ratio greatly increased with the advance of maturity. The reduction in peel weight may be attributed to the conversion of starch to soluble sugars and their subsequent transfer to the pulp. Due to the conversion of starch in the pulp, sugar concentration greatly increases thereby resulting in a high osmotic pressure. Water is thus withdrawn from the skin and the pulp/peel ratio is further increased (Wardlaw et al., 1939; Lodh et al., 1971 and Lal et al., 1974). The dry matter increased with maturity due to significant increases in carbohydrates, especially, cellulose and starch. Acidity also increased till the time of maximum dry matter accumulation in the fruit most likely due to conversion of hexose sugars to carboxylic acids (Mayer and Anderson, 1955).

The observations on the changes in vitamin C contents, which increased during the first two months of fruit growth and decreased thereafter, are in conformity with those of Harris and Poland (1939) and Lodh et al. (1971). It has been suggested
that net vitamin C concentration is the balance between its synthesis and destruction in the fruit. Further, a relation between the rate of respiration and ascorbic acid content has also been indicated (Harris and Poland, 1939). The rapid decrease in the concentration of starch in late maturity stages, which was not accompanied by corresponding rises in sugars, would also indicate a high rate of respiration of the fruit with consequent utilization of carbohydrates in the process. According to Lodh et al. (1971), the peel at that stage is subjected to mechanical pressure by the expansion in volume of the pulp and the energy requirement is more. The utilization of carbohydrate for the supply of energy is consequently greater and therefore a sharp decrease in starch concentration takes place.

The present studies have indicated that under West Bengal conditions both Kabuli and Champa fruits reach the maturity standard in slightly over 100 days. By about 105 days the skin colour turns light green, the ridges flatten and the fruit becomes more or less round.
Keeping the fruit unharvested, after the optimum time for harvesting, is not advisable because of various practical considerations. The harvest indices for different banana cultivars grown in this State should, therefore, be worked out to standardise the most suitable time of harvest of the fruit.

Developmental physiology of summer and winter Martaman fruits

In the comparative study of physico-chemical and edibility characters of Champa and Kabuli fruits, it has been shown that the composition of the fruit is influenced by the season in which the fruit is matured. Only the harvested fruits were analyzed for the purpose. In the fruit development study, it was considered to be of interest to examine how the developmental pattern of Martaman fruits grown in two seasons is affected. The changes in physical and biochemical characters of fruit were found to be influenced mainly by temperatures during the period of fruit development. The summer-maturing Martaman, however, showed superior physico-chemical and edibility characters than the winter-maturing fruit. This could be explained by the excellent adaptation of Martaman to the hot tropical and subtropical conditions of our State.
Changes in physico-chemical characters during fruit ripening after harvest

The loss of dry matter during the ripening stages was due to an increase in the rate of respiration of the fruits.

Dry matter and pulp/peel ratio

The increase in pulp/peel ratio may also be due to greater increase in respiratory activity of the peel in comparison to the pulp tissue (Lodh et al., 1971).

The very sharp rise in total soluble solids in all the cultivars, which would serve as an index of fruit ripening, might be attributed to a rise in the activities of enzymes participating in the conversion of insoluble reserve polysaccharides to soluble sugars. Maximum acidity was noted during the pre-ripening stages but as the ripening advanced, there was a fall in the total titratable acidity.

A decrease in vitamin C concentration was also noted with the progress of ripening. Similar trends in acidity and vitamin C contents were noted by Miller and Bazore (1945) and Lodh et al. (1971) who related such changes to post-harvest respiratory activity of the fruit.
According to Barnell (1941), due to respiratory demands, there may be an excess production of invertase and starch-splitting enzymes, leading to a high concentration of reducing and non-reducing sugars. Lal et al. (1974) made similar observations and also recorded significant increases in the activity of glutamate-oxalacetate transaminase, glutamate-pyruvate transaminase and aldolase at the climacteric stages of fruit ripening. Young et al. (1975) investigated the biochemical changes during pre-ripening and ripening stages and showed a rapid conversion of starch to glucose and fructose in the post-climacteric stage; phosphorylase was one of the major enzymes participating in the starch-sugar conversion reactions.

There was no change in the contents of total nitrogen and the mineral elements during ripening. The transfer of elements from peel to pulp was not of any major significance in the ripening process of the different cultivars.

Post-ripening changes in the fruit

The studies on post-ripening changes were primarily undertaken to evaluate the keeping quality of the fruits, especially from an export point of view. In all the seven cultivars studied viz. Kabuli, Giant Governor, Lacatan, Martaman,
Amritsagar, Champa and Jurmony Kanthali, there was a progressive decrease in pulp and peel weight with increased pulp-peel ratio. The total soluble solids especially total sugars, titratable acidity and vitamin C concentrations decreased due to breakdown by hydrolytic and respiratory enzymes involved in aerobic and anaerobic respiration of fruit. Nayyar et al. (1958) noted significant accumulation of ethyl alcohol during anaerobic respiration which would give the typical undesirable over-ripening flavour.

Notwithstanding the similar and general trend of changes in physico-chemical characters during the post-ripening stages, certain significant varietal differences could be noticed. The loss of total sugars was maximum in Giant Governor and minimum in Jurmony Kanthali with Champa, Amritsagar and Martaman falling in between. Total soluble solids showed a similar pattern but little varietal differences were noted in respect of proteins and minerals.

These results would suggest that the keeping quality of fruits of Jurmony Kanthali, Champa, Amritsagar and Martaman was better than the fruits of the Cavendish group viz. Giant Governor, Kabuli and Lacatan. The question now is whether we should export these cultivars with a better quality.
For the selection of the right cultivar for export purposes, there are many other considerations viz. the yield potential and fruit quality of the cultivar, management of the crop such as manuring, pest and disease control and cost of production and year-round availability. The cultivar Kanthali, which has excellent keeping quality, is totally unfit for the export market because of poor fruit quality and low production. The cultivar Champa has got good keeping quality and production is also very good but it suffers from the very small size of fruits. The plant is very tall and orchard management is difficult. Martaman has excellent fruit quality and moderate keeping quality but suffers from production deficiencies. The spread of Martaman in this State is seriously affected because of its susceptibility to the Panama disease. Amritsagar is also an excellent cultivar so far as its quality of fruits is concerned but here also the problem is the big size of the plant which makes management practices difficult. It would thus appear that a compromise has to be made between the various factors which determine the acceptibility of the cultivar by foreign customers. With this in view, it may be surmised that suitable steps should be taken to control the Panama disease which is the major handicap of Martaman growers. If this is done, Martaman will definitely prove to be the most acceptable banana for the export trade. Attention should also be given to increase the production of
Amritsagar, which may serve as a partial substitute for Martaman.

For the present, our export programme should include the Cavendish bananas of high production potentialities and efforts should be made to improve their storabilities by suitable physico-chemical methods.