EVALUATION OF SELECTED BANANA (*Musa* spp.) VARIETIES GROWN IN KERALA FOR POSTHARVEST ATTRIBUTES

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Evaluation of selected banana (*Musa* spp.) varieties grown in Kerala for postharvest attributes"** is a bona-fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Certified that this thesis, entitled **"Evaluation of selected banana (*Musa* spp.) varieties grown in Kerala for postharvest attributes"** is a record of research work done independently by **Ms. Reni, M.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Dedicated to

My Parents

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Commit your works to the Lord
And your plans will be established
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Introduction

INTRODUCTION

Banana is one of the most important commercial fruits which occupies the first place amongst the fresh fruits and vegetables in the world trade. Banana, known as 'wonder berry' is one of the popular fruits available to the common man. It forms the staple food of millions of people across the globe, providing a more balanced diet than any other fruit or vegetable. As a diet, banana is filling, easy to digest, nearly fat free, rich source of carbohydrate with calorific value of 67 calories 100 g^{-1} and is free from sodium, making it a salt free diet. It contains various vitamins and therapeutic values for the treatment of many diseases. Owing to its multi faceted uses-from underground stem up to the male flower - it is referred as Kalpatharu (a plant of virtues) (Chadha, 2001).

India ranks first in the production of banana in the world with a total production of 16.81 million tonnes from an area of 0.49 million ha (Singh, 2002). With respect to area and production, it ranks second only to mango in India and contributes 37 per cent of the total fruit production. Banana the premier fruit crop of Kerala is cultivated in an area of 1,06,054 ha with an annual production of 7,69,085 tonnes (FIB, 2004). The humid tropical climate with good rainfall distribution makes it possible to grow this crop almost in every part of Kerala. Easily available round the year unlike the seasonal availability of other tree fruits, high nutritive value and low market price have made banana a unique commodity.

India is endowed with diverse agroclimatic conditions which have encouraged the development and sustenance of a large number of varieties catering to local needs. Despite having such a rich wealth of genetic diversity, very few accessions are being cultivated on a commercial scale, depending upon the agroclimate, local needs and preferences of the region. However, the situation is fast changing with the increasing commercialisation of production in order to meet the growing demand for banana in both domestic and export markets. Consequently, a new thrust is rapidly emerging to identify varieties from the gene pool for better fruit quality parameters and longer shelf life. Achievement of this objective involves screening of accessions for postharvest parameters so as to enable to select varieties with desirable characteristics (Olorunda, 1993).

Despite its high economic importance banana has some special problems as a commercial fruit. Its shelf life is comparatively short, hardly a week in normal tropical conditions. Since bananas are generally eaten only when they are ripe, short shelf life creates serious difficulties for their efficient marketing particularly when markets are located at a long distance from the production area and results in heavy postharvest loss.

The losses during transport, wholesale and retail storage of banana are much greater than other fruits. A combination of high perishability, high ambient temperature, slow marketing systems and poor market conditions lead to losses in fruit quality and ultimately to postharvest losses. Postharvest management is essentially required to be improved for better return and reduced losses (Singh, 2002). The application of refrigeration is a method commonly used to extend the storage life of many commodities. However, reducing the temperature during prolonged storage periods is limited by the susceptibility of banana to chilling injuries and abnormal ripening due to its tropical nature. Since the total produce in India is mainly handled at ambient temperature, proper storage of this delicious fruit is essential during its postharvest operations.

For developing countries like India, less expensive and cost effective postharvest methods are needed to be evolved. Effective methods followed to extend shelf life of fruits include different precooling treatments, use of chemicals such as ethylene absorbents, wax emulsion coatings and fungicides. Methods combining the use of polyethylene bags with ethylene absorbents, fungicides and other chemical dip treatments which retard the ripening process are comparatively cheaper and can be widely adopted. The use of modified atmosphere storage of bananas has considerable potential as an inexpensive means for prolonging the life of the fruit (Scott, 1975).

In the recent years a modernisation in marketing of fruits is evident, with the introduction of increasing number of supermarkets in Kerala. There is a growing demand for fresh banana in gulf market also. The banana export trade is expected to expand and become a year round feature and capture markets in most of the foreign countries. It is, therefore imperative to find out ways and means to reduce the spoilage during the postharvest period. Hence developing a suitable packaging and postharvest handling system for retail marketing in domestic market and for export of commercial varieties of banana in Kerala is highly essential.

Banana is an ideal fruit for processing on account of its year round availability, comparatively cheaper price and its suitability for development of a wide range of processed products. Only a negligible proportion of banana produced is processed. The most popular processed product is Nendran chips, which is still in cottage scale while some bigger manufacturers are processing banana puree for export. However, there is scope for converting bananas into several other processed products like figs, jam, jelly, powder, flour, baby food, health drink, RTS beverages, wine, alcohol, sauce, pickles, chutneys, animal feed, fibre etc. Hence, identification of varieties with ideal postharvest attributes assumes importance.

The state of Kerala is blessed with a wide array of banana varieties with specific regional preferences and commercial importance. However, information on systematic postharvest characterization of these banana accessions is lacking. Long shelf life is a beneficial attribute in postharvest handling and marketing of banana, especially in those oriented for export market. In banana, the onset of climacteric is an irreversible process. Therefore, commercial exploitation of longer shelf life attribute of banana cultivars can significantly reduce the losses occurring in the post ripening phase.

A thorough knowledge of the postharvest behaviour of banana is a prerequisite for adopting any technology to extend shelf life and minimise postharvest loss in banana. In this context the present study was taken up with the following objectives:

1. To evaluate banana varieties for postharvest attributes.
2. To study physical, chemical and physiological changes during postharvest period in banana.
3. To study the effect of postharvest treatments on extension of shelf life of banana.
4. To study the effect of packaging on shelf life of banana varieties.

Review of Literature

2. REVIEW OF LITERATURE

Banana is grown on commercial scale in India and has gained popularity in International fruit trade. The postharvest life of banana is very short and it creates problem when marketed in distant places from the production centre and bulk amount of fruit is spoiled. Therefore, suitable measures are necessary to extend the storage life to avoid postharvest loss in banana. The present studies were, therefore conducted with a view to evaluate the banana varieties for better postharvest attributes, study the ripening behaviour and the effect of different postharvest treatments and packaging materials on storage and quality of banana. The literature related to these aspects has been reviewed in this chapter.

2.1 EVALUATION OF BANANA VARIETIES FOR POSTHARVEST ATTRIBUTES

2.1.1 Physical characters

2.1.1.1 Fruit weight

Tripathi *et al.* (1981) studied four banana varieties and reported that physical characters of the fruit varied widely among varieties, weight of the fruits ranged from 81.6 g to 222.5 g. Uma *et al.* (1999) reported variation in fruit weight between cultivars Jahaji, Malbhog and Neypoovan. Studies conducted by Sabeena (2000) revealed that the weight of the fruit ranged from 35 g for Njalipoovan to 153.3 g for Monthan. According to Almazan (1991) average finger pulp weight was higher in plantains than in cooking bananas.

2.1.1.2 Pulp:Peel ratio

Desai and Deshpande (1978) reported that pulp:peel ratio was highest in Rasthali and lowest in Dwarf Cavendish. According to Tripathi *et al.* (1981) pulp to peel ratio in four banana varieties varied from 1.0 to 3.4. Sen *et al.* (1982) studied three varieties of edible banana, Champa, Kabuli and Martaman and reported that the pulp:peel ratio of the three varieties varied from 1.3 to 1.9.

In studies with Robusta banana, Krishnamurthy (1989) reported a pulp:peel ratio of 1.5 at optimum maturity. Burdon *et al.* (1993) reported that the ratio of fruit pulp to fresh peel weight differed between cultivars from 1.18 to 2.28 in plantain and cooking banana. In studies with banana cv. Neypoovan, Kumar *et al.* (1998) reported a peel:pulp ratio of 1:7.72.

Ngalani *et al.* (1998) reported that pulp/peel ratio varied from 2.43 to 3.76 in banana cultivars. Pulp:peel ratio reported by Uma *et al.* (1999) in cultivars Jahaji, Malbhog and Neypoovan were 4.81, 4.53 and 4.40 respectively. On evaluation of banana varieties, Sabeena (2000) reported that the pulp/peel ratio of banana in the raw stage ranged from 0.60 to 2.40 in Palayankodan and Kadali respectively.

2.1.1.3 Fruit firmness

Desai and Deshpande (1978) observed a fruit firmness of 1.69 kg cm^{-2} in Chakkarakeli and 2.24 kg cm^{-2} in Dwarf Cavendish. In Robusta banana, Krishnamurthy (1989) reported a firmness of 12 kg cm^{-2} at optimum maturity.

Pulp hardness in banana cultivars as reported by Ngalani *et al.* (1998) varied from 0.31 to 0.45 kg cm^{-2}. Silva *et al.* (1998) observed that 'Nanicao' and 'Caipira' varieties showed greater fruit firmness during ripening whereas 'Mysore' and 'Prata Ana' showed the lowest rates. According to Ngalani *et al.* (1999) the firmness of the varieties evaluated differed significantly (1.1 to 1.9 kg cm^{-2}). Sabeena (2000) found that the firmness of the fruit ranged from 1.43 kg cm^{-2} in Palayankodan to 4.06 kg cm^{-2} in Nendran.

2.1.2 Chemical constituents

2.1.2.1 TSS

Sheela (1982) reported a total soluble solids of 26.76°brix in Palayankodan. Significant variation in the TSS in Palayankodan accessions was reported by Rajeevan (1985). In studies carried out at Banana Research Station, Kannara significant variation in the TSS was observed in Nendran clones (KAU, 1987).

Syamal and Mishra (1989) reported that TSS content in variety Champa and Malbhog varied from 20.7 to 24.5°brix. Charles *et al.* (1993) observed a TSS content of 19.5°brix in Poovan. In Nendran banana Anil (1994) obtained a TSS of 22.2 per cent.

Rajamony *et al.* (1994) in an experiment with 27 banana clones of genomic group AAB noticed that total soluble solids content varied from 22 per cent in Mottapoovan to 30 per cent in Kodapanillakunnan. According to Ram *et al.* (1994) TSS content of banana varieties ranged from 14.1 to 14.3 per cent. Comparison of varieties Dwarf Cavendish, Champa and Patakapura for TSS content revealed a high value for TSS in the variety Patakapura (Das *et al.*, 1996). Agrawal *et al.* (1997) observed a total soluble solids content of 21.2°brix in Robusta variety.

In Nendran variety Ancy (1997) reported a TSS content of 26.75 per cent and Deepa (1997) a TSS content of 29.13 per cent. Studies with cv. Borjahaji (AAA) Deka and Harmine (1997) revealed a TSS of 11.5 per cent. Kumar *et al.* (1998) reported a TSS content of 29.4°brix in banana cv. Neypoovan. Ngalani *et al.* (1998) found that the total soluble solid content in banana cultivars varied from 6.6 to 5.2°brix.

On evaluation of 67 accessions of banana Shivashanker (1999) reported that the TSS varied from 17.4 (Kanai Bansai) to 29.3 (Malbhog). In banana cultivars Jahaji, Malbhog and Neypoovan Uma *et al.* (1999) reported a TSS of 23.92, 25.08 and 28.6°brix respectively. The total soluble solids content ranged from 10.67° brix (Monthan) to 22.67°brix in Karpooravalli (Sabeena, 2000).

2.1.2.2 Acidity

In studies with Dwarf Cavendish, Rasthali and Chakkarakeli, Desai and Deshpande (1978) found that acidity was highest in Rasthali (5.79 meq 100 g^{-1}) and lowest in Dwarf Cavendish (3.89 meq 100 g^{-1}). The acidity in Palayankodan fruits as estimated by Sheela (1982) was 0.502 per cent. Significant variation in acidity was observed in Nendran clone (KAU, 1987) in studies carried out at Banana Research Station, Kannara.

Syamal and Mishra (1989) reported that the titrable acidity in Rajavazhai and Malbhog was 0.18 per cent. The acidity in Poovan as evaluated by Charles *et al.* (1993) was 0.58 per cent. Rajeevan and Mohanakumaran (1983) reported 0.3 to 0.48 per cent acidity in four plantain cultivars cultivated in Kerala. On evaluation of Dwarf Cavendish, Champa and Patakapura, Das *et al.* (1996) opined that highest values for titrable acidity was in cultivars Dwarf Cavendish and Champa.

Agrawal *et al.* (1997) reported an acidity of 0.48 per cent in Robusta. In Nendran variety Ancy (1997) observed an acidity of 0.354 per cent. Deka and Harmine (1997) found that in fruits of cv. Borjahaji (AAA) the titrable acidity was 0.4 per cent.

Shivashankar (1999) reported that the acidity in banana accessions ranged from 0.4 per cent to 1.1 per cent. Uma *et al.* (1999) estimted the acidity in the cultivars Jahaji, Malbhog and Neypoovan as 0.46, 0.43 and 0.41 per cent respectively. The acidity in banana varieties ranged from 1.44 per cent in Karpooravalli to 0.15 per cent in Nendran as reported by Sabeena (2000). Shivashankar (2003) reported an acidity of 0.48 per cent in Neypoovan banana on ripening.

2.1.2.3 Total, reducing and non reducing sugars

Ketiku (1973) reported 17.3 per cent total sugar content in ripe banana pulp. Total sugar content in Chakkarakeli was 8.54 per cent and Rasthali 7.34 per cent as reported by Desai and Deshpande (1978). In Palayankodan fruits according to Sheela (1982) total sugar was 14.85 per cent, reducing sugar 13.82 per cent and non-reducing sugar 1.03 per cent. According to Rajendran (1983) the total sugar content in Palayankodan was 15.82 per cent with reducing sugar 15.07 per cent and 0.77 per cent of non reducing sugar.

Chacon *et al.* (1987) reported that the pulp of ripe banana contains 15-20 per cent sucrose, fructose and glucose. Krishnamurthy (1989) observed a total sugar content of 18.2 per cent in Robusta. In varieties Champa and Malbhog total sugar content varied from 19.2 to 21.1 per cent (Syamal and Mishra, 1989).

Investigations by Kanagaratnam *et al.* (1990) indicated found that Kappal had the highest total sugar content of 28.33 per cent while Kathali and Etharai had significantly higher reducing sugar of 16.38 per cent and 17.33 per cent respectively. Charles *et al.* (1993) observed a total sugar of 13.75 per cent, reducing sugar 12.67 per cent and non-reducing sugar 1.08 per cent in Poovan. In cooking banana Suntharalingam and Ravindran (1993) reported a total sugar content of 2.8 per cent.

Evaluations by Anil (1994) revealed that a total sugar of 26.13 per cent, non-reducing and reducing sugar content of 8.52 per cent and 17.62 per cent respectively in Nendran banana. In Robusta variety of banana Agrawal *et al.* (1997) observed a reducing sugar and total sugar content of 11.6 per cent and 16.4 per cent respectively. In Nendran variety Ancy (1997) reported a reducing sugar 12.86 per cent, non-reducing sugar 1.549 per cent and total sugar content 14.46 per cent.

The total, reducing and non-reducing sugar content in the variety Nendran as reported by Deepa (1997) was 20.53 per cent, 15.29 per cent and 5.15 per cent respectively. According to Ghosh *et al.* (1997) the total sugar content in the variety Champa was 20 per cent.

In studies with Nendran banana Sindhu (1999) observed that the fruits had 11.79 per cent reducing sugar. 2.51 per cent non-reducing sugar and 14.3 per cent total sugar. Sabeena (2000) evaluated banana varieties for their chemical constituents and observed that the total sugar content varied from 14.13 per cent to 21.73 per cent, reducing sugar 13.38 per cent to 20.9 per cent and non-reducing sugar content 0.51 per cent to 1.53 per cent.

Chadha and Dass (2002) reported that ripe banana fruits had 3.6 to 24.6 per cent reducing sugars and 0 to 14.6 per cent non-reducing sugars. Studies conducted by Balamohan *et al.* (2002) on cooking bananas revealed that Pisang Nangka had highest sugar content and Pisang Abu the lowest on ripening.

2.1.2.4 Moisture

Ketiku (1973) reported that the moisture content of Cavendish banana is 75 per cent while that of plantains is only 60 per cent. According to Marriott (1980) the plantain and banana pulp contain about 60 and 70 per cent moisture respectively.

Chadha (1992) reported a moisture content of 70 per cent in ripe bananas. In fruits of cv. Borjahaji (AAA) at maturity the moisture content was 75 per cent (Deka and Harmine, 1997). Rao (1999) opined that the major differences between plantain and banana are that the plantain contain lower moisture percentage.

The moisture content in the banana varieties ranged from 61.00 per cent (Njalipoovan) to 77.23 per cent (Red Banana) (Sabeena, 2000). In ripe banana fruits the moisture content as reported by Chadha and Dass (2002) was 60.6 to 79.8 per cent.

2.1.2.5 Vitamin C

Patil and Magen (1976) reported that banana contained several important vitamins like thiamine, niacin and ascorbic acid. Desai and Deshpande (1978) reported an ascorbic acid content of 7.94 mg 100 g^{-1} in Rasthali and 1.56 mg 100 g^{-1} in Dwarf Cavendish. Akinyele and Keshimo (1980) reported that Paranta variety had a vitamin C content of 9.4 mg 100 g^{-1} of edible portion.

Villalonga (1981) estimated the vitamin C content in the cultivars - Pineo Gigant, Pineo Euano, Pineo Martenico, Martenico Cryaco, Manzana Topocho and Cenizo and found that ascorbic acid ranged from 1.20 to 2.66 mg 100 g^{-1}. Investigations by Dube (1988) revealed that ripe banana contains 7 mg 100 g^{-1} of vitamin C. Chadha (1992) reported eleven vitamins including A, B and C in ripe banana. Suntharalingam and Ravindran (1993) reported a vitamin C content of about 9 mg 100 g^{-1} on dry basis. In Nendran banana Anil (1994) observed an ascorbic acid content of 9.37 mg 100 g^{-1}.

Das *et al.* (1996) found that highest values for ascorbic acid was in the cultivars Dwarf Cavendish and Champa. Deepa (1997) reported a vitamin C content of 3.07 mg 100 g^{-1} in Nendran banana. According to Ghosh *et al.* (1997) the ascorbic acid content in the fruit of the Champa variety was 4.4 mg 100 g^{-1} of the pulp. Rao (1999) observed a vitamin C content of 32 mg 100 g^{-1} in ripe banana. Sabeena (2000) observed that highest vitamin C content was in Robusta (11.33 mg 100 g^{-1}) and lowest in Nendran (6.8 mg 100 g^{-1}).

In ripe banana fruits Chadha and Dass (2002) reported a vitamin C content of 5 to 17 mg 100 g^{-1}. In Nendran banana Menon and Peter (2002) reported an ascorbic acid content of 7 mg 100 g^{-1}.

2.1.2.6 *β Carotene*

Villalonga (1981) reported that the vitamin A content in the cultivars Pineo Gigant, Pineo Enano, Pineo Martenico, Martenico Cryaco, Manzana Topochs, Cenizo ranged from 0.02 to 0.38 mg 100 g^{-1} except for Titiaro with 1.09 mg 100 g^{-1} of vitamin A. Dube (1988) observed in ripe banana a carotene content of 78 μg 100 g^{-1}. Sabeena (2000) reported highest β-carotene in Nendran (333.6 μg 100 g^{-1}) followed by Palayankodan (287 μg 100 g^{-1}). Chadha and Dass (2002) reported in ripe banana a carotene content of 8 to 470 IU.

2.1.2.7 *Tannin*

Tannins impart astringency to fruits. Dopamine represents about 80 per cent of the tannin in the pulp at harvest (Robinson, 1996). According to Chadha and Dass (2002) mature banana fruit just beginning to ripen contain 1.52 to 1.66 per cent tannins.

2.1.2.8 *Pectin*

Desai and Deshpande (1978) reported a pectin content of 0.25 per cent in Dwarf Cavendish and 0.22 per cent in Chakkarakeli. Robinson (1996) reported that ripe pulp contains 0.5 to 0.7 per cent pectin. In cv. Borjahaji (AAA) Deka and Harmine (1997) observed a pectin content 0.8 per cent.

2.1.2.9 *Starch*

According to Ketiku (1973) starch content of the unripe and ripe pulp was found to be 83.2 and 66.4 per cent respectively on dry weight basis. The author also reported that plantains even when ripe are much starchier than ripe banana. In plantains 66 per cent of the solids are starch. In another study on banana, Ketiku (1976) reported that the starch content of the cultivar Omini was 5.2 per cent and

Paranta 2.9 per cent. Starch content in Chakkarakeli and Rasthali as reported by Desai and Deshpande (1978) was 9.74 per cent and 9.01 per cent respectively.

Chacon *et al.* (1987) observed 17.7 per cent of starch in green banana. Investigations by Dube (1988) revealed that ripe banana contains 1 to 2 per cent starch. About 70 per cent starch was reported in cooking banana by Suntharalingam and Ravindran (1993). Starch content in banana varieties ranged from 0.98 per cent in Red Banana to 2.77 per cent in Kadali (Sabeena, 2000).

2.1.3 Shelf life

Krishnamurthy (1989) reported that at room temperature, Robusta fruits reached ripeness in 16 days. Sarkar *et al.* (1995) in a study on shelf life of banana cv. Giant Governor (AAA group), found that the PLW was higher during the earlier period of storage (0 to 7 days) as compared to the periods thereafter.

Studies on storage behaviour of three commercially important banana cultivars (Dwarf Cavendish, Champa and Patakapura) revealed that Dwarf Cavendish had minimum PLW and longest shelf life. With respect to marketability both Dwarf Cavendish and Champa were found to be statistically on par on the eighth day of storage. The fruits of cv. Dwarf Cavendish took more time to come to edible maturity compared to other varieties (Das *et al.*, 1996).

Seberry *et al.* (1998) reported that FHIA-01 (SH-3481) known as Gold finger and Lady finger (Pome, AAB) had longer shelf life after ripening than Williams (Cavendish, AAA) but Gold finger fruits softened more slowly than the other two cultivars. There was a low incidence of ripe fruit rots in Gold finger.

Silva *et al.* (1998) evaluated the postharvest ripening characteristics of the banana genotypes for enhanced shelf life. They observed that 'Nanicao' and 'Caipira' varieties showed greater fruit firmness during ripening whereas 'Mysore' and 'Prata Ana' showed the lowest rates.

On evaluation of 67 accessions of banana for shelf life and quality parameters. Shivashankar (1999) reported that there was large variations in green life and shelf life among the accessions. The PLW varied from 1.81 per cent (Gros Michel) to 22.26 per cent (Chenkadali), green life two days (Anai Komban) to 18 days (Chenkadali) shelf life two days to 10 days (Malbhog).

2.2 PHYSICAL, CHEMICAL AND PHYSIOLOGICAL CHANGES DURING POSTHARVEST PERIOD IN BANANA

2.2.1 Physical changes

2.2.1.1 Pulp : peel ratio

Almazan (1991) studied changes in cooking banana and plantain cultivars during ripening and reported that average finger pulp weight was higher in plantains than in cooking bananas and it increased in plantains but decreased in cooking bananas during ripening. Pulp:peel ratio increased during ripening and was highest in cv. Fougamon (cooking banana).

Biochemical studies in banana fingers (*Musa paradisiaca* spp.) revealed that pulp:peel ratio in mature fruits was 1.31 and ripe fruits 3.1. The sharp increase in pulp to peel ratio in ripe fruits may be due to the transportation of some components from peel to pulp (Singh *et al.*, 1980). Tripathi *et al.* (1981) reported an increase in pulp/peel ratio in banana during ripening.

Sen *et al.* (1982) studied the physico-chemical changes in three varieties of edible banana, Champa, Kabuli and Martaman. All the three varieties showed a similar pattern with their fresh weight decreasing at a higher rate in the earlier period followed by a steady rate for the subsequent periods. The pulp:peel ratio of the three varieties of banana varied from 1.3 to 1.9 after harvest and at ripe stage increased to 2.7 to 2.8.

Fresh peel ratio in the green unripe fruit was in the range 1.22-1.68 and increasing to 2.3-2.6 at advanced ripeness (Asedu, 1987). Pulp/peel ratio increased from 1.5 to 3.0 on ripening in Robusta fruits (Krishnamurthy, 1989). Studies by Gheyas and Haque (1989) found that the pulp:peel ratio increased during ripening in banana varieties.

Firmin (1991) reported that in plantains the fruit weight, pulp weight, peel weight decreased during ripening. The pulp to peel ratio increased from 1.08 to 6.7 in ripe fruits. According to John and Marchal (1995) the change in the pulp peel fresh weight ratio which increases by 40 per cent as the fruit ripens is put forward to support the idea of water movement. Ngalani *et al.* (1998) reported that in banana pulp to peel ratio significantly increased from stage 1 (mature green fruit) to stage 7 of ripeness (fully yellow with black spots). The average peel thickness was reduced from 3.1 mm in mature green plantain to 2.6 mm in yellow plantain (Firmin, 1991).

2.2.1.2 Fruit firmness

Progressive loss in the firmness in the course of banana ripening was observed by Sen *et al.* (1982). Krishnamurthy (1989) reported that in Robusta banana firmness decreased from 12 kg cm^{-2} to 1.0 kg cm^{-2} on ripening. Ngalani and Tchango (1998) reported that the pulp hardness or firmness significantly decreased on ripening. The rate of weight loss of fruits of French Clair and IRFA 904 was highest (22.8 to 25.0%) compared to other hybrids and cultivars which varied from 12.6 to 16.8 per cent.

According to Peacock (1980) an early part of the ripening process is the softening of the fruit. This happens partly because of loss of water from the peel but primarily because of the changes in the chemistry of cell walls.

2.2.1.3 Moisture content

Significant increase in moisture percent during ripening was reported by Gheyas and Haque (1989). Ripening increases the water concentration in the pulp of Giant Cavendish bananas from 73 to 82 per cent (Marchal *et al.*, 1998).

2.2.2 Chemical changes

According to Aravindakshan (1981) biochemical constituents in banana during the postharvest period of ripening and storage varied considerably with respect to variety, specific situation, time of harvest, method of ripening and storage conditions. Seymour *et al.* (1987) and Semple and Thompson (1988) reported that

Cavendish banana cultivars can fail to completely degreen when they are ripened at 25°C above resulting in fruit which are ripe in every other aspect but remaining green.

2.2.2.1 TSS

Gheyas and Haque (1989) evaluated four banana varieties *viz.* Amritsagar, Sabri, Champa and Japkathali and reported that TSS increased significantly during ripening. Jha *et al.* (1990) reported that during ripening many qualitative changes occur within the fruit including significant increase in total soluble solids from stage 1 to 7 of ripeness. Investigations by Munasque and Mendoza (1990) indicated that TSS content increased as the fruit ripened.

Significant increase in TSS was observed by Ngalani *et al.* (1998) on ripening of banana. Prabha and Bhagyalakshmi (1998) conducted studies in ripening banana cv. Robusta and reported that the total content of soluble sugars increased from 1.8 to 19 per cent during ripening. Ngalani *et al.* (1999) observed significant increase in TSS of banana pulp from stage 1 to 5 of ripening.

2.2.2.2 Acidity

Studies conducted on banana varieties by Sen *et al.* (1982) revealed that acidity increased as the fruit ripened and the degree of increase was higher in the variety Champa than in Martaman or Kabuli. Manay and Shadaksharaswamy (1987) opined that acid content of most fruit decrease as the fruit ripens resulting in changes in the pigment of some fruits. In Robusta, titrable acidity increased from 0.15 to 0.4 per cent followed by a decline (Krishnamurthy, 1989). During ripening titrable acidity decreases to a minimum (Jha *et al.*, 1990).

Investigations on ripening behaviour of 'Senorita' banana by Munasque and Mendoza (1990) indicated that titrable acidity decreases on ripening. They also reported that titrable acidity increased until colour index 3 (more green than yellow) and then declined as the fruit turned yellow in colour. Almazan (1991) studied chemical changes in cooking banana and plantain cultivars during ripening and reported that increase in total acid content during ripening was greater in plantains than in cooking bananas. Firmin (1991) reported that ripening increased total acidity of the pulp from 2.55 m eq 100 g^{-1} in mature green plantains to 5.13 m eq 100 g^{-1} in ripe plantains but then decreased to 4.4 m eq 100 g^{-1} in very ripe plantains.

2.2.2.3 *Total, reducing and non reducing sugars*

Sen *et al.* (1982) reported that the sugar content increased in the ripening fruit and the increase in sugar contents was comparatively much higher between three to six days than between zero to three days in storage. Total sugar and reducing sugar content were 1.32 and 0.52 per cent respectively in unripe bananas and 19.7 and 10.3 per cent in the ripe fruit (Chacon *et al.*, 1987). In studies with banana cv. Prata, Carvalho *et al.* (1988a) reported that total sugars increased from 0.95 to 1.3 per cent in green fruits to 18.23 to 19.03 per cent during ripening.

On ripening of Robusta banana the total sugars increased from 0.8 to 18.2 per cent (Krishnamurthy, 1989). Lizada *et al.* (1990) and Munasque and Mendoza (1990) also reported that total sugar content increased on ripening.

Firmin (1991) observed that sugar levels increased during ripening from 1.38 per cent in mature green fruits to 75.5 per cent in very ripe plantains. Investigations by Ni and Eads (1993) showed that during ripening from the green to the ripe yellow stage the sucrose, fructose and glucose concentrations increased from 2.2 to 8.5 per cent FW, 0.5 to 5.3 per cent FW and from 0.4 to 4.3 per cent FW respectively. Ngalani *et al.* (1999) observed a significant increase in reducing sugar content on ripening of banana.

2.2.2.4 *Chlorophyll content*

Seymour *et al.* (1987) reported that chlorophyll is present in the peel at concentration of 12.13 mg cm^{-2} of the fruit surface in banana and plantains. During ripening the chlorophyll in the peel degrades revealing the yellow carotenes and xanthophylls. The pulp of normal preclimacteric bananas at the time of harvest is creamy white or pale yellow in colour. As it ripens, the pulp becomes more yellow in colour (Wainwright and Hughes, 1990).

Postharvest changes during ripening of banana was studied by Wasker and Roy (1992). They reported that the change in the colour of the banana peel from green to yellow is the most obvious change which occurs during postharvest life of a fruit. The green banana peel contains about 50 to 100 μg g^{-1} fruit weight chlorophyll. During ripening all the chlorophyll is lost and total yellow pigments remain approximately constant.

2.2.2.5 Starch

Biochemical studies in banana fingers (*Musa paradisiaca* spp.) revealed that the starch content at mature stage was 88 mg g^{-1} whereas in ripe fruit it was 57 mg g^{-1}. The decrease on ripening indicates a rapid change in carbohydrate metabolism during ripening (Singh *et al.*, 1980). Marriot *et al.* (1981) and George (1981) reported that starch hydrolysis with formation of sucrose, glucose and fructose is slower in plantains and less complete than in bananas even when the fruit is fully soft and yellow.

Terra *et al.* (1983) found that starch concentration, sequence of appearance of sucrose, glucose and fructose, activity of some enzymes of sucrose synthesis were followed during ripening of preclimacteric bananas. As starch was degraded sucrose content increased and preceded formation of glucose and fructose. At the same time, while UDP-glucose pyrophosphorylase activity remained constant, activity of sucrose synthetase and invertase increased. The observed sugar and enzyme changes indicated that starch to sucrose transformation via, glucose-1-phosphate-UDP-glucose may be an important mechanism for starch disappearance during ripening.

The starch content was 17.7 per cent in green bananas and 0.82 per cent in ripe bananas (Chacon *et al.*, 1987). Manay and Shadaksharaswamy (1987) reported that starch content was relatively high in unripe fruit but it changes to sugar in ripe fruits. Carvalho *et al.* (1988a) reported that in banana cv. Prata, the starch content fell from 19.2-21.9 per cent to 2.1-3.0 per cent.

According to Lizada *et al.* (1990) the most striking chemical change during ripening is the hydrolysis of starch to simple sugars. They also reported that in dessert banana there is reduction in starch content on ripening from around 15-25 per cent to less than 5 per cent in ripe pulp. Decrease in starch content on ripening of 'Senorita' banana was also reported by Munasque and Mendoza (1990). Studies of Almazan (1991) revealed that sugar formation from starch was greater in plantains during ripening, and conversion slowed down in cooking bananas at full yellow peel stage.

Decrease in starch content from 77.5 per cent to 2.09 per cent on ripening of banana was reported by Firmin (1991). Investigations by Ni and Eads (1993) showed that rigid components, mostly starch during ripening of banana decreased from 20 per cent FW at the mature green stage to 2.0 per cent FW in the ripe yellow stage. Clendennen and May (1997) reported that fruit ripening is accompanied by a massive conversion of starch to sugars. Prabha and Bhagyalakshmi (1998) and Ngalani *et al.* (1999) observed a decrease in starch content during ripening of banana.

2.2.2.6 Tannin

Dhua and Sen (1989) reported that active tannin contents of the pulp and peel of the Giant Governor banana was larger at the early stages of fruit development but declined with maturity. The pulp contained more active tannin than the peel in the early stages of fruit development. But active tannin content in the pulp fell steadily with maturity while the peel retained a relatively larger amount of tannin. Krishnamurthy (1989) found that total tannins increased gradually with a slight peak of 160 mg 100 g^{-1} pulp around 13 to 16 days followed by a decline in Robusta. Investigations by Chang and Hwang (1990a) revealed that during ripening of banana, tannin was translocated from the peel to the flesh where it was mobilised by PPO.

Almazan (1991) reported that tannins were higher in plantains and did not change significantly during ripening except in Bluggoe bananas (cooking). Wasker and Roy (1992) studied postharvest changes during ripening of banana and reported that the banana pulp tannins decreased in the ripe fruit to about one fifth of the value in the green, preclimacteric fruit. Mustaffa *et al.* (1997) studied the changes in tannins in Cavendish banana and reported that there was a significant difference in the tannin content between different portions of hands within a bunch and between different fingers within a hand during maturity.

2.2.2.7 *Pectin*

Kojima *et al.* (1994) reported that pulp softening was related to the sequential degradation of starch and pectic and hemicellulosic polysaccharides in pulp cell walls. The cellulose content of the pulp did not change. Another study on softening of banana was carried out by Kojima (1996). Results of chemical analysis revealed that the partial breakdown characterised by a decrease in arabinose, mannose and galactose contents in the hemicelluloses of the cell wall preceded the break down of starch. These observations suggested that the associated process whereby the contents of pectic and hemicellulosic polysaccharides and starch decrease is the main cause for the pulp softening process. The results suggested that cell wall polysaccharides, pectin and hemicelluloses, rather than starch, were the chemical components responsible for the changes in the firmness of the pulp.

Mustaffa *et al.* (1997) studied the changes in pectic substances in Cavendish banana and reported that pectins increased at the early stages, reaching a maximum at week 12 and then slowly decreased.

Prabha and Bhagyalakshmi (1998) conducted studies on the carbohydrate metabolism in ripening fruit of cv. Robusta and reported that starch and pectic fractions decreased considerably in ripe fruit pulp.

2.2.3 Physiological changes

2.2.3.1 *Enzyme activity*

Desai and Deshpande (1977) reported that the relative activities of five hydrolytic and oxidative enzymes *viz.*, α-amylase, starch phosphorylase, acid phosphatase and catalase increased markedly in bananas during ripening. Desai and Deshpande (1978) reported α-amylase activity of 1.69 mg g^{-1} and 0.49 mg g^{-1} in Chakkarakeli and Rasthali respectively. Associated with the carbohydrate changes during banana ripening Terra *et al.* (1983) observed increase in activity of ∝ and β-amylase, invertase and phosphorylase.

Desai *et al.* (1984) investigated the hormonal regulation of some hydrolytic and oxidative enzymes during ripening of three cvs. of banana *viz.* Pachabale, Rasabale and Rajabale and reported that the activities of enzymes were much lower in Rasabale than in the other two cultivars. Manay and Shadaksharaswamy (1987) reported that during ripening of the fruit the enzymes bring about changes such as softening of the edible portion, changes in colour, carbohydrate and flavour.

Nabeesa and Unnikrishnan (1988) observed that in Red Banana ∝-amylase and invertase activity increased at the time of rapid increase in total sugars during ripening. Chang and Hwang (1990b) determined the enzyme activity of *Musa accuminata* at different seasons and found that amylase activity was significantly higher in the spring.

Prabha and Bhagyalakshmi (1998) reported that amylase, cellulase, hemicellulase, pectinesterase activity increased with ripening. They also opined that pectinase may play a more dominant role in softening than cellulase in banana fruits during ripening. Amylase, xylanase and laminarinase may also contribute to loosening of cellular structures.

2.2.3.2 Respiration

Associated with banana ripening Hyodo *et al.* (1983) observed a rise in ethylene production and respiration climacteric. Terra *et al.* (1983) reported that the fruit entered the ripe edible state at or shortly after the respiratory peak. Mas banana fruits exhibited a respiratory climacteric peak when the fruits were allowed to ripen at an ambient temperature of 28°C for 7 days after harvesting (Tan *et al.*, 1990).

In a study on differential protein accumulation in banana fruit during ripening it was found the ripening process in banana begins with an increase in respiration and ethylene production. The carbondioxide production peak appears about one day after the ethylene peak. It subsequently declined as the fruit entered the post climacteric period (Puigjaner *et al.*, 1992).

Wasker and Roy (1992) reported that the ripening of banana fruits exhibit a climacteric pattern of respiration. After harvest a steady value of about 20 mg CO_2 kg^{-1} hr^{-1} in the hard green fruit rises to about 125 mg CO_2 kg^{-1} hr^{-1} at the climacteric peak and then falls to about 100 mg CO_2 kg^{-1} hr^{-1} as ripening proceeds. Preclimacteric respiration rates vary from 60 to about 250 mg CO_2 kg^{-1} hr^{-1}. The increase from preclimacteric to climacteric varies from four to ten folds.

Zhang *et al.* (1993) observed that the climacteric peak and the peaks of ethylene production of banana fruits appeared 14 days earlier at 30°C than at 20°C. Clendennen and May (1997) reported that banana fruit ripening is associated with a burst of respiratory activity. Maneerat *et al.* (1997) determined the respiration rates of bananas and reported that temperature dependence of the respiration rate constants followed Arrhenius type relationship. Padmavathi and Reddy (2002) found that the total respiration reached a peak on 9th day in Dwarf Cavendish banana.

2.3 STANDARDISATION OF METHODS TO ENHANCE SHELF LIFE OF VARIETIES

2.3.1 Effect of postharvest treatments on extension of shelf life of banana

2.3.1.1 Hot water treatment

Armstrong (1982) found that a 15 minute 50°C hot water immersion treatment of Brazilian variety bananas to control fruit flies, disinfested bananas without detriment to either fruit quality or shelf life. Ripening of the 50°C immersed fruit was delayed by 24 to 32 hrs. This delay in ripening may have been the result of temporary cessation of the normal ripening system physiology caused by the heat itself.

Frith and Chalker (1983) conducted experiments on hot water treatment of banana fruit. Mature green banana fruits when immersed in water at 50°C for 20 minutes remained hard green after 4 days whereas control fruits had started to turn yellow. Treated fruits were still green after 14 days when the controls were over ripe.

However, the 50°C/15 minutes and 54°C/20 minutes treatments caused some blackening. The 50°C/15 minutes and 54°C/10 minutes treatments appeared to give the greatest reduction in ripening without affecting fruit quality. Sarkar *et al.* (1995) reported that in the fruits treated with hot water at 52°C the PLW was 8.8 per cent, TSS content minimum and acidity higher.

The results of hot water dips indicated that temperature of 45 to 47.5°C and immersion times of 15 to 30 minutes could effectively control banana crown rot caused by *Fusarium* and *Colletotrichum*. Lower temperature and shorter times also have a positive effect. Temperature above 50°C caused peel darkening and incomplete soluble solids accumulation (Cabrera *et al.*, 1998).

Dominguez *et al.* (1998) reported that temperature below 50°C caused a delay in peel colour development, but did not affect soluble solids accumulation. Temperature in the range 50-55°C caused peel darkening, incomplete soluble solids accumulation and increased chilling sensitivity of the fruits. Disruption of the normal ACC oxidase activity of peel and pulp appeared to be involved in these responses.

A 45°C hot water treatment for 20 minutes reduced crown rot caused by *Chalara paradoxa* from 100 per cent to less than 15 per cent. When fruits were exposed to hot water at 50°C for 20 minutes, crown rot was reduced to less than 3 per cent. The results suggest that hot water treatment has the potential to replace chemical fungicides to control crown rot of banana (Reyes *et al.*, 1998).

The effect of hot air treatment in banana *Musa acuminata* cv. Dayeqing fruits was investigated by Ye *et al.* (1998). Treatment with hot air at 45°C for 12 minutes inhibited the degradation of chlorophyll 'a' in peel. The peaks of respiration rate and ethylene evolution in hot air treated fruits occurred later and were smaller than those of the control. Treated fruits maintained better cell membrane integrity.

2.3.1.2 Precooling

Olorunda *et al.* (1978) stored unripe Cavendish banana fruits at 5-7°C before ripening at 20°C. Yellow colour development was retarded by 5°C pretreatment whereas prestorage at 7°C improved colour development slightly.

In experiments with banana, Chitarra and Lajolo (1985) observed a significant increase in metabolism at 25°C and 30°C compared to 20°C and ripening was advanced by 16 and 16.5 days respectively.

In trials with cv. Poyo storage at 30-40°C was interrupted by 1 to 3 cooling periods at 20°C of 12 hours either in air or in atmospheres with 50 per cent O_2 or 5 per cent O_2. Cooling periods reduced high temperature damage, especially when fruits stored at 30°C received three cooling periods in 50 per cent O_2 (Dick and Marcellin, 1985). Blackbourn *et al.* (1989) reported that in Cavendish banana fruits stored at 20°C a total loss of chlorophyll occurred within seven days.

Rodriguez *et al.* (1995) conducted studies on pre-cooling (hydrocooling) of banana fruits for five and ten minutes under different storage conditions. Fresh weight loss was not affected by treatment. Precooling maintained the green colour of the fruits for 20±2 days. Precooling durations more than 10 minutes are not recommended due to the lowering of pulp temperature close to 13°C, predisposing the fruits to chilling injury. In bananas packed with transit cooling the ethylene levels in polyethylene bags were lower than those without cooling during storage (Arec *et al.*, 1996).

Studies on hydrocooling in Kesar mango by Kapse and Katrodia (1997) revealed that longest shelf life occurred in fruits precooled at 12°C followed by those precooled at 16°C and the controls. Nayak and Thangaraj (2000) studied the effect of different precooling methods *viz.*, hydrocooling, contact-icing and air cooling in delaying ripening of bananas harvested at 80 per cent maturity and found that hydrocooling at 5°C for 60 minutes extended shelf-life up to 15 days compared to 12 days in non-precooled fruits. Hydrocooled (45-60 minutes) fruits reached final ripening stage after 16-17 days compared to 15 days in control. The quality of hydrocooled fruits remained unaffected, while the PLW was reduced to 11.68 per cent when precooled for 60 minutes compared to 15.39 per cent in control.

2.3.1.3 Coating

The effects of skin coatings on Dwarf Cavendish bananas were investigated by Yehoshua (1966). Successful coatings gave the following desirable effects - extension of storage life by 5 to 15 days, delay in the climacteric rise and the ripening process by 1 to 2 weeks as measured by respiratory activity, rate of softening and degreening, inhibition of the darkening of the banana skin, delay and reduction of incidence of decay, improvement in appearance of the skin of the fruit by imparting a glossy skin and preventing shrinkage and darkening. Dalal *et al.* (1969) reported that Dwarf Cavendish banana hands dipped in 1 per cent aqueous solution of Brassicol-75 having an application of CFTRI antifungal paste, remained green, clean and fresh and showed no stem end rot for a period of 18 days.

In an experiment on the effect of wax coating on bananas of varying maturity, Dalal *et al.* (1970) reported that Dwarf Cavendish banana bunches of 80-90 per cent maturity with pulp to peel ratio 1.5 to 1.87 treated with 8 per cent wax emulsion remained green during 21 days of storage at 55±1°F; RH 85 per cent. The untreated fruits of the same maturity were turning yellow.

Agnihotri and Ram (1971) reported that application of fungicidal wax emulsion was beneficial in minimising the loss in weight, spoilage percentage and delayed the ripening process in banana. The rate of respiration was also minimum in wax treated fruits after 8 days of storage. The percentage of marketable banana fingers was higher (61%) in the waxed lot.

When sucrose esters of fatty acids were included in a fruit coating Tal Prolong to retard ripening the ester remained substantially intact on the fruit surfaces during storage at 17 or 18°C for atleast 30 days (Bhardwaj *et al.*, 1984).

The effects of Tal Prolong, a commercial fruit coating, on the shelf life and selected quality attributes of plantain were investigated by Olorunda and Aworh (1984). Relative to untreated fruits, yellow colour development was retarded by 4 to 8 days and changes in pH and total acidity were delayed in plantain dipped in 1.5 per cent or 2.5 per cent prolong solution when stored at 30°C or at 20-24°C.

Banks (1985) conducted studies on responses of banana fruit to Prolong coating. A climacteric rise in respiration was absent from fruits coated with Prolong immediately before or after ripening initiation, delaying coating by a further 24 hour arrested development of the climacteric in mid rise. Coating the fruits delayed the chlorophyll loss which normally accompanies ripening. Hussein *et al.* (1985) reported that coating Prolong 1.5 per cent delayed ripening of banana.

Studies by Krishnaiah *et al.* (1985) indicated that protection of banana fruits using food-grade fruit coatings controlled the fungal rot of bananas in storage. The formulation WT-23 effectively controlled *Gloeosporium*, *Rhizopus* and *Aspergillus*. In cv. Robusta it was found that Tal Prolong delayed ripening by 4 to 5 days (Krishnamurthy and Kushalappa, 1985).

Rao and Chundawat (1986) observed that rate of ripening in banana cv. Lacatan at ambient temperature was slow in terms of relatively lower percentage of ripe fruits in the fruits which received waxol.

Surface coating of banana with the sucrose stearate emulsion delayed the ripening of the fruits (Kolekar *et al.*, 1988). The control fruits were of eatable quality up to 6^{th} day whereas the treated fruits were of good quality even on 10^{th} day.

Storage studies of chemical treated banana fruits disclosed that sucrose esters of fatty acids (Tal-Prolong) as well as the combination of a fungicide with wax emulsion (Topsin or Benomyl plus wax emulsion) proved to be the most effective postharvest treatments to prolong the shelf life of banana (Desai *et al.*, 1989). Dillon *et al.* (1989) reported that banana fruits coated with Prolong ripened more slowly than untreated fruits.

Shaikh *et al.* (1991) in their studies on extension of shelf life of banana with wax emulsion reported that coating bananas with the emulsion decreased gaseous exchange between the fruit and the outside atmosphere, thus modifying the atmosphere within the fruit without impeding the ripening process. The treated bananas had a good taste after ripening and no unpleasant flavour was detected.

Extension of shelf life of ripened fruits in Dwarf Cavendish bananas (cv. Naine) was studied by Goburdhun (1994) and found that Semperfresh delayed ripening and extended shelf life compared with untreated fruits. Sarkar *et al.* (1995) reported that the PLW and TSS was minimum in fruits treated with waxol. The results of the experiment conducted by Das and Medhi (1996) revealed that 6 per cent wax emulsion significantly reduced the weight loss and fruit rot. The rate of change in TSS/acid ratio was also less under 6 per cent wax emulsion.

Lin *et al.* (1996) studied the effects of Prolong coating on banana fruit during ripening. It was found that Prolong delayed chlorophyll breakdown in peel, decreased fruit firmness and increased ethylene production of the whole fruit. It was suggested that Prolong coating on banana fruits during ripening reduced the ethylene biosynthesis through partially inhibiting ethylene forming enzyme activity by reducing the supply of oxygen.

James and Gregor (2000) reported that treatment of fresh fruit with sucrose esters establishes a modified atmosphere within the fruit. A semperfresh coating provides several benefits like reduced ethylene production, lower respiration rate, extended green life, fresh appearance, delayed softening and breakdown in storage, reduced weight loss and shrivelling and flavour preservation. They also found that treated fruits turned black slower than the untreated fruits.

2.3.1.4 Calcium chloride treatment

Desai *et al.* (1989) found that calcium chloride was effective in retarding banana ripening. Effect of application of $CaCl_2$ on ripening of banana cv. Robusta was studied by Huddar *et al.* (1989). It was found that $CaCl_2$ treatment resulted in hastened ripening by 3 to 4 days. The conversion of starch to sugars, changes in acidity and TSS were at faster rate in treated fruits as compared to control fruits.

In another study Huddar *et al.* (1990) reported that $CaCl_2$ treatment advanced ripening in banana. After 14 days of storage, bananas treated with 6 per cent $CaCl_2$ showed the lowest firmness and highest titrable acidity, reducing sugar and total sugar contents. The shelf life ranged from 8.8 days (6% $CaCl_2$) to 11.5 days (0.5% $CaCl_2$) compared with 14.4 days for the control.

Chukwu *et al.* (1995) conducted studies on the extension of ripening period of Musa fruit and reported that best results were achieved with the combination of semperfresh and $CaCl_2$ treatment which extended the green life of fruits without adverse effects.

Pathak *et al.* (1999) reported that fruit ripening at room temperature was accelerated in *Musa acuminata* fruits by dipping in $CaCl_2$ 0.2 per cent for four hours. By $CaCl_2$ infiltration, Sindhu (1999) observed extended shelf life in Nendran banana.

2.3.1.5 Other chemical retardants

Desai *et al.* (1984) reported that GA or kinetin retarded the activities of hydrolytic and oxidative enzymes during ripening of banana. Ram and Vir (1984) reported that Benzimidazole fungicides controlled *A. niger* prolonging shelf life up to eight days in banana fruit.

Postharvest treatment with GA_3 at lower concentration reduced the relative activity of catalase and Pectin Methyl Esterase enzymes and postponed their metabolism and pectin breakdown, thereby responsible for extended shelf life of fruits (Das *et al.*, 1996).

In an experiment conducted by Hwang and Chen (1993) banana fruits treated with a preservative agent Jiaoxuan 2 could be stored satisfactorily for around 90 days at 11-25°C. The PLW was maximum in the control and minimum in fruits treated with GA_3, fungicides like Blitox, Bavistin and Dithane M-45 (Sarkar *et al.*, 1995). Chattopadhyay and Hasan (1996) in their study on quality of banana cv. Giant Governor observed that maximum increase in TSS and total sugar was recorded by the application of GA_3 at 50 mg^{-1}.

The effect of aldehyde on ripening of Bali banana was studied by Hong *et al.* (1997) and found that respiration rate, cell membrane permeability, enzyme activities and chlorophyll contents were all lower in treated fruits than in the controls and storage life was prolonged to about 18 days.

Sisler *et al.* (2000) conducted investigations on regulation of banana ripening. The gaseous compound 1-methyl-cyclopropene (1-MCP) inhibited a range of plant responses to ethylene, including ethylene induced ripening of bananas. Srivastava and Dwivedi (2000) reported that salicylic acid treatment has been found to delay the ripening of banana fruits.

An experiment conducted to extend the shelf life by treating Thellachakrakeli fruits with growth regulators and antioxidants along with waxing revealed that ripening was slower in sodium benzoate + wax treated fruits followed by GA_3 + wax treated fruits on 9^{th} day. The shelf life at ambient temperature with above treatments was 12 days against 8 days in the control. The delayed ripening and extended shelf life with antioxidants and growth regulators are attributed to low ethylene production and delayed climacteric (Reddy *et al.*, 2002).

2.3.2 Effect of packaging on shelf life of banana varieties

2.3.2.1 Modified atmosphere packaging

Liu (1970) reported that hard, green preclimacteric bananas could be kept in their unripe stage for a longer period in sealed polyethylene bag than in open air. Small quantities of Purafil in sealed bags was helpful in retarding ripening unless ripening had already started.

Studies on Dwarf Cavendish banana fruits by Fuchs and Gorodeiski (1971) indicated that fruits stored in sealed polyethylene bags with or without $KMnO_4$ was still green after 14 days whereas control fruits became ripe after seven days of storage.

Scott *et al.* (1971) reported that bananas when packed in sealed polyethylene bags and transported to distant markets, remained in a hard green condition, similar to that at packing, whereas the control fruit had ripened. Weight loss and mechanical injury were also reduced by the polyethylene bags. Best results were obtained by treatment with thiabendazole to control crown rots and by packing an C_2H_4 absorbent with the fruit.

Investigations by Scott and Gandanegara (1974) revealed that packing bananas in polyethylene appreciably extended their storage life. The addition of an ethylene absorbent produced a further increase in storage life. Best conditions were storage in polyethylene bags with ethylene absorbent at 12.8°C.

In another study Scott (1975) reported that the use of MAS of bananas has considerable potential as an inexpensive means for prolonging the shelf life of banana fruits. Sealed polyethylene bag can be used to produce MA around the fruit at a wide range of temperature and by removing ethylene by $KMnO_4$ a further extension in storage life is obtained.

The shelf life and fruit quality were greater and the spoilage due to fungal infection was nil in banana fruits of cv. Robusta when treated with wax emulsion and stored in polyethylene bags containing $KMnO_4$ and $Ca(OH)_2$ and the shelf life and quality were further enhanced when stored at 15°C and 80-90 per cent RH (Rao and Rao, 1979).

In an experiment on retardation of ripening in Basrai bananas stored in cartons the chemical treated fruit recorded relatively lower percentage of fruit rot indicating the retarded ripening. The days to reach 100 per cent ripening was 12.47 days in cartons with ethylene absorbent $KMnO_4$ as against the control (11.45 days) (Rao and Chundawat, 1984). Desai *et al.* (1984) reported that cvs. of banana viz. Pachabale, Rasabale and Rajbale could be held in polyethylene bags at 20°C upto 35 days.

Krishnamurthy and Kushalappa (1985) had observed that waxol and prolong treated fruits kept in ventilated polyethylene packs showed delayed ripening by six days and untreated fruits kept in sealed purafil packs also showed a seven day delay in ripening. Weight loss during storage was considerably less in fruits kept in polyethylene bags than in unpacked fruits. The C_2H_4 absorbent provided maximum delay in ripening and the best quality.

Carvalho *et al.* (1988a) in studies with banana cv. Prata observed that fruits stored in polyethylene bags had lower starch contents, higher sugar contents and a softer texture during ripening. In another study Carvalho *et al.* (1988b) reported that wrapping delayed ripening by four to six days in ambient conditions and by eight days at high RH. Loss in fruit weight and pulp:peel ratio were less at high RH. Respiration was slower in wrapped than in non-wrapped fruits. Tan *et al.* (1990) reported that modified atmosphere storage conditions created by the respiration of fruits in polyethylene bags prolonged the preclimacteric life of the fruits.

Li *et al.* (1991) treated banana fruits with a complex preservative and stored in polyethylene bags containing C_2H_4 absorbent. Fruits remained fresh 8-18 days longer with the preservative. After storage for 22 days the pericarp had higher contents of chlorophyll, carotenoids and anthocyanins.

Experiments were conducted on chemical regulation of ripening in banana bunches cv. Lacatan by Rao and Chundawat (1991). After GA treatment bunches were wrapped in polyethylene film with ethylene absorbent $KMnO_4$. The treatments were beneficial in delaying ripening, reducing weight loss and bruising and including the C_2H_4 absorbent inside the polyethylene film further delayed ripening.

Nair *et al.* (1992) conducted studies on low O_2 effect and storage of Mas bananas (Musa, AA group). After storage for 6 weeks the fruits lost little weight, produced negligible C_2H_4 and ripened normally when removed from storage.

Mohammed and Campbell (1993) studied the quality changes in 'Lacatan' and 'Gros Michel' bananas stored in sealed polyethylene bags with an ethylene absorbent. They found that fruits stored at 20°C in LDPE bags with $KMnO_4$ also increased firmness and greenness and reduced decay. Prasad *et al.* (1993) reported that

Nendran banana stored under MA at 13°C kept well up to 6 weeks in fresh green and firm condition as against 3 weeks in ventilated pouches and kept in open condition.

Banana hands were stored in polyethylene bags containing ethylene absorbant Purafil after dipping for one minute in benomyl (1.7 mM) or prochloraz (1.3 mM) for 40 days at 20°C, then ripened with ethylene in air for nine days. All fruits were hard and green when removed from storage and ripened normally in air (Wade *et al.*, 1993). A postharvest fungicide treatment that controlled diseases of the bunch during modified atmosphere storage and subsequent ripening would be a valuable adjunct to bunch storage technology.

Sarananda *et al.* (1994) studied the effects of low O_2 levels on the quality of banana cv. Embul, stored at 13.5°C for 20 or 30 days. After 20 and 30 days, weight loss was lower following storage in O_2 at 1,3 and 5 per cent compared with control (21% O_2). Storage life, external appearance and eating quality of fruits were similar for the 1, 3 and 5 per cent O_2. Physico chemical parameters of ripe fruits stored at all O_2 levels were similar to those of control fruits. The incidence of crown rot in green fruits stored at low levels of O_2 were lower than in control fruits.

Extension of storage life of Rasthali bananas under modified atmosphere at low temperature was studied by Aradhya *et al.* (1995). The studies indicated that the fruits harvested at 75 per cent maturity could be stored under MA at 13°C in fresh and green condition up to 6 weeks and in ventilated pouches and in control up to 3 weeks.

Rahman *et al.* (1995) reported that storage life could be considerably extended by sealing apple bananas in 100 guage polyethylene film at 13-14°C provided the film was sufficiently permeable to prevent CO_2 levels from becoming toxic to the fruits. It is concluded that with the appropriate packing and storage conditions it is possible to store the fruits for long enough to enable transportation internationally by sea freight.

Chillet *et al.* (1996) conducted investigation on packaging banana bunches in sealed plastic bags (polybags) and compared with standard polyfilm packaging.

During a 28 day storage period at 13.5°C, rates of fungal rot (anthracnose) caused by *Colletrotrichum musae* development and fruit ripening were slowed down when polybags were kept sealed. Das *et al.* (1996) found that shelf life of polyethylene wrapped fruits treated with GA_3 at 25 ppm was significantly higher compared to the unwrapped control fruits.

Investigations by Elzayat (1996) revealed that packaged (wrapping in polyethylene before packing in cartons) banana fruits cv. Magcobi were in good condition after storage for one month and had a shelf life of 5-7 days in ambient conditions. These fruits ripened normally following storage whereas control fruits were distorted in shape and decayed after storage.

Ketsa and Ketsa (1996) stored banana hands of cv. Kluai Khai in sealed polyethylene bags with perforations at ambient temperature. Development of senescent spots was inhibited in sealed polyethylene bags, while control fruits (in plastic boxes covered with polyethylene bags) showed serious development. Prasad and Singh (1996) reported that modified atmosphere packaged fruits retain orchard freshness for longer periods.

Ming *et al.* (1997) reported that banana fruits treated with Tekduo and Shibagong (produced in Germany) for 3 minutes before packing in PVC bags containing ethylene absorbent and storing at room temperature reduced the occurrence of bitter rot and improved keeping quality.

It was found that physiological weight loss was least for fruits packed in 300 or 400 guage, non-perforated polyethylene packs, fruits remaining in marketable condition up to 28 days. TSS, total sugars and ascorbic acid contents were highest for fruits kept in coloured polyethylene packs (Sarkar *et al.*, 1997). Shukor *et al.* (1997) reported that Berangan bananas can be stored for 8 weeks in 2 per cent O_2 and for 5 weeks in 5 per cent O_2 atmosphere at 14°C.

Analyses of C_2H_4 and CO_2 concentration within polyethylene bags confirmed that 1-MCP suppressed both C_2H_4 evolution and respiration (Ming *et al.*, 1999). The results indicate that application of 1-MCP in combination with the use of PE bags can greatly extend the postharvest life of banana.

Studies conducted by Mustaffa *et al.* (2002a) on Robusta banana revealed that fruits stored after treatment with vegetable oil in 400 guage polybags with 0.5 per cent ventilation, extended shelf life up to 13 days recorded highest peel chlorophyll with minimum PLW and pulp peel ratio. Fruits with cushion and Bavistin 500 ppm as postharvest dip reduced pedicel shrinkage and finger rot and extended shelf life up to 11 days without affecting fruit quality. In another study with Nendran banana, Mustaffa *et al.* (2002b) found that fruits after vegetable oil treatment when stored in polybags with ventilation under ambient conditions significantly increased shelflife.

Narayana *et al.* (2002) stored Neypoovan (AB group) banana fruits in 400 guage LDPE bags at 13.5°C after different fungicide treatments and found that Bavistin was most effective in extending storage life, controlling the spoilage and maintaining the quality of fruits.

2.3.2.2 Vacuum packaging

Liu (1976) reported that Dwarf Cavendish bananas stored for 28 days in 1 per cent oxygen or in 1/10 atmospheric pressure at 14°C remained green and firm until the end of storage. The stored bananas had normal eating quality when ripe.

In an investigation on low O_2 effect and storage of Mas bananas (AA group). Nair *et al.* (1992) found that mature green Mas bananas hermetically sealed in tight polyethylene bags can be stored for 4 weeks or more at 17°C.

Banana fruits stored in sealed polyethylene bags (evacuated collapsed bags, ECB's) at 17°C showed very little change in gaseous composition within ECB's after four and six weeks of storage. After 16 weeks when fruits were starting to change colour, the ethylene concentration still did not exceed 1 $\mu l\ l^{-1}$. Oxygen concentration decreased slightly from 5 per cent after four weeks of storage to 3.7 per cent after 16 weeks (Nair *et al.*, 1996).

Experiments were conducted by packing fresh banana of variety 'Rasthali' in polyethylene bags by Rajeev and Sreenarayanan (1998) and found that by keeping green and unripe banana in evacuated polyethylene bags at room temperature, the shelf life could be maintained for more than 40 days compared to banana packed with ethylene absorbent, air packed and banana stored open to atmosphere.

Emerald and Sreenarayanan (1999) reported that shelf life of banana fruits cv. Rasthali was extended by packing in 300 guage low density polyethylene bags under air and vacuum. The study revealed that fruits packed under vacuum with and without ethylene absorbent retained freshness, firmness and greenness for 30 days at ambient condition when compared to fruits kept in open atmosphere. The fruits stored under vacuum ripened within three to four days when removed from the bags and kept in open atmosphere.

Banana fruits pretreated with waxing, oil film coating, purafil packets, tissue paper wrapping along with control and polybag packing were stored under vacuum and stored at room (36°C) and refrigeration temperature (20°C). Shelf life of four and eight weeks at room and refrigeration temperature was obtained during the storage of banana (Geetha *et al.*, 2000b). Increase in shelf life by packing under vacuum, was reported in papaya, sapota (Geetha *et al.*, 2000a, 2000c) and in guava by Kannan and Thirumaran (2000).

Gouthami (2001) reported that maximum days to ripening was obtained by packing in vacuum with ethylene absorbent sachet (42.67 days).

2.3.2.3 Use of ethylene absorbents

Om Prakash *et al.* (1985) reported the usefulness of $KMnO_4$ at 1500 ppm in delaying the ripening and extending the shelf life of banana fruits. Jayaraman and Raju (1992) in their investigation on evaluation of permanganate based ethylene scrubber for extending the shelf life of fresh fruits reported a shelf life of seven days by using the scrubber sachets for banana under ambient temperature whereas control fruits had a shelf life of only three days.

Satyan *et al.* (1992) conducted studies on the effects of storage temperature and modified atmosphere on cooking bananas. The storage life was increased when the absorbent ($KMnO_4$) was present. Reducing the storage temperature from 28 to 13°C further increased storage life. Lin and Zang (1993) reported that banana fruits when treated with $KMnO_4$ - amargosite yellowed and matured later than controls.

Effect of postharvest reatments on the storage of banana fruits was studied by Patil and Hulmani (1998). Among different combinations, bavistin with ethylene absorbent was the most promising for extending the shelf life of banana fruits by maintaining higher values for TSS, sugars, acidity and starch at the end of storage.

Xin *et al.* (1998) reported that ethylene absorbent treatment in modified atmosphere storage of banana fruit significantly increased the storage life of banana fruits at high temperature.

Packing of Rasthali banana with ethylene absorbent resulted in more green life than the control and sensory evaluation showed that overall acceptability was similar for the stored fruits compared to fresh fruits (Shanmugasundaram *et al.*, 2002).

2.3.2.4 Effect of humidity on storage of banana

George and Marriott (1983) studied the effect of humidity in plantain ripening and reported that the storage life is shorter under low humidity than under high humidity conditions. The CO_2 evolution was maximum and the rate of respiration and ethylene evolution was at its peak when stored under low humidity condition.

Studies on postharvest storage of banana at ambient temperature showed that by continuously flushing the storage atmosphere with air saturated with moisture, it is possible to ensure less weight loss and slower changes in firmness and brix/acid ratio and as a consequence extend the storage life by five days as compared to the control (Ramana *et al.*, 1989).

2.3.2.5 *Use of CFB boxes*

Effect of chemicals and packaging on the shelf life and quality of banana cv. Giant Governor was evaluated by Sarkar *et al.* (1994) and found that fruits treated with GA_3 + waxol exhibited minimum PLW and was satisfactory for 16 days in storage when kept in bamboo basket and cardboard box.

Studies were conducted by Aradhya *et al.* (1995) on the effect of modifications in the MAP of Rasthali banana in CFB boxes on the storage life. The results indicate that a storage life of 50 days was obtained by storing under MA with ethylene absorbent at optimum low temperature along with various postharvest treatments and package of practices. The fruits stored for 50 days were fresh, firm, green in appearance and free of infection. On the 50^{th} day of storage, the fruits showed 3 per cent PLW, TSS 8 per cent, total acidity 0.32 per cent and total sugars 2.8 per cent and in the ripe fruits TSS 25.8 per cent, total acidity 0.41 per cent and total sugars 18.3 per cent.

Mature and fully developed banana fruits of cv. Dwarf Cavendish were dipped in GA_3, $CaCl_2$, Bavistin or their combinations and stored at ambient temperature in corrugated paper boxes with uniform vents and paper lines. Fruits packed in corrugated paper boxes after GA_3 treatment was the most effective treatments for prolonging the shelf life of banana fruits by reducing weight loss, delaying ripening and associated colour development and reducing the pulp:peel ratio (Acharya *et al.*, 1997).

Materials and Methods

3. MATERIALS AND METHODS

The present study on "Evaluation of selected banana (*Musa* spp.) varieties grown in Kerala for postharvest attributes" was carried out in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala during August 2000 to 2003. Vellanikkara lies between 10° 32' N latitude and 76° 17' E longitude at an altitude of 23 m above MSL, enjoys a warm humid climate.

The study was carried out in three different experiments.

1. Evaluation of banana varieties for postharvest attributes
2. Physical, chemical and physiological changes during postharvest period in banana
3. Standardisation of methods to enhance shelf life of varieties

Banana fruits were collected from Banana Research Station, Kannara which were maintained as per the Package of Practice Recommendations of Kerala Agricultural University (KAU, 1996). The bunches were harvested at 80 per cent maturity stage. The bunches after harvest were carefully transported on the same day to the laboratory. Hands free from injuries were selected and used for the study.

3.1 EVALUATION OF BANANA VARIETIES FOR POSTHARVEST ATTRIBUTES

Twenty five accessions of banana representing six genomic groups AA, AB, AAA, AAB, ABB and AAAA from the germplasm maintained at BRS, Kannara were screened for their postharvest attributes. The fruits were catalogued as per IBPGR descriptor list for banana (IPGRI, 1996).

The list of selected banana varieties are presented in Table 1 (Plates 1 to 25).

Table 1. List of selected banana varieties

Sl.No.	Accessions	Genomic group
1	Matti	AA
2	Kadali	AA
3	Njalipoovan	AB
4	Koompillakannan	AB
5	Poomkalli	AB
6	Robusta	AAA
7	Red Banana	AAA
8	Dwarf Cavendish	AAA
9	Amritsagar	AAA
10	Grand Naine	AAA
11	Poovan	AAB
12	Palayankodan	AAB
13	Nedunendran	AAB
14	Zanzibar	AAB
15	Chengalikodan	AAB
16	Manjeri Nendran	AAB
17	Chinali	AAB
18	Dudhsagar	AAB
19	BRS I	AAB
20	BRS II	AAB
21	Monthan	ABB
22	Batheesa	ABB
23	Kanchikela	ABB
24	Karpooravalli	ABB
25	Bodles Altafort	AAAA

3.1.1 Observations

3.1.1.1 Physical characters

3.1.1.1.1 Finger weight

Weight of individual fingers from the mid-hand of the bunch at harvest were recorded and expressed in gram.

3.1.1.1.2 Length of finger

The distance between the pedicel and apex was measured and expressed in cm.

Plate 1. Matti

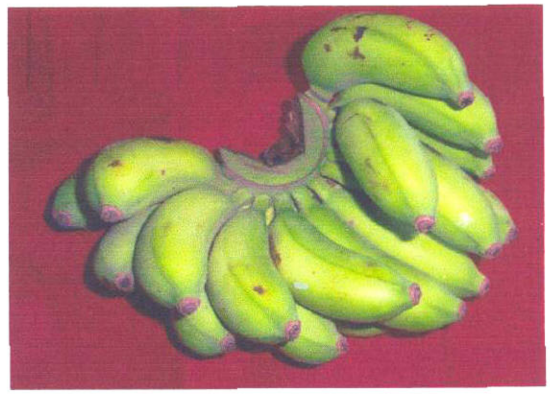


Plate 2. Kadali

Plate 3. Njalipoovan

Plate 4. Koompillakannan

Plate 5. Poomkalli

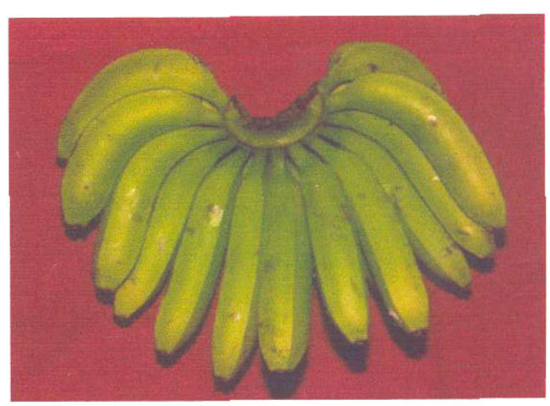


Plate 6. Robusta

Plate 7. Red Banana

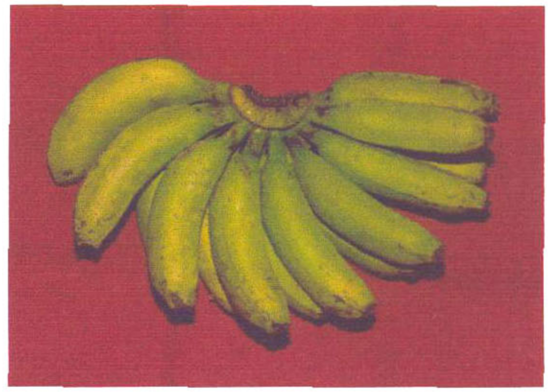


Plate 8. Dwarf Cavendish

Plate 9. Amritsagar

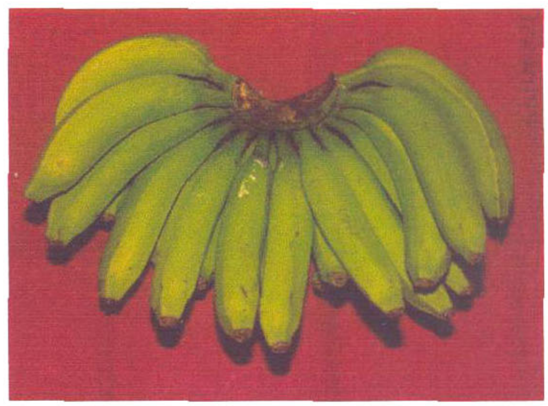


Plate 10. Grand Naine

Plate 11. Poovan

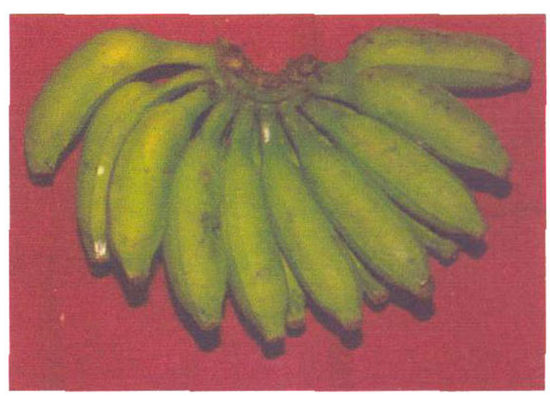


Plate 12. Palayankodan

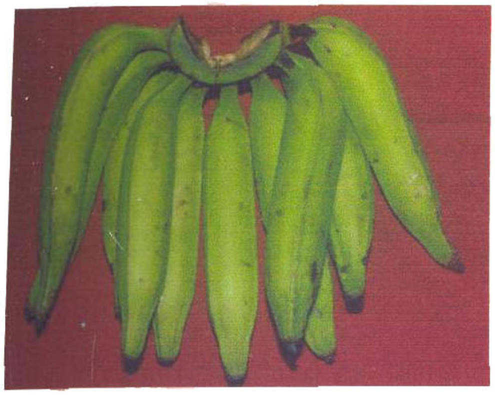


Plate 13. Nedunendran

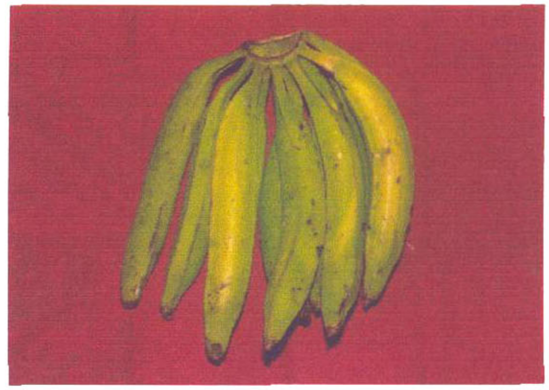


Plate 14. Zanzibar

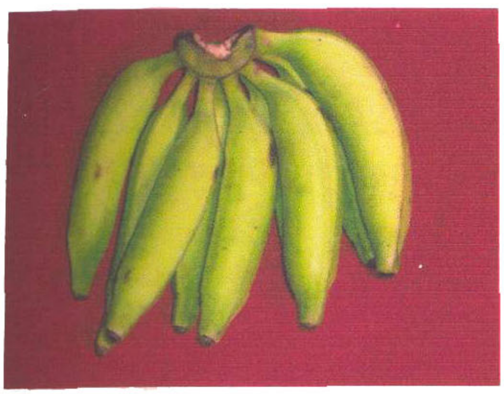


Plate 15. Chengalikodan

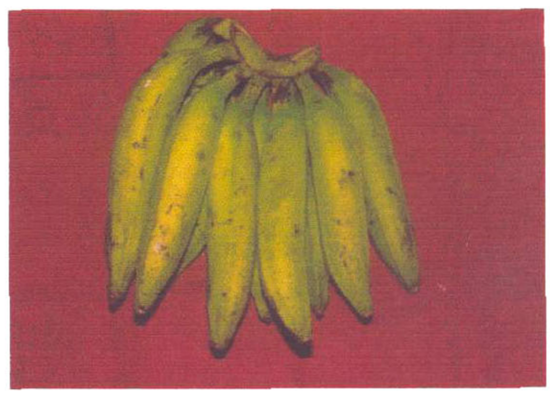


Plate 16. Manjeri Nendran

Plate 17. Chinali

Plate 18. Dudhsagar

Plate 19. BRS I

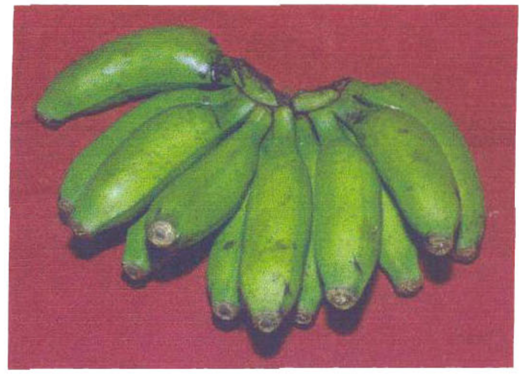


Plate 20. BRS II

Plate 21. Monthan

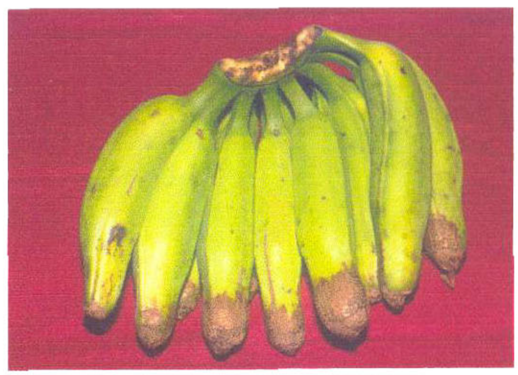


Plate 22. Batheesa

Plate 23. Kanchikela

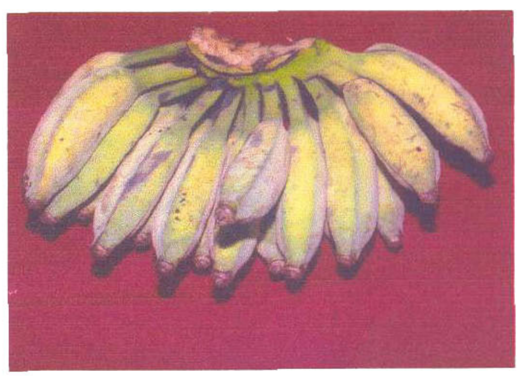


Plate 24. Karpooravalli

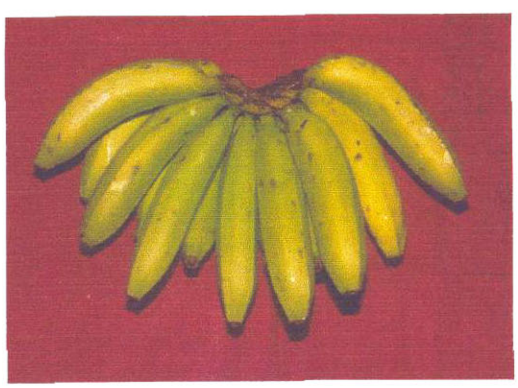


Plate 25. Bodles Altafort

3.1.1.1.3 Volume of finger

The volume of the finger was estimated by water displacement method and expressed in ml.

3.1.1.1.4 Pulp weight

After removing the peel, pulp weight was recorded and expressed in gram.

3.1.1.1.5 Peel weight

After separating the peel, the peel weight was recorded and expressed in gram.

3.1.1.1.6 Pulp/peel ratio

Weight of pulp and peel were recorded separately and relative proportion of pulp and peel were worked out.

3.1.1.1.7 Peel thickness

Peel thickness was measured using a screw guage and expressed in mm.

3.1.1.1.8 Specific gravity

Specific gravity was computed from volume/weight measurements.

3.1.1.2 Chemical constituents

Chemical constituents of ripe fruits were analysed in table varieties whereas in culinary varieties green fruits were analysed.

3.1.1.2.1 TSS

TSS was measured/recorded directly using a Erma hand refractometer (range 0-32°brix) and expressed in degree brix.

3.1.1.2.2 Acidity

Titrable acidity was estimated as per the procedure described by Ranganna (1986).

3.1.1.2.3 pH

pH was determined using the digital pH meter (Digital pH meter pH 5652 A of Electronics Corporations of India).

3.1.1.2.4 Total, reducing and non-reducing sugars

Total sugars and reducing sugars were determined as per the procedure described by Ranganna (1986). The non-reducing sugars were obtained by subtracting the percent of reducing sugars from the total sugars.

3.1.1.2.5 Moisture

Moisture content was estimated as percent moisture after drying pre weighed fresh samples in hot air oven at 60±5°C to constant weight.

3.1.1.2.6 Vitamin C

Vitamin C content of the fruits were estimated by 2,6-dichlorophenol indophenol dye method (Mahadevan and Sridhar, 1974).

3.1.1.2.7 β carotene

β carotene was estimated colorimetrically by dissolving the powdered sample in saturated n-butanol and reading the absorbance at 433.8 nm wave length and expressed as μg 100 g^{-1} (AOAC, 1975).

3.1.1.2.8 Tannin

Tannin content was determined as tannic acid by colorimetric method (Ranganna, 1986) and expressed as percentage.

3.1.1.2.9 ***Pectin***

Total pectin content was estimated gravimetrically. Pectin was extracted and precipitated as calcium pectate. After thorough washing the precipitate was dried and weighed. Pectin content was expressed as per cent calcium pectate (Ranganna, 1986).

3.1.1.2.10 Starch

Starch content was determined by colorimetric method using anthrone reagent as proposed by McGready *et al.* (1950).

3.1.1.3 Shelf life

Fruits were stored under ambient conditions of temperature 24°C to 30°C and relative humidity 70 to 80 per cent and the following observations were recorded.

3.1.1.3.1 Fresh weight (g)

Individual hands were separated from the bunch and fresh weight was recorded and expressed in gram.

3.1.1.3.2 Physiological loss in weight (PLW)

PLW was calculated on the initial weight basis at three days interval and expressed in percentage.

$$PLW\ (\%) = \frac{\text{Initial weight - weight after storage}}{\text{Initial weight}} \times 100$$

3.1.1.3.3 Shelf life

The shelf life was calculated as number of days from harvest till the fruit remained marketable. The fruits were rated as not marketable when more than 50 per cent of fruits in a bunch showed more than 50 per cent blackening as spots, specks and lesions.

3.1.1.3.4 Finger retention

Number of days upto which fingers were retained on the hand without dehiscence was recorded.

3.1.1.3.5 Spoilage

The organisms present at the site of spoilage (outer surface of skin) were identified by pathological examination and recorded.

3.1.1.3.6 Organoleptic evaluation

A score chart was prepared based on a ten point scale ranging from zero to ten (0-2 poor, 3-5 satisfactory, 6-8 good, 9-10 excellent quality). The organoleptic evluation was done by a panel of 10 semitrained persons. The parameters considered were appearance, sweetness, taste, flavour, overall acceptability.

3.2 PHYSICAL, CHEMICAL AND PHYSIOLOGICAL CHANGES DURING POSTHARVEST PERIOD IN BANANA

Eight varieties showing superior postharvest attributes and commercially important were selected from the first experiment to study the physical, chemical and physiological changes during postharvest period in banana. The varieties selected were

1. Njalipoovan
2. Palayankodan
3. Robusta
4. Red banana
5. Grand Naine
6. Chengalikodan
7. BRS I
8. BRS II

The changes in physical, chemical and physiological parameters in these varieties were studied during the different stages of ripening indicated by change in peel colour as mature green unripe stage (S_1), colour changing (S_2), full ripe (S_3) and over ripe stage (S_4).

3.2.1 Observations

3.2.1.1 Physical

Observations on the following parameters were noted at specified intervals.

3.2.1.1.1 Fruit colour

Colour of fruit was recorded based on visual observations with reference to Horticultural colour Guide (Graf, 1985).

3.2.1.1.2 Fruit weight

Fruit weight was recorded after harvest till senescence at different stages of ripening.

3.2.1.1.3 Pulp percentage

Pulp percentage was recorded after peeling the fruit.

$$\text{Pulp \%} = \frac{\text{Weight of pulp}}{\text{Weight of fruit}} \times 100$$

3.2.1.1.4 Peel percentage

Peel percentage was recorded after recording the weight of peel.

$$\text{Peel percentage} = \frac{\text{Weight of peel}}{\text{Weight of fruit}} \times 100$$

3.2.1.1.5 Fruit firmness

Flesh firmness of fruit was recorded using a hand held fruit pressure tester (Model F 011 and F 327, Effigi, Italy) fitted with 8 mm probe. Two measurements were taken from each fruit on opposite sides without removal of peel and was expressed in kg cm^{-2}.

3.2.1.2 Chemical changes

Changes in the following chemical constituents were studied at fixed intervals during the postharvest period.

3.2.1.2.1 TSS

TSS estimated as in 3.1.1.2.1.

3.2.1.2.2 Acidity

Acidity was estimated as in 3.1.1.2.2.

3.2.1.2.3 Total, reducing and non-reducing sugar

Total, reducing and non-reducing sugar was estimated as in 3.1.1.2.4.

3.2.1.2.4 Moisture

Moisture content was estimated as in 3.1.1.2.5.

3.2.1.2.5 Tannin

Tannin content was estimated as in 3.1.1.2.8.

3.2.1.2.6 Pectin

Pectin content was estimated as in 3.1.1.2.9.

3.2.1.2.7 Starch

Starch content was estimated as in 3.1.1.2.10.

3.2.1.2.8 Chlorophyll

Total chlorophyll, chlorophyll a and chlorophyll b were estimated in milligram g^{-1} fresh tissue of peel by the method suggested by Shoaf and Lium (1976) and expressed by the formulae.

$$\text{Total chlorophyll} = 2.8\ (\text{OD } 652) \times \frac{V}{W \times 100}\ (\text{mg g}^{-1})$$

$$\text{Chlorophyll a} = 12.7\,(\text{OD } 663) - 2.69\,(\text{OD } 645) \times \frac{V}{W \times 100}$$

$$\text{Chlorophyll b} = 22.9\,(\text{OD } 645) - 4.68\,(\text{OD } 663) \times \frac{V}{W \times 100}$$

Where OD 652 is absorbance at 652 wave length
OD 663 is absorbance at 663 wave length
OD 645 is absorbance at 645 wave length
V = volume, W = weight of the sample.

3.2.1.3 Physiological changes

3.2.1.3.1 Respiration rate (mg CO_2 kg^{-1} hr^{-1})

The rate of respiration of fruits were monitored as suggested by Akinaga and Kohde (1993). Weighed quantity of fruits was placed in a fixed volume glass vessel in which 25 ml of 2 N KOH was placed and kept under dark conditions at room temperature. The CO_2 generated was absorbed in the KOH for a fixed duration and excess KOH was estimated after precipitating the carbonates as $BaCO_3$ using $BaCl_2$. The volume of HCl required to neutralize excess KOH was used to arrive at the quantity of CO_2 evolved from the fruits based on the factor.

1 ml of 0.2 N HCl = 4.4 mg CO_2

The rate of respiration was expressed as mg CO_2 evolved kg $fruit^{-1}$ hr^{-1} = (V x 4.4 x N)/W x T

where V = volume of HCl (0.2 N) in blank - Vol. of 0.2 N HCl in sample
N = normality of HCl
W = Weight of sample in kg
T = Measuring time in hours

3.2.1.4 Enzyme activity

3.2.1.4.1 Amylase

Amylase activity was estimated as per the procedure described by Sadasivam and Manickam (1997).

3.2.1.4.2 Invertase

Activity of enzyme invertase was estimated as per the method suggested by Malik and Singh (1980).

3.2.2 Effect of postharvest treatments on extension of shelf life of banana

Four varieties found desirable with respect to postharvest attributes in Experiment II were selected for Experiment III.

The varieties used for the study were

1. Njalipoovan
2. Palayankodan
3. Robusta
4. Chengalikodan

Hands from mature bunches were subjected to the following postharvest treatments and kept under ambient conditions for ripening.

T_1) Hot water treatment at 45 ± 5°C

Water was heated to 45 ± 5°C in a water bath. Fruits were packed in a nylon-net bag and it was ensured that the fruits were fully immersed in water. The hands were removed from hot water after two minutes and drained.

T_2) Precooling with tap water

Banana hands packed in a nylon-net bag were fully immersed in water. The hands were removed from water after ten minutes and the water was drained.

T_3) Precooling with cold water (10°C)

Water was cooled in a refrigerator to 10°C. Banana hands taken in a nylon net bag were fully immersed in cold water for 15 minutes, thereafter removed from water and kept under ambient condition for ripening.

T_4) Precooling with ice flakes

Ice flakes were collected from Icematic ice flaking machine and were spread all over the banana hands to be cooled. Ice was used at rate of 1:1. A contact time of 10 minutes was allowed. After draining water and ice flakes the banana hands were kept under ambient conditions for ripening (Plate 26).

T_5) Coating with edible waxes at cut ends of hands

The cut ends of banana hands were immersed in Waxol - 12% (an aqueous wax emulsion) (Dalal and Singh, 1971) and kept under ambient conditions for ripening.

T_6) Vacuum infiltration with 1% $CaCl_2$

Harvested fruits were vacuum infiltered in calcium chloride solution of one per cent concentration at a pressure of 0.5 kg cm^{-2} for 3 minutes and after draining the salt solution, banana hand were kept under ambient condition for ripening.

T_7) Dipping in 1% $CaCl_2$

Banana hands were fully immersed in 1% $CaCl_2$ solution for 3 minutes. After draining the salt solution banana hands were kept under ambient condition for ripening.

T_8) Control

Banana hands were stored under ambient conditions for ripening.

3.2.3 Effect of packaging on shelf life of banana varieties

The experiment was conducted for developing a suitable and convenient retail package which can extend the shelf life of banana hands. Banana bunches of uniform maturity were harvested and from them hands of uniform size were separated and pooled. The cut ends of banana hands were dipped in Bavistin @ 1000 ppm (Carbendazim 50% w.p.) for one minute and then air dried and packed in retail packages.

Plate 26. Precooling with ice flakes

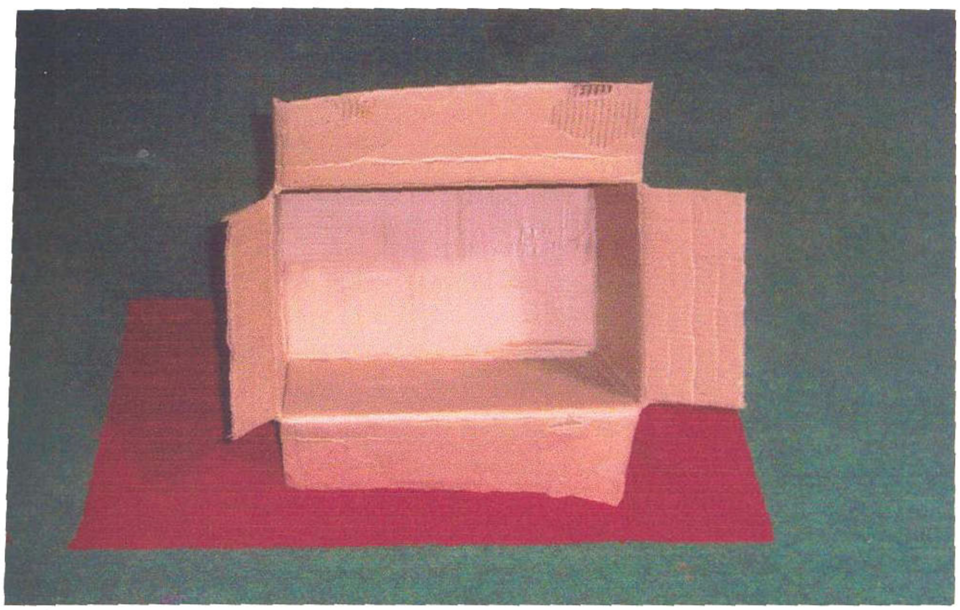


Plate 27. CFB box

Varieties selected for the study were

1) **Palayankodan**
2) Njalipoovan
3) Chengalikodan

Treatments

P_1) Cling film

Banana hands were wrapped in cling film and kept under ambient conditions for ripening (ITACT L 100™ of Flero Film Wraps (India) Ltd., Aurangabad).

P_2) Polyethylene cover 100 guage with ventilation

Banana hands were packed in a transparent low density polyethylene bag of 100 guage thickness and of 35 x 25 cm (L x B where L = length in cm and B = breadth in cm) with uniform ventilation of 1 per cent. The bags were then heat sealed using a heat sealing machine (Quick seal™ of Sevana (India Ltd.) and stored under ambient condition.

P_3) Polyethylene cover 100 guage without ventilation

Banana hands were packed in a transparent low density polyethylene bag of 100 guage thickness and of 35 x 25 cm L x B where L = length in cm and B = breadth in cm without ventilation.

P_4) Sealed polyethylene cover with ethylene absorbent

Ethylene absorbent was prepared by impregnating vermiculite with potassium permanganate. Saturated solution of potassium permanganate was poured into dried vermiculite and left for 30 minutes. The absorbent mixture was kept in muslin cloth bags and sealed in unglazed soft tissue paper sachets. The absorbent was used at the rate of 20 g kg^{-1} of fruit. After that banana hands were packed in a transparent low density polyethylene bag of 100 guage thickness and of size 35 x 25 cm.

P_5) CFB Box

Corrugated fibre board box of 5 ply, with 30 cm x 25 cm x 20 cm L x W x H measurement was used where L = length in cm, w = width in cm, H = height in cm for packing banana hands (Plate 27).

P_6) CFB Box with polyethylene lining

Polyethylene (P.E) lining was provided by wrapping the hands with a polyethylene sheet of 100 guage thickness and of length 60 cm and breadth 60 cm. Then the banana hands were kept in corrugated fibre board of 5 ply with 30 cm x 25 cm x 20 cm L x W x H was used where L = length in cm, W = width in cm, H = height in cm.

P_7) CFB box with polyethylene lining + ethylene absorbent

Ethylene absorbent was prepared as in treatment P_4, fruits were kept in CFB Box with polyethylene lining as in treatment P_6

P_8) Vacuum package in 150 guage polyethylene bag

Banana hands were placed in polyethylene bag. The polyethylene bag was sealed leaving a small opening of the size of the suction tube using a electric sealing machine. The suction tube of the vacuum pump was placed in the opening of the polyethylene bag and the vacuum pump was put on. After the vacuum is created inside the polyethylene bag indicated by the collapse of the polyethylene bag around the fruit, the opening was sealed and the vacuum pump was put off. Vacuum pump used was Tosniwal High Vacuum Pump ¼ H.P. motor with a capacity of 100 lit min^{-1}.

P_9) Control

Banana hands were kept open in a paper plate under ambient conditions.

All the packages were kept in ambient conditions of temperature 24°C to 30°C and relative humidity 70 to 80 per cent.

3.2.4 Observations

3.2.4.1 Weight of hand

Weight of hand was recorded as in experiment 1.1.

3.2.4.2 Physiological loss in weight (PLW)

PLW was calculated as in experiment 1.2.

3.2.4.3 Spoilage

Spoilage recorded as in experiment 1.5.

3.2.4.4 Shelf life

Shelf life calculated as in experiment 1.3.

3.2.4.5 Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand

Number of days taken by the fully mature green fruit from date of harvest to reach 50 per cent yellowing on more than 50 per cent fingers of the hand.

3.3.3.6 Days to 100 per cent yellowing on all the fingers of the hand

Number of days taken by the fully mature green fruit from date of harvest to reach 100 per cent yellowing on all the fingers of the hand.

3.2.4.7 Organoleptic evaluation

Organoleptic evaluation for assessing the appearance, taste, sweetness and over all acceptance of ripe fruits after storage was carried out by a trained panel of ten members using a ten point scale ranging from zero to ten (0-2 poor, 3-5 satisfactory, 6-8 good, 9-10 excellent quality).

3.2.4.8 Chemical composition on ripening

3.2.4.8.1 TSS

TSS estimated as in 3.1.1.2.1.

3.2.4.8.2 Acidity

Acidity estimated as in 3.1.1.2.2.

3.2.4.8.3 Total, reducing and non reducing sugars

Total, reducing and non reducing sugars was recorded as in 3.1.1.2.4.

3.3 STATISTICAL ANALYSIS

The observations recorded were analysed statistically according to the procedure described by Panse and Sukhatme (1985). The data on sensory evaluation of fruit samples were subjected to Freedman two way analysis and Krusskal Wallis one way analysis (Siegel, 1956).

Results

4. RESULTS

The results of the studies conducted in the Department of Processing Technology, College of Horticulture under the project "Evaluation of selected banana (*Musa* spp.) varieties grown in Kerala for postharvest attributes" are presented in this chapter under the following heads.

4.1 Evaluation of banana varieties for postharvest attributes

4.2 Physical, chemical and physiological changes during postharvest period in banana

4.3 Standardization of methods to enhance shelflife of varieties.

EXPERIMENT-I

4.1 EVALUATION OF BANANA VARIETIES FOR POSTHARVEST ATTRIBUTES

4.1.1 Fruit morphological characters

Twenty five varieties of banana representing six genomic groups AA, AB, AAA, AAB, ABB and AAAA from the germplasm maintained at BRS, Kannara were morphologically described for fruit characters as per INIBAP/IPGRI (*Musa* descriptors). The accessions included in the study were Matti, Kadali, Njalipoovan, Koompillakannan, Poomkalli, Robusta, Red Banana, Dwarf Cavendish, Amritsagar, Grand Naine, Poovan, Palayankodan, Nedunendran, Zanzibar, Chengalikodan, Manjeri Nendran, Chinali, Dudhsagar, BRS-I, BRS-II, Monthan, Batheesa, Kanchikela, Karpooravalli and Bodles Altafort. Twenty one fruit characters relating to fruit position, number of fruits, fruit length, fruit shape, transverse section of fruit, fruit apex, remains of flower relicts at fruit apex, fruit pedicel length, fruit pedicel width, pedicel surface, fusion of pedicels, immature fruit peel colour, mature fruit peel colour, fruit peel thickness, adherence of the fruit peel, cracks in fruit peel, pulp colour before maturity, pulp colour at maturity, fruit fall from hands, flesh texture and predominant taste were taken into consideration. The varieties were found to exhibit considerable variation for fruit characters.

4.1.1.1 Fruit position

Of the twenty five varieties evaluated fruit position in 17 varieties were curved upward, whereas it was curved towards stalk in Matti, Njalipoovan,

Table 2. Fruit morphological characters as per INIBAP/IPGRI (Musa descriptor) of selected banana accessions

Sl. No.	Varieties	Fruit position	No. of fruits	Fruit length (cm)	Fruit shape (longitudinal curvature)	Transverse section of fruit	Fruit apex
1	Matti	Curved towards stalk	13-16	≤ 15	Slightly curved	Rounded	Lengthily pointed
2	Kadali	Curved upward	≤ 12	≤ 15	Straight	Rounded	Blunt tipped
3	Njalipoovan	Curved towards stalk	13-16	16-20	Slightly curved	Rounded	Bottle necked
4	Koompillakannan	Curved towards stalk	13-16	16-20	Straight	Rounded	Bottle necked
5	Poomkalli	Curved towards stalk	13-16	16-20	Slightly curved	Rounded	Lengthily pointed
6	Robusta	Curved upward	13-16	21-25	Straight in the distal part	Slightly ridged	Blunt tipped
7	Red Banana	Curved upward	≤ 12	≤ 15	Straight in the distal part	Rounded	Blunt tipped
8	Dwarf Cavendish	Curved upward	13-16	21-25	Slightly curved	Slightly ridged	Blunt tipped
9	Amritsagar	Curved upward	13-16	21-25	Straight in the distal part	Slightly ridged	Blunt tipped
10	Grand Naine	Curved upward	≤ 12	16-20	Slightly curved	Pronounced ridges	Blunt tipped
11	Poovan	Curved upward	≤ 12	16-20	Straight	Rounded	Blunt tipped
12	Palayankodan	Curved upward	13-16	≤ 15	Slightly curved	Slightly ridged	Bottle necked
13	Nedunendran	Curved upward	≤ 12	26-30	Straight in the distal part	Slightly ridged	Lengthily pointed
14	Zanzibar	Pendant	≤ 12	≥ 31	Straight in the distal part	Slightly ridged	Lengthily pointed
15	Chengalikodan	Curved upward	≤ 12	26-30	Straight in the distal part	Slightly ridged	Lengthily pointed
16	Manjeri Nendran	Curved upward	13-16	26-30	Straight in the distal part	Pronounced ridges	Lengthily pointed
17	Chinali	Curved upward	≤ 12	21-25	Slightly curved	Slightly ridged	Bottle necked
18	Dudhsagar	Curved upward	≥ 17	≤ 15	Straight	Slightly ridged	Bottle necked
19	BRS I	Curved upward	13-16	16-20	Straight	Pronounced ridges	Blunt tipped
20	BRS II	Curved upward	13-16	≤ 15	Slightly curved	Slightly ridged	Bottle necked
21	Monthan	Curved upward	≤ 12	21-25	Straight	Pronounced ridges	Blunt tipped
22	Batheesa	Parallel to stalk	≤ 12	26-30	Straight	Pronounced ridges	Blunt tipped
23	Kanchikela	Curved upward	13-16	21-25	Straight	Pronounced ridges	Lengthily pointed
24	Karpooravalli	Parallel to stalk	≥ 17	16-20	Straight	Slightly ridged	Bottle necked
25	Bodles Altafort	Parallel to stalk	13-16	21-25	Straight in the distal part	Pronounced ridges	Blunt tipped

Contd.

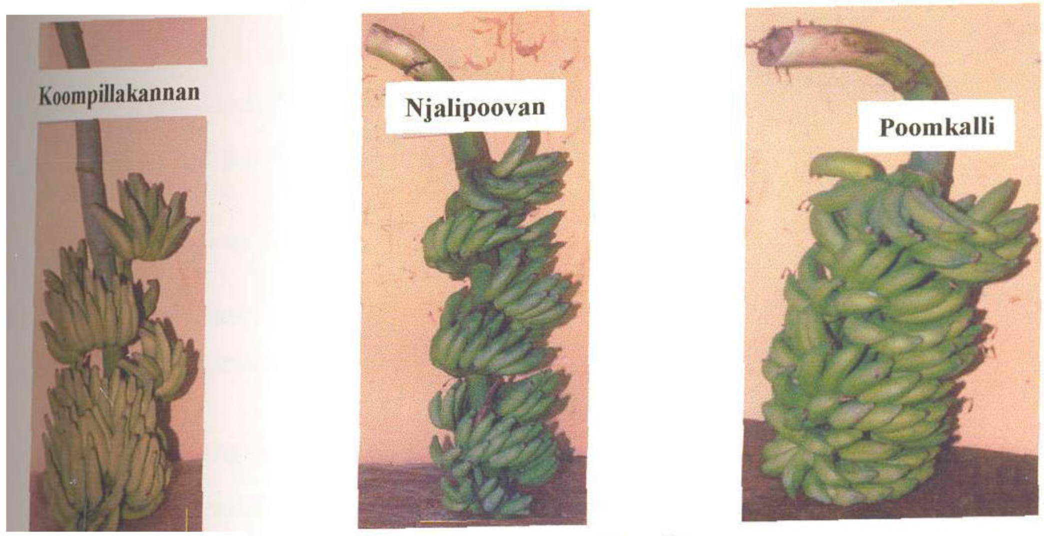
Table 2. Continued

Sl. No.	Varieties	Remains of flower relicts at fruit apex	Fruit pedicel length (mm)	Fruit pedicel width (mm)	Pedicel surface	Fusion of pedicels	Immature fruit peel colour	Mature fruit peel colour	Fruit peel thickness
1	Matti	Base of the style prominent	11-20	> 10	Hairless	Partially fused	Light green	Bright yellow	Two or less
2	Kadali	Persistent style	11-20	> 10	Hairless	No visible sign of fusion	Light green	Yellow	Two or less
3	Njalipoovan	Persistent style	≥ 21	> 10	Hairless	,,	Dark green	Bright yellow	Two or less
4	Koompillakannan	Persistent style	≥ 21	> 10	Hairless	Partially fused	Dark green	Yellow	Two or less
5	Poomkalli	Base of the style prominent	≥ 21	> 10	Hairless	Partially fused	Light green	Yellow	Two or less
6	Robusta	Without any floral relicts	11-20	> 10	Hairless	No visible sign of fusion	Dark green	Light green	Three or more
7 .	Red Banana	Base of the style prominent	≤ 10	> 10	Hairless	,,	Brown/rusty brown	Orangish red	,,
8	Dwarf Cavendish	Base of the style prominent	≤ 10	> 10	Hairless	,,	Light green	Yellow	,,
9	Amritsagar	Persistent style	≤ 10	> 10	Hairless	,,	Light green	Bright yellow	,,
10	Grand Naine	Without any floral relicts	≤ 10	> 10	Hairless	,,	Light green	Light green	,,
11	Poovan	Persistent style	≤ 10	> 10	Hairless	Partially fused	Dark green	Bright yellow	Two or less
12	Palayankodan	Without any floral relicts	≥ 21	> 10	Hairless	No visible sign of fusion	Dark green	Bright yellow	Two or less
13	Nedunendran	Base of the style prominent	≥ 21	> 10	Hairless	,,	Light green	Bright yellow	Three or more
14	Zanzibar	Base of the style prominent	≥ 21	> 10	Hairless	,,	Light green	Bright yellow	,,
15	Chengalikodan	Base of the style prominent	≥ 21	> 10	Hairless	,,	Light green	Bright yellow	,,
16	Manjeri Nendran	Without any floral relicts	≥ 21	> 10	Hairless	,,	Light green	Bright yellow	,,
17	Chinali	Base of the style prominent	11-20	> 10	Hairless	,,	Green	Bright yellow	,,
18	Dudhsagar	Base of the style prominent	≥ 21	> 10	Hairless	,,	Light green	Bright yellow	Two or less
19	BRS I	Without any floral relicts	≤ 10	> 10	Hairless	,,	Light green	Yellow	Three or more
20	BRS II	Without any floral relicts	11-20	> 10	Hairless	,,	Green	Bright yellow	,,
21	Monthan	Persistent style	≥ 21	> 10	Hairless	,,	Light green	Yellow	,,
22	Batheesa	Base of the style prominent	≥ 21	> 10	Hairless	,,	Light green	Yellow	,,
23	Kanchikela	Without any floral relicts	≥ 21	> 10	Hairless	,,	Light green	Yellow	,,
24	Karpooravalli	Base of the style prominent	11-20	> 10	Hairless	,,	Light green	Yellow	Two or less
25	Bodles Altafort	Persistent style	11-20	> 10	Hairless	,,	Light green	Yellow	Two or less

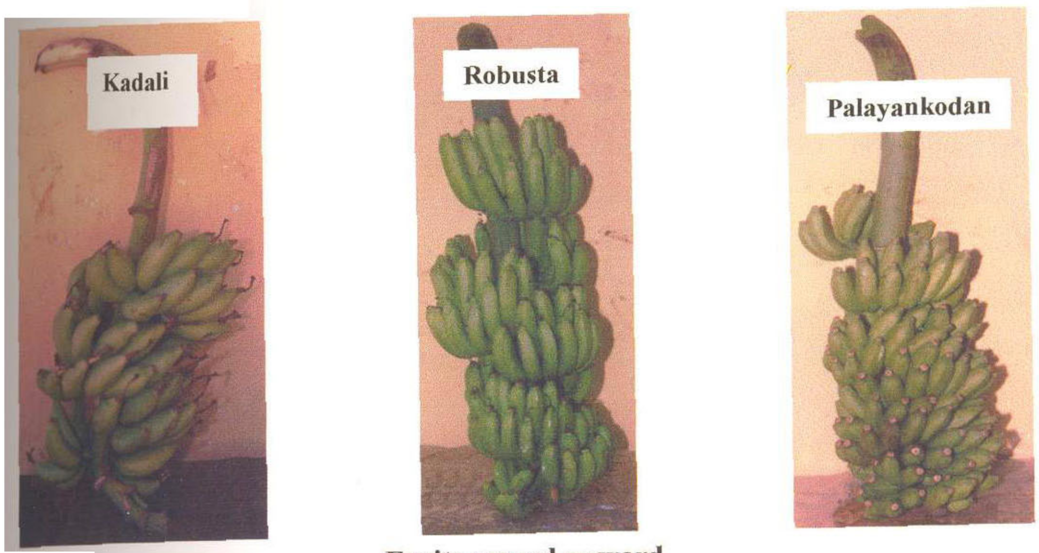
Contd.

Table 2. Continued

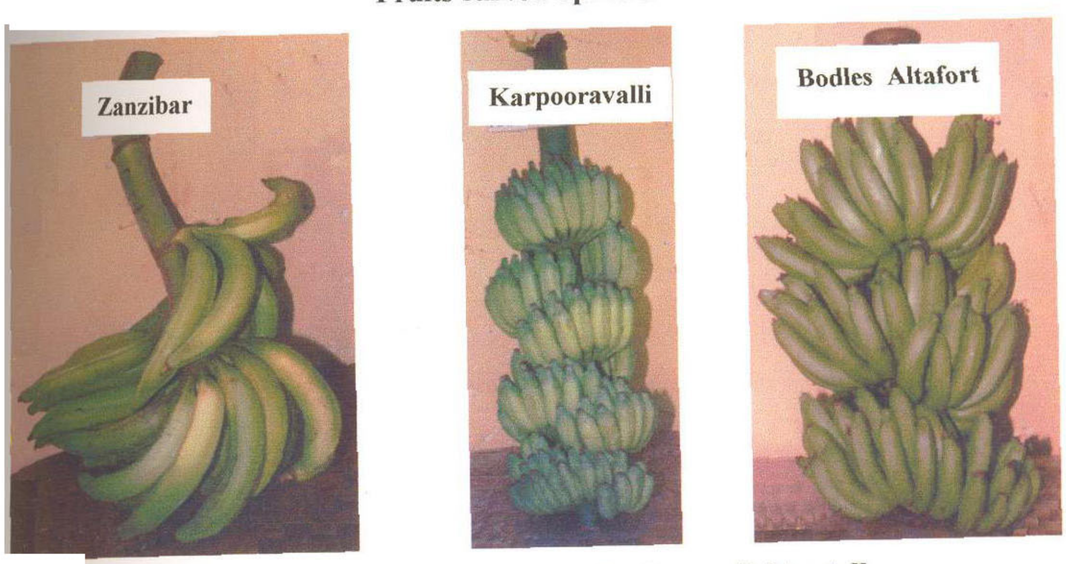
Sl. No.	Varieties	Adherence of the fruit peel	Cracks in fruit peel	Pulp colour before maturity	Pulp colour at maturity	Fruit fall from hands	Flesh texture	Predominant taste
1	Matti	Fruit peels easily	Without cracks	Cream	Cream	Persistent	Soft	Sweet
2	Kadali	,,	,,	White	Cream	Persistent	,,	Sweet
3	Njalipoovan	,,	,,	White	White	Persistent	,,	Sweet
4	Koompillakannan	,,	,,	White	White	Deciduous	,,	Sweet
5	Poomkalli	,,	,,	White	Cream	Persistent	,,	Sweet and acidic
6	Robusta	,,	,,	White	Cream	Deciduous	,,	Sweet
7	Red Banana	,,	,,	Ivory	Yellow	Persistent	,,	Sweet
8	Dwarf Cavendish	,,	,,	Cream	Cream	Deciduous	,,	Sweet
9	Amritsagar	,,	,,	Cream	Cream	Deciduous	,,	Sweet
10	Grand Naine	,,	,,	White	Cream	Deciduous	,,	Sweet
11	Poovan	,,	Cracked	White	Cream	Deciduous	Firm	Sweet and acidic
12	Palayankodan	,,	Without cracks	White	Cream	Persistent	Soft	,,
13	Nedunendran	,,	,,	Beige	Orange yellow	Persistent	Firm	,,
14	Zanzibar	,,	,,	Beige	Orange yellow	Persistent	,,	,,
15	Chengalikodan	,,	,,	Beige	Orange yellow	Persistent	,,	,,
16	Manjeri Nendran	,,	,,	Beige	Orange yellow	Persistent	,,	,,
17	Chinali	,,	,,	Beige	Yellow	Deciduous	Soft	,,
18	Dudhsagar	,,	,,	Cream	Cream	Persistent	,,	,,
19	BRS I	,,	,,	White	White	Deciduous	,,	,,
20	BRS II	,,	,,	Cream	Cream	Persistent	,,	,,
21	Monthan	Fruit does not peel easily	,,	White	White	Deciduous	,,	Astringent
22	Batheesa	,,	,,	White	White	Persistent	,,	Astringent
23	Kanchikela	,,	,,	White	White	Persistent	,,	Astringent
24	Karpooravalli	Fruit peels easily	,,	Ivory	Cream	Persistent	,,	Sweet and acidic
25	Bodles Altafort	Fruit peels easily	,,	Cream	Cream	Persistent	,,	Sweet



Fruits curved towards stalk



Fruits curved upward



Fruits pendant

Fruits parallel to stalk

Plate 28. Fruit position of selected banana varieties

Koompillakannan and Poomkalli and parallel to stalk in Batheesa, Karpooravalli, Bodles Altafort and pendant in Zanzibar (Table 2) (Plate 28).

4.1.1.2 *Number of fruits*

In ten varieties number of fruits was ≤12, in thirteen varieties between 13 to 16 and in Karpooravalli and Doodhsagar ≥17.

4.1.1.3 *Fruit length*

In six varieties single fruit length was ≤15 cm, in seven varieties between 16 to 20 cm and between 21-25 cm, in four varieties between 26-30 cm (Nedunendran, Chengalikodan, Manjeri Nendran and Batheesa) and in one variety (Zanzibar) ≥31 cm.

4.1.1.4 *Fruit shape*

The fruit shape was slightly curved in eight accessions straight in nine accessions, straight in the distal part in eight accessions (Plate 29).

4.1.1.5 *Transverse section of fruit*

In seven varieties *viz.*, Matti, Kadali, Njalipoovan, Koompillakannan, Poomkalli, Red Banana and Poovan round transverse section of fruit was observed. Slightly ridged transverse section was seen in eleven varieties and seven varieties were with pronounced ridges (Plate 30).

4.1.1.6 *Fruit apex*

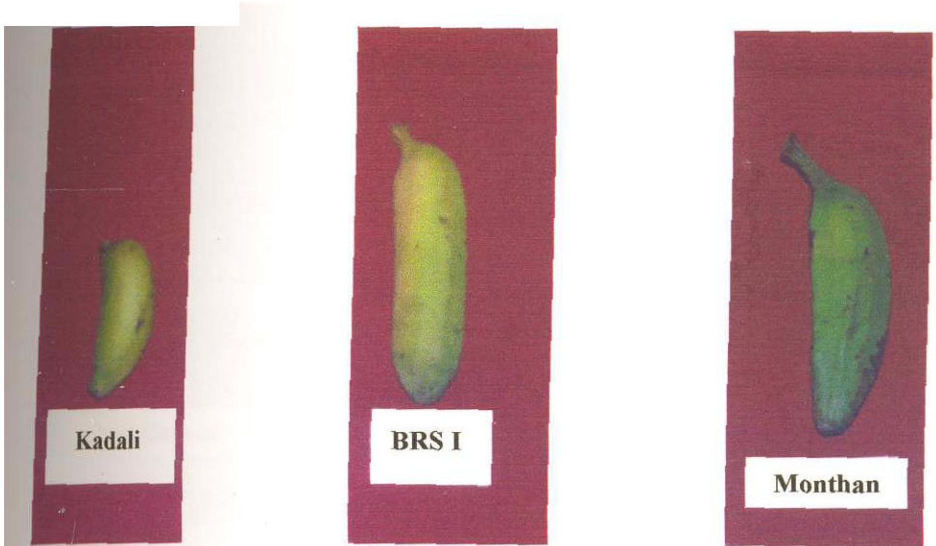
Fruit apex was lengthily pointed in seven varieties, in 11 varieties it was blunt tipped and in seven varieties it was bottlenecked (Plate 31).

4.1.1.7 *Remains of flower relicts at fruit apex*

Base of the style was prominent in 11 varieties. Of the remaining 14 varieties seven had persistent style whereas seven were without any floral relicts.

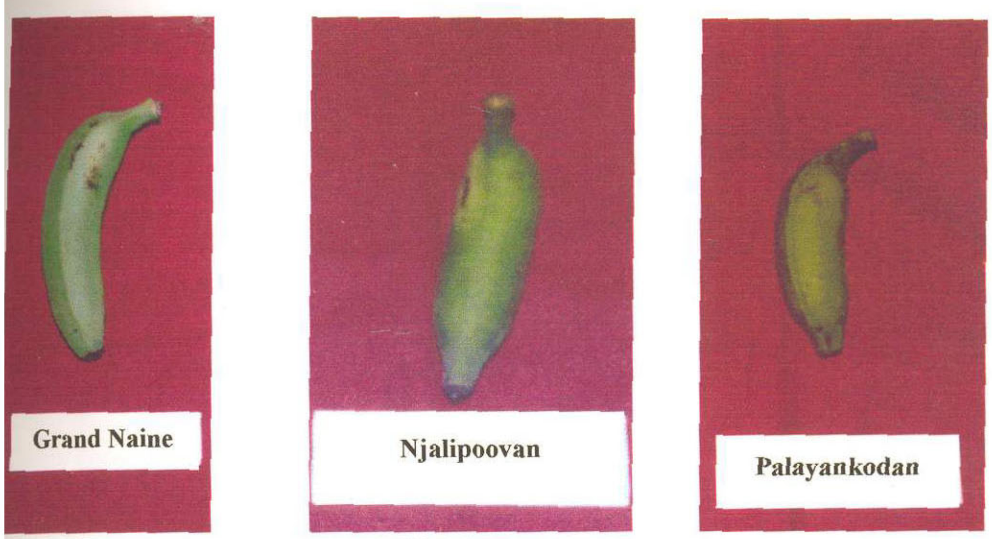
4.1.1.8 *Fruit pedicel length*

In thirteen varieties the fruit pedicel length was ≥21 mm, in nine varieties between 11 to 20 mm and in three varieties *viz.*, Red Banana, Amritsagar and BRS-I ≤10 mm.



Straight

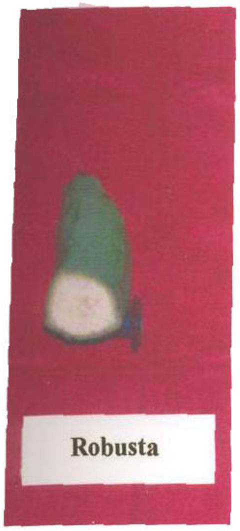
Straight in the distal part

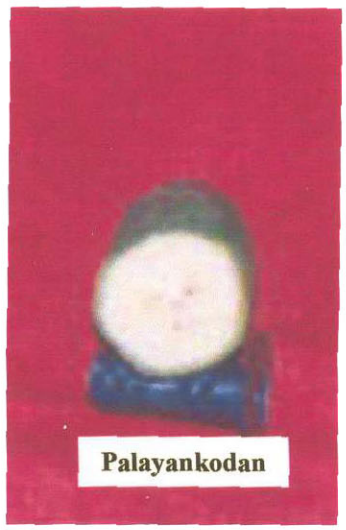


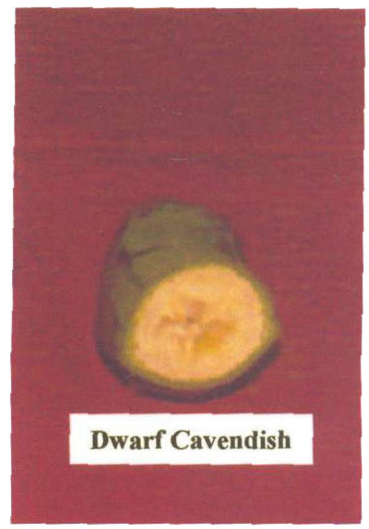
Slightly curved

Plate 29. Fruit shape of selected banana varieties

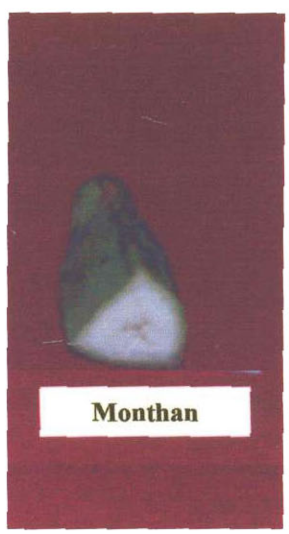
Rounded

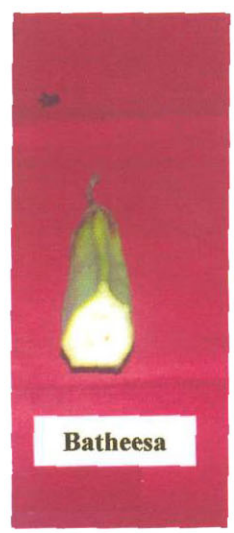






Slightly ridged

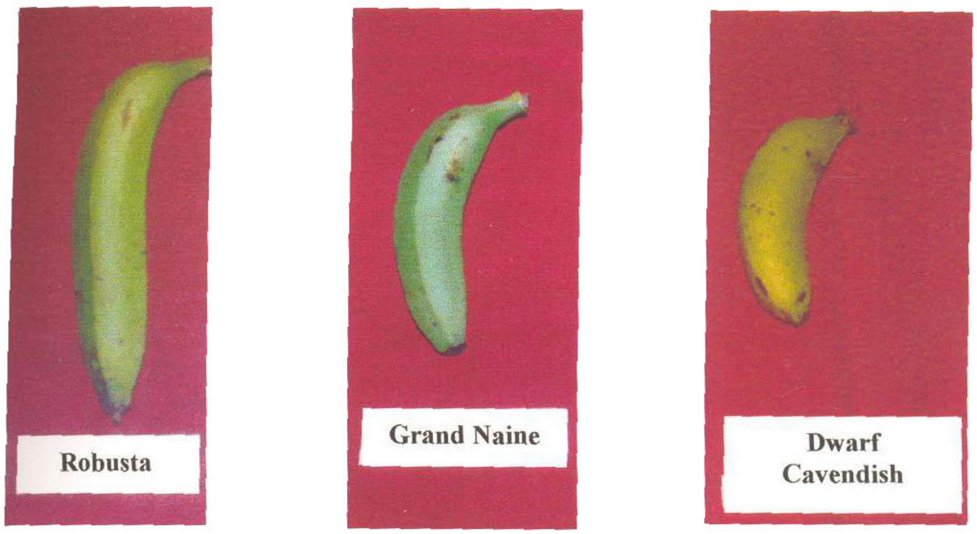




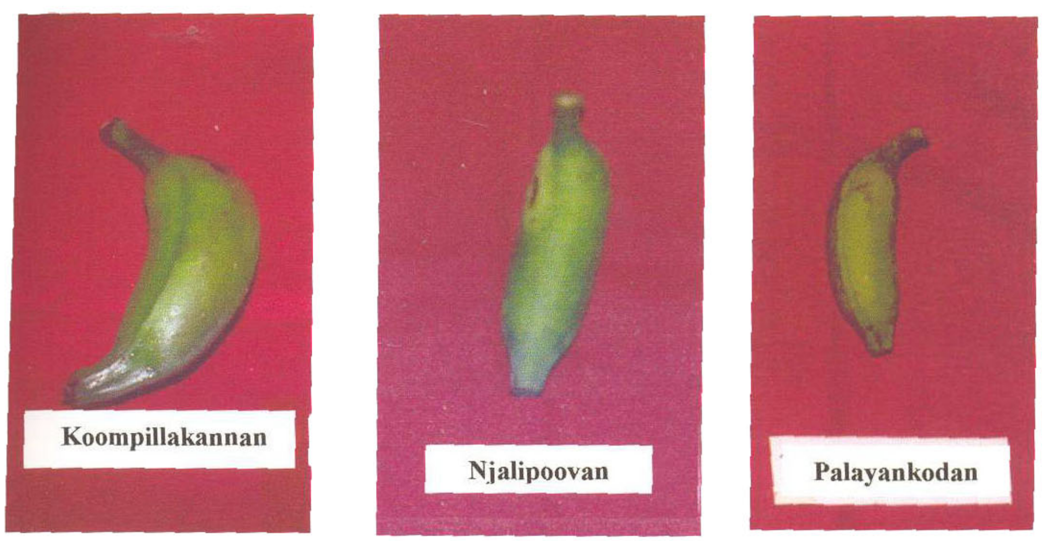
Pronounced ridges

Plate 30. Transverse sections

Lengthily pointed



Blunt tipped



Bottle necked

Plate 31. Variation in fruit apex between banana varieties

4.1.1.9 Fruit pedicel width

In all the varieties studied the fruit pedicel width was >10 mm.

4.1.1.10 Pedicel surface

The pedicel surface in all the twenty five varieties evaluated was found to be hairless.

4.1.1.11 Fusion of pedicels

Pedicel was partially fused in Matti, Koompillakannan, Poomkalli and Poovan. In all other accessions no visible sign of fusion was observed.

4.1.1.12 Immature fruit peel colour

In seventeen varieties immature fruit peel colour was light green, in seven varieties dark green and in Red Banana it was brown/rusty brown.

4.1.1.13 Mature fruit peel colour

Peel colour of mature fruit in twelve varieties was bright yellow, in ten varieties yellow, light green in Robusta and Grand Naine and orangish red in Red Banana.

4.1.1.14 Fruit peel thickness

Fruit peel thickness in ten varieties was two millimetre or less and in 15 varieties three millimetre or more.

4.1.1.15 Adherenoe of the fruit peel

Peel could be easily separated from the fruit on ripening in 22 accessions studied and difficult to peel in the culinary varieties Monthan, Batheesa and Kanchikela.

4.1.1.16 Cracks in fruit peel

Cracks in fruit peel was observed in Poovan. All the other varieties was without cracks.

4.1.1.17 Pulp colour before maturity

Pulp colour before maturity was either white, cream, ivory or beige. In twelve varieties pulp colour before maturity was white whereas in thirteen varieties it was cream, ivory or beige.

4.1.1.18 Pulp colour at maturity

Colour change from beige to orange yellow was observed in Nendran clones and Zanzibar at maturity. Njalipoovan, Koompillakannan, BRS-I and culinary varieties retained white colour even at maturity. Colour change was not very much evident in other accessions.

4.1.1.19 Fruit fall from hands

In nine varieties the fruits were deciduous and in 16 varieties it was persistent.

4.1.1.20 Flesh texture

In Poovan and Nendran clones firm flesh texture was observed where as in all the other varieties the flesh texture was soft.

4.1.1.21 Predominant taste

In Poomkalli, Poovan, Palayamkodan, Nendran clones, Chinali, Doodhsagar, BRS-I and II, the predominant taste was sweet and acidic. In Matti, Kadali, Njalipoovan, Koompillakannan, Robusta, Red Banana, Dwarf Cavendish, Amritsagar, Grand Naine and Boldles Altafort the predominant taste was sweet whereas in the culinary varieties Monthan, Batheesa and Kanchekela astringent taste was observed.

4.1.2 Evaluation of banana varieties for physico-chemical constituents

Twenty five varieties of banana were evaluated for physical characters, chemical constituents and shelf life.

4.1.2.1 *Physical characters*

Physical characters like finger weight, length of finger, volume of finger, pulp weight, peel weight, pulp/peel ratio and peel thickness were recorded. Significant difference for various physical characters were observed among the different varieties (Table 3).

4.1.2.2 *Finger weight*

The varieties showed significant difference with respect to finger weight. Maximum value for finger weight was obtained in the variety Zanzibar (262.5 g) and minimum value in Matti (36.5 g). Nendran clones and culinary varieties recorded comparatively higher fruit weight [Nedunendran (159.5 g), Chengalikodan (158.5 g), Manjeri Nendran (147 g), Monthan (159 g), Batheesa (167.5 g) and Kanchikela (175.5 g)].

4.1.2.3 *Finger length*

Finger length differed significantly between the varieties and highest value for finger length was recorded in the variety Zanzibar (30.8 cm) and lowest value in Matti (10.85 cm).

4.1.2.4 *Volume of finger*

Significant difference existed between varieties for volume of fruit. It was found that volume was maximum in the variety Zanzibar (295 ml) and minimum in Matti (53 ml).

4.1.2.5 *Pulp weight*

Significant varietal variation was observed in the pulp weight of fruits. Variety Zanzibar recorded maximum pulp weight (160 g) and Matti minimum (21.5 g).

4.1.2.6 *Peel weight*

Variety Zanzibar with a peel weight of 102.5 g differed significantly from other varieties and varieties Matti and Kadali the lowest values (15 g and 15.5 g respectively).

Table 3. Physical characters of fingers of selected banana varieties

Sl. No.	Variety	Finger weight (g)	Length (cm)	Volume (ml)	Pulp weight (g)	Peel weight (g)	Pulp/peel ratio	Peel thickness (mm)	Specific gravity
1	Matti	36.50	10.850	53.000	21.500	15.000	1.430	1.060	0.690
2	Kadali	59.00	14.100	63.500	43.500	15.500	2.780	2.020	0.920
3	Njalipoovan	55.50	16.550	59.000	38.500	17.000	2.245	2.015	0.935
4	Koompillakannan	59.00	15.600	64.000	37.000	22.000	1.680	1.615	0.925
5	Poomkalli	110.000	15.950	212.500	83.500	26.500	3.150	2.090	0.520
6	Robusta	131.00	21.200	132.500	78.500	52.500	1.495	3.160	0.990
7	Red Banana	123.500	15.100	131.500	84.500	39.000	2.160	3.065	0.935
8	Dwarf Cavendish	98.500	20.600	128.000	57.500	41.000	1.395	3.110	0.770
9	Amritsagar	125.500	22.900	120.000	77.500	48.000	1.615	2.945	1.045
10	Grand Naine	107.000	20.450	99.000	59.500	47.500	1.250	3.080	1.080
11	Poovan	122.000	18.250	152.500	91.000	31.000	2.925	2.025	0.800
12	Palayankodan	81.000	14.100	91.500	53.500	27.500	1.945	2.035	0.885
13	Nedunendran	159.500	25.750	153.500	94.500	65.000	1.445	3.965	1.040
14	Zanzibar	262.500	30.800	295.000	160.000	102.500	1.565	4.115	0.890
15	Chengalikodan	158.500	27.600	179.000	97.500	61.000	1.600	4.005	0.885
16	Manjeri Nendran	147.000	28.750	212.500	86.000	61.000	1.410	4.010	0.690
17	Chinali	138.500	20.800	152.500	84.000	54.500	1.550	3.045	0.910
18	Dudhsagar	70.500	13.300	82.500	37.500	33.000	1.135	2.160	0.855
19	BRS-I	148.500	18.350	162.500	87.000	61.500	1.410	3.945	0.915
20	BRS-II	96.500	13.200	91.500	62.500	34.000	1.840	3.975	1.050
21	Monthan	159.000	22.150	212.500	78.500	80.500	0.970	4.130	0.745
22	Batheesa	167.500	27.200	217.500	89.000	78.500	1.170	4.120	0.770
23	Kanchikela	175.500	24.500	174.500	98.500	77.000	1.275	4.065	1.010
24	Karpooravalli	66.000	16.100	88.000	39.000	27.000	1.450	2.120	0.750
25	Bodles Altafort	126.500	22.950	166.000	71.000	55.500	1.280	3.070	0.765
	CD (0.05)	0.0633*	2.174*	6.042*	5.433*	3.568*	0.744*	0.652*	0.357*

* - Significant at 5% level

4.1.2.7 Pulp/peel ratio

Significant difference was observed between the varieties for pulp/peel ratio. Maximum pulp/peel ratio was registered in the variety Poomkalli (3.15) and minimum in Monthan (0.97).

4.1.2.8 Peel thickness

Peel thickness showed significant variation between the varieties. The culinary varieties had thicker peel as compared to table varieties. Peel thickness was highest in Monthan (4.13 mm) followed by Batheesa (4.12 mm) and lowest in Matti (1.06 mm).

4.1.2.9 Specific gravity

Specific gravity was found to be highest in Grand Naine (1.08) and lowest in Matti (0.69).

4.1.3 Chemical constituents

General analysis of variance for chemical constituents like TSS, acidity, pH, total, reducing and non reducing sugars, tannin, pectin, moisture, starch, vitamin C and ß carotene showed significant difference among the varieties (Table 4).

4.1.3.1 TSS

Significant difference among the varieties was seen for TSS.

Maximum values for TSS was recorded in the varieties Zanzibar and Chinali (32.5°brix) and minimum in the culinary variety Kanchikela (6.5°brix). Varieties Chengalikodan (32°brix), Koompillakannan (31.5°brix), Nedunendran, Manjeri Nendran, Matti and Njalipoovan (30.5°brix) also recorded higher TSS compared to other varieties.

4.1.3.2 Acidity

Acidity varied significantly among the varieties and the variety Batheesa recorded minimum value (0.192%) and BRS-I the maximum (0.794%) followed by BRS-II (0.743%).

Table 4. Chemical constituents of selected banana varieties

Sl. No.	Varieties	TSS (°Brix)	Acidity (%)	pH	TSS/Acid ratio	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
1	Matti	30.5	0.448	4.685	68.080	16.745	13.405	3.340
2	Kadali	27.0	0.416	4.765	64.900	16.030	10.500	5.530
3	Njalipoovan	30.5	0.640	4.040	47.660	23.525	19.980	3.545
4	Koompillakannan	31.5	0.335	4.530	94.150	23.810	20.435	3.375
5	Poomkalli	26.5	0.432	4.550	61.470	16.240	11.930	4.310
6	Robusta	24.5	0.250	5.125	98.445	23.900	23.040	0.565
7	Red Banana	27.5	0.276	5.360	95.030	18.120	16.795	1.325
8	Dwarf Cavendish	23.5	0.257	5.405	91.435	23.220	21.630	1.590
9	Amritsagar	27.5	0.287	5.515	95.985	18.655	17.360	1.295
10	Grand Naine	28.5	0.320	4.530	89.065	16.905	16.065	0.840
11	Poovan	29.5	0.448	4.610	65.845	23.545	18.095	5.450
12	Palayankodan	25.5	0.416	4.320	61.755	23.465	21.045	2.420
13	Nedunendran	30.5	0.480	4.055	63.895	25.005	20.160	4.845
14	Zanzibar	32.5	0.480	4.090	67.940	25.040	19.735	5.305
15	Chengalikodan	32.0	0.544	3.895	59.030	33.385	27.075	6.310
16	Manjeri Nendran	30.5	0.544	3.705	56.205	22.140	18.230	3.910
17	Chinali	32.5	0.432	4.020	75.380	21.190	15.670	5.520
18	Dudhsagar	28.5	0.352	4.495	81.510	18.800	15.180	3.620
19	BRS-I	24.5	0.794	3.005	30.965	20.680	14.560	6.120
20	BRS-II	23.5	0.743	3.000	31.665	18.675	14.215	4.460
21	Monthan	8.0	0.224	5.590	36.460	1.485	0.755	0.730
22	Batheesa	7.5	0.192	5.695	39.065	1.470	0.730	0.740
23	Kanchikela	6.5	0.256	5.465	25.390	1.340	0.955	0.385
24	Karpooravalli	29.5	0.416	4.285	71.240	21.190	14.825	6.365
25	Bodles Altafort	28.5	0.353	4.200	80.770	18.905	17.340	1.565
	CD (0.05)	1.57*	0.29*	0.58*	4.35*	2.10*	2.56*	2.18*

* - Significant at 5% level

Contd.

Table 4. Continued

Sl. No.	Varieties	Moisture (%)	Vitamin C (mg 100 g^{-1})	β-carotene (µg 100 g^{-1})	Tannin (%)	Pectin (%)	Starch (%)
1	Matti	69.660	6.450	135.155	0.287	0.680	1.140
2	Kadali	73.480	4.585	161.985	0.102	0.645	1.300
3	Njalipoovan	64.780	3.440	93.030	0.299	0.940	1.075
4	Koompillakannan	68.435	2.680	82.885	0.299	0.685	1.422
5	Poomkalli	70.365	2.410	80.075	0.725	0.940	1.700
6	Robusta	79.410	2.060	136.405	0.234	0.645	1.120
7	Red Banana	76.020	5.775	152.350	0.264	0.720	1.106
8	Dwarf Cavendish	81.500	1.495	148.700	0.440	0.335	1.104
9	Amritsagar	73.740	4.215	135.045	0.489	0.705	1.048
10	Grand Naine	70.265	2.200	135.700	0.259	0.850	1.125
11	Poovan	72.180	2.655	140.500	0.429	1.000	1.258
12	Palayankodan	70.600	2.845	119.585	0.420	1.160	1.805
13	Nedunendran	65.660	5.470	214.340	0.613	0.975	2.094
14	Zanzibar	63.380	4.130	233.220	0.620	0.930	2.290
15	Chengalikodan	64.140	6.100	266.605	0.551	0.980	2.080
16	Manjeri Nendran	64.460	5.800	213.630	0.722	0.900	2.149
17	Chinali	62.160	2.300	71.690	0.469	0.925	1.126
18	Dudhsagar	66.560	2.345	88.715	0.317	0.800	1.643
19	BRS-I	71.880	4.330	137.655	0.412	0.935	1.366
20	BRS-II	71.260	2.700	152.885	0.395	1.025	1.277
21	Monthan	73.060	1.725	52.300	1.228	2.735	22.460
22	Batheesa	65.445	4.885	82.055	1.264	3.485	25.385
23	Kanchikela	85.040	2.990	89.265	1.640	3.535	23.307
24	Karpooravalli	67.120	2.070	70.870	0.505	1.075	1.442
25	Bodles Altafort	70.690	1.875	167.510	0.264	0.780	1.280
	CD (0.05)	2.34*	1.58*	6.92*	0.55*	0.58*	1.27*

* - Significant at 5% level

4.1.3.3 pH

Variation in pH was also significant between the varieties.

Highest value for pH was recorded in the culinary varieties Batheesa (5.695) and Monthan (5.590). Among the table varieties highest value was recorded by Amritsagar (5.515) followed by Dwarf Cavendish (5.405).

Lowest value for pH was registered by BRS-I and BRS-II (3.00).

4.1.3.4 Total sugars

Significant variation was noticed for total sugars among the varieties.

Total sugar was found to be highest in the variety Chengalikodan (33.39%) followed by Zanzibar and Nedunendran (25.04 and 25.00% respectively). Among the table varieties lowest value was recorded by the varieties Kadali and Poomkalli (16.03% and 16.24% respectively).

Of the twenty five varieties evaluated total sugar was found to be lowest in the culinary variety Kanchikela (1.34%) followed by Batheesa and Monthan (1.47% and 1.49%).

4.1.3.5 Reducing sugars

Among the different varieties evaluated significant variation was observed for reducing sugars. Reducing sugar was found to be highest in the variety Chengalikodan (27.075%) followed by Robusta (23.04%) and among the table varieties lowest value was noticed in Kadali (10.5%) followed by Poomkalli (11.93%).

The culinary varieties in general registered low values for reducing sugars. Batheesa registered the lowest value (0.73%) followed by Monthan (0.76%) and Kanchikela (0.96%).

4.1.3.6 Non-reducing sugars

Among the table varieties non-reducing sugar was highest in the variety Karpooravalli (6.37%) and lowest in Grand Naine (0.84%).

The culinary variety Kanchikela registered the lowest value (0.39%) for non-reducing sugars.

4.1.3.7 Moisture

Significant difference in moisture content was observed among the varieties. Moisture content in banana varieties ranged from 62.16 per cent in the variety Chinali to 85.04 per cent in the culinary variety Kanchikela.

4.1.3.8 Vitamin C

Significant difference for values of vitamin C was noticed among the varieties. Maximum value for vitamin C was registered by the variety Matti (6.45 mg 100 g^{-1}) followed by Chengalikodan (6.1 mg 100 g^{-1}). Minimum value was registered by the variety Dwarf Cavendish (1.5 mg 100 g^{-1}).

4.1.3.9 β-carotene

Varieties differed significantly for β-carotene content. Chengalikodan registered maximum value for ß carotene (266.61 μg 100 g^{-1}) followed by Zanzibar (233.22 μg 100 g^{-1}) and Monthan the minimum (52.3 μg 100 g^{-1}).

4.1.3.10 Tannin (%)

There was significant difference for tannin content in the various varieties. Kanchikela registered higher values for tannin content (1.64%) followed by Batheesa (1.26%) and Monthan (1.23%). Among the table varieties Poomkalli registered the maximum value (0.73%) followed by Manjeri Nendran (0.72%) and minimum by Kadali (0.10%).

4.1.3.11 Pectin (%)

High values for pectin content was recorded in the culinary varieties of banana and Kanchikela recorded the maximum (3.54%). Among the table varieties higher pectin content was registered in the variety Palayankodan (1.16%) followed by Karpooravalli (1.08%) and minimum in Dwarf Cavendish (0.34%).

4.1.3.12 Starch (%)

Higher starch content were recorded in the culinary varieties Batheesa (25.39%), Kanchikela (23.31%) and Monthan (22.46%). Among the table varieties higher starch content was recorded in the variety Zanzibar (2.29%) and minimum in Amritsagar (1.05%).

4.1.4 Shelf life

The shelf life was calculated as number of days till the fruit remained marketable. Unmarketability was attributed when more than 50 per cent of fruits in a hand showed more than 50 per cent blackening as spots, specks and lesions. Results of shelf life are mentioned under subtitles of PLW, shelf life, finger retention and spoilage below.

4.1.4.1 Physiological loss in weight (PLW)

The average values for PLW differed significantly among the varieties. Highest value for PLW was recorded by Grand Naine (26.46%) followed by Koompillakannan (25.54%) at the end of storage period whereas lowest value was recorded by Batheesa (9.63%) (Table 5).

The PLW was recorded cumulatively at three days interval in all the varieties. The varieties differed significantly with respect to PLW on all the days of observations (Table 6).

Minimum values for PLW was recorded by the variety Amritsagar (1.09%) followed by Zanzibar (1.25%) on the third day of storage, whereas maximum values for PLW was recorded by Nedunendran (9.87%) followed by Koompillakannan (6.21%).

On the 6^{th} day of storage minimum PLW was registered by Zanzibar (4.07%) followed by Red Banana (4.20%) and maximum by Koompillakannan (20.38%) followed by Kadali (15.25%).

Table 5. Shelf life of selected banana varieties

Sl.No.	Varieties	Total shelf life (Days)	Finger retention (Days)	Cumulative PLW (%)
1	Matti	10.000	10.000	22.850
2	Kadali	9.500	9.500	18.910
3	Njalipoovan	13.000	13.000	17.135
4	Koompillakannan	9.500	7.000	25.540
5	Poomkalli	15.000	15.000	21.620
6	Robusta	11.500	10.000	10.670
7	Red Banana	15.500	15.500	12.100
8	Dwarf Cavendish	12.000	11.000	17.150
9	Amritsagar	14.000	12.000	15.260
10	Grand Naine	15.500	15.500	26.460
11	Poovan	11.000	10.000	19.830
12	Palayankodan	13.000	11.000	15.940
13	Nedunendran	12.000	12.000	20.965
14	Zanzibar	14.500	14.500	15.485
15	Chengalikodan	17.000	17.000	15.715
16	Manjeri Nendran	15.000	15.000	15.470
17	Chinali	9.000	9.000	12.345
18	Dudhsagar	11.000	11.000	21.060
19	BRS-I	11.000	9.000	11.045
20	BRS-II	12.000	12.000	14.170
21	Monthan	9.000	9.000	13.785
22	Batheesa	7.000	7.000	9.630
23	Kanchikela	12.000	12.000	14.360
24	Karpooravalli	14.000	14.000	24.305
25	Bodles Altafort	17.500	17.500	23.050
	CD (0.05)	18.690*	1.880*	2.659*

* - Significant at 5% level

Table 6. Trend of PLW in selected banana varieties under ambient conditions

Sl.No.	Varieties	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)
1	Matti	2.225	13.540	19.850	ND	ND
2	Kadali	5.595	15.245	18.910	ND	ND
3	Njalipoovan	1.515	8.275	10.385	17.135	ND
4	Koompillakannan	6.205	20.380	25.540	ND	ND
5	Poomkalli	2.440	9.385	10.970	18.850	21.620
6	Robusta	1.575	6.000	8.790	ND	ND
7	Red Banana	1.355	4.200	5.655	10.840	12.100
8	Dwarf Cavendish	3.095	8.655	12.970	15.260	ND
9	Amritsagar	1.085	5.585	7.000	17.150	ND
10	Grand Naine	4.235	11.410	14.890	20.230	25.870
11	Poovan	3.605	11.085	15.330	ND	ND
12	Palayankodan	1.530	7.155	10.285	13.81	ND
13	Nedunendran	9.870	14.510	16.615	18.21	ND
14	Zanzibar	1.245	4.070	5.660	11.110	ND
15	Chengalikodan	1.645	5.290	7.250	14.480	15.670
16	Manjeri Nendran	2.365	7.515	9.130	13.865	15.470
17	Chinali	2.990	9.965	12.345	ND	ND
18	Dudhsagar	3.845	9.880	15.610	ND	ND
19	BRS-I	1.835	5.965	9.085	ND	ND
20	BRS-II	1.460	8.045	9.660	ND	ND
21	Monthan	2.390	9.735	13.785	ND	ND
22	Batheesa	2.915	9.630	ND	ND	ND
23	Kanchikela	3.010	8.160	10.070	ND	ND
24	Karpooravalli	2.795	7.730	13.250	23.755	ND
25	Bodles Altafort	3.090	8.520	10.620	16.78	19.34
	CD (0.05)	1.598*	1.968*	2.34	NA	NA

* - Significant at 5% level; ND - Not determined due to termination of shelf life; NA - Not analysed statistically

Minimum PLW on 9th day after storage was registered by Red Banana and Zanzibar (5.66%) and maximum PLW by Koompillakannan (25.54%).

On 12th day of storage only eleven varieties were available for estimating PLW as the rest of the varieties were discarded due to spoilage. Minimum PLW was registered by Red Banana (10.84%) and maximum PLW by Karpooravalli (23.76%).

On 15th day of storage only seven varieties were available for estimation of PLW and minimum PLW was recorded by Red Banana (12.1%) and maximum by Grand Naine (25.87%).

4.1.4.2 Shelf life

Shelf life of a fruit is the number of days a fruit is in edible or consumable stage.

Significant variation in shelf life was observed among the varieties. Maximum shelf life was recorded by the variety Bodles Altafort (17.5 days) and Chengalikodan (17 days) and minimum by the variety Chinali (9 days) under ambient conditions. Red Banana, Grand Naine (15.5 days), Manjeri Nendran, Poomkalli (15 days), Zanzibar (14.5 days), Amritsagar, Karpooravalli (14.0 days) also recorded longer shelf life compared to other varieties.

4.1.4.3 Finger retention

Number of days upto which fingers were retained on the hand without dehiscence was considered for finger retention.

Different varieties showed significant variation with respect to the values for finger retention. Fingers of varieties Bodles Altafort and Chengalikodan were retained in the hands for maximum days (17.5 & 17.0 days respectively) and Koompillakunnan the minimum (7.0 days) duration.

4.1.4.4 Spoilage

Pathological examination of the spoiled fruits revealed the presence of the following pathogens.

Botrydiplodia theobromae
Colletotrichum gloeosporioides
Rhizopus sp.

4.1.5 Organoleptic evaluation

Organoleptic evaluation of twenty two table varieties revealed that significant difference existed for qualities like appearance, sweetness, taste, flavour and overall acceptability (Table 7).

The highest score for appearance was recorded by the varieties Njalipoovan and Dwarf Cavendish (7.4) and lowest by Matti (5.2).

With respect to sweetness maximum values were registered by the varieties Kadali, Koompillakunnan and Dwarf Cavendish (7.2) and minimum by Poomkalli (4.5) followed by BRS II (5.3).

Varieties Kadali and Koompillakunnan registered top score for taste (7.4) and Poomkalli and BRS II the lowest (4.9).

Maximum values for flavour was registered by the variety Kadali (7.4) followed by Robusta and Dwarf Cavendish (7.2). Minimum value was registered by the variety Poomkalli (4.2).

Varieties differed significantly for overall acceptance. Higher scores for overall acceptability was obtained for Kadali, Matti, Robusta, Red Banana, Dwarf Cavendish, Amritsagar, Grand Naine, Poovan and Zanzibar.

EXPERIMENT II

4.2 PHYSICAL, CHEMICAL AND PHYSIOLOGICAL CHANGES DURING POST HARVEST PERIOD IN BANANA.

Physical, chemical and physiological changes at four stages *viz.*, mature green unripe stage, colour changing, full ripe and over ripe stages in eight varieties were recorded during postharvest period (Plate 32).

Table 7. Organoleptic evaluation of ripe fruits of selected banana varieties

Sl.No.	Varieties	Sensory evaluation score				
		Appearance	Sweetness	Taste	Flavour	Overall acceptance
1	Matti	5.2	7.1	6.8	6.8	7.1
2	Kadali	6.1	7.2	7.4	7.4	7.3
3	Njalipoovan	7.4	6.2	6.8	6.5	6.5
4	Koompillakannan	5.4	7.2	7.4	6.1	6.5
5	Poomkalli	6.2	4.5	4.9	4.2	5.2
6	Robusta	6.4	7.0	6.7	7.2	7.4
7	Red Banana	7.0	6.1	6.5	6.6	6.8
8	Dwarf Cavendish	7.4	7.2	6.7	7.2	7.0
9	Amritsagar	7.0	6.5	6.2	6.4	6.9
10	Grand Naine	6.8	7.1	7.2	6.6	6.9
11	Poovan	5.7	6.4	6.2	5.8	7.3
12	Palayankodan	6.0	5.9	5.7	5.9	5.7
13	Nedunendran	5.8	6.9	6.8	7.0	6.7
14	Zanzibar	7.1	6.4	7.1	7.0	7.1
15	Chengalikodan	6.3	6.3	7.1	7.0	6.5
16	Manjeri Nendran	6.7	6.3	6.7	6.8	6.6
17	Chinali	6.1	6.9	6.4	6.4	6.8
18	Dudhsagar	5.4	6.2	6.1	6.9	6.4
19	BRS-I	6.4	5.4	5.4	5.2	5.0
20	BRS-II	6.0	5.3	4.9	5.4	5.0
21	Karpooravalli	5.6	6.6	6.6	6.1	6.4
22	Bodles Altafort	6.2	7.1	6.9	7.0	6.8
	Co-efficient of concordance	0.314*	0.270*	0.350*	0.391*	0.330*

* - Significant at 5% level

Plate 32. Stages during ripening of banana varieties

4.2.1 Physical constituents

The physical parameters *viz.*, pulp percentage, peel percentage, pulp/peel ratio and fruit firmness differed significantly between the different stages in various varieties (Table 8).

4.2.1.1 Pulp percentage

Pulp percentage showed an increasing trend from stage I to stage IV in all the varieties.

Percentage of pulp in stage I was found to be lowest in BRS I (50.48%) and highest in Njalipoovan (68.55%) whereas in stage IV highest value was registered in Njalipoovan (78.52%) and lowest in Grand Naine (65.61%).

4.2.1.2 Peel percentage

Peel percentage showed a decreasing trend in all the varieties over different stages.

Lowest peel percentage in stage I was recorded in Njalipoovan (31.44%) and highest in Robusta (47.92%) followed by Grand Naine (47.57%).

Highest peel percentage in stage IV was recorded in Grand Naine (34.39%) followed by Robusta (33.48%) whereas it was lowest in Njalipoovan (21.47%).

4.2.1.3 Pulp/peel ratio

Pulp/peel ratio showed an increasing trend in all the varieties over different stages. Pulp/peel ratio was found to be maximum in Njalipoovan in stage I and IV (2.18 and 3.77 respectively) whereas lowest pulp/peel ratio was found in BRS I in stage I (1.05) and in Grand Naine (1.91) followed by Robusta (1.99) in stage IV.

4.2.1.4 Fruit firmness

Firmness of the fruit was found to decrease in all the varieties as the fruit ripens.

Table 8. Physical changes during ripening of banana varieties

Sl. No.	Varieties	Pulp (%)				Peel (%)			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	61.230^{lmn}	67.760^{fghij}	76.810^{abc}	77.007^{ab}	38.767^{cde}	34.090^{defgh}	24.070^{klm}	22.990^{lm}
2	Njalipoovan	68.553^{fghi}	72.440^{bcdef}	74.953^{abcde}	78.520^{a}	31.440^{fghi}	27.553^{ijkl}	25.040^{jklm}	21.473^{m}
3	Grand Naine	52.430^{op}	55.197^{op}	63.177^{jklm}	65.607^{hijkl}	47.570^{a}	44.800^{ab}	36.820^{cde}	34.390^{defg}
4	Robusta	52.077^{op}	56.567^{no}	64.387^{ijklm}	66.523^{ghijk}	47.917^{a}	43.957^{ab}	35.610^{cdef}	33.477^{efgh}
5	Chengalikodan	60.970^{lmn}	62.733^{jklm}	65.493^{hijkl}	70.013^{efgh}	39.030^{cd}	37.263^{cde}	34.507^{defg}	29.987^{ghij}
6	Red Banana	59.957^{mn}	63.110^{jklm}	68.403^{fghi}	70.873^{defg}	40.037^{bc}	36.550^{cdef}	29.840^{ghij}	29.127^{hijk}
7	BRS-I	50.483^{p}	50.733^{p}	62.573^{klm}	71.807^{cdef}	46.810^{a}	48.333^{a}	37.473^{cde}	28.167^{ijkl}
8	BRS-II	64.090^{ijklm}	72.437^{bcdef}	73.747^{abcde}	75.577^{abcd}	38.570^{cde}	27.553^{ijkl}	26.233^{ijklm}	24.383^{klm}

Values with same superscripts do not differ significantly

Contd.

Table 8. Continued

Sl. No.	Varieties	Pulp/Peel ratio				Fruit firmness (Kg cm^{-2})			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	1.593^{jklmno}	2.137^{fghijk}	3.333^{ab}	3.350^{bcde}	9.967^{ab}	6.483^{e}	3.150^{gh}	1.867^{jk}
2	Njalipoovan	2.183^{fghij}	2.633^{cdef}	3.017^{bcd}	3.773^{a}	9.750^{a}	6.517^{e}	3.183^{gh}	1.850^{jk}
3	Grand Naine	1.103^{no}	1.237^{mno}	1.770^{ijklm}	1.913^{ghijkl}	9.133^{a}	8.417^{bc}	2.317^{hij}	1.110^{k}
4	Robusta	1.087^{no}	1.303^{lmno}	1.817^{hijklm}	1.987^{ghijk}	9.150^{ab}	7.050^{de}	3.383^{g}	1.500^{jk}
5	Chengalikodan	1.563^{jklmno}	$1.687^{ijklmno}$	1.917^{ghijkl}	2.637^{cdef}	10.133^{a}	7.767^{cd}	6.350^{e}	3.133^{gh}
6	Red Banana	1.500^{klmno}	1.710^{ijklmn}	2.303^{efghi}	2.443^{defgh}	9.183^{ab}	6.117^{ef}	2.983^{ghi}	1.427^{jk}
7	BRS-I	1.047^{o}	1.040^{o}	$1.673^{ijklmno}$	2.553^{cdefg}	9.200^{ab}	6.450^{e}	3.177^{gh}	1.683^{jk}
8	BRS-II	1.597^{jklmno}	2.650^{cdef}	2.860^{bcde}	3.110^{bc}	9.250^{ab}	5.367^{f}	3.483^{g}	2.087^{ijk}

Values with same superscripts do not differ significantly

Fruit firmness was maximum in stage I and minimum in stage IV.

Maximum value for firmness was recorded in stage I in Chengalikodan (10.133 kg cm^{-2}) and minimum in stage I was in the variety Grand Naine (9.133 kg cm^{-2}).

Lowest value for firmness in stage IV was recorded in the variety Grand Naine (1.11 kg cm^{-2}) and highest in Chengalikodan (3.13 kg cm^{-2}).

4.2.2 Chemical constituents

The chemical constituents varied significantly over different stages in the different varieties (Table 9).

4.2.2.1 TSS

TSS was found to increase in the various stages in different varieties. Minimum TSS was recorded in Palayankodan (3.67°brix) and maximum in Njalipoovan (6.33°brix) in stage I.

In stage IV highest and lowest values for TSS was recorded in Njalipoovan (29.67°brix) and BRS I (20.67°brix) respectively.

4.2.2.2 Acidity

Acidity showed an increasing trend upto stage II and on full ripening decreased in the different varieties.

Minimum and maximum values for acidity in stage I was recorded by Grand Naine (0.14%) and Chengalikodan and BRS I (0.377%) respectively.

In stage II the values for acidity ranged between 0.29 per cent in Red Banana to 0.793 per cent in BRS I. In stage III and IV acidity showed a decreasing trend and in stage IV the maximum and minimum values for acidity was recorded in BRS I (0.724%) and Robusta (0.247%) respectively.

Table 9. Chemical changes during ripening of banana varieties

Sl. No.	Varieties	TSS (° brix)				Acidity (%)			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	3.667^{n}	13.000^{lm}	25.000^{cde}	24.000^{cdef}	0.247^{hi}	0.640^{cd}	0.416^{f}	0.402^{f}
2	Njalipoovan	6.333^{n}	14.333^{kl}	30.333^{a}	29.667^{a}	0.190^{ij}	0.736^{ab}	0.630^{cd}	0.580^{de}
3	Chengalikodan	5.333^{n}	16.333^{jk}	30.000^{a}	29.000^{ab}	0.377^{fg}	0.656^{bcd}	0.543^{e}	0.509^{e}
4	Grand Naine	4.667^{n}	14.000^{kl}	26.667^{bc}	25.667^{cd}	0.140^{j}	0.409^{f}	0.319^{gh}	0.301^{gh}
5	Robusta	4.333^{n}	18.333^{ij}	23.333^{defg}	22.333^{efg}	0.309^{gh}	0.500^{e}	0.251^{hi}	0.247^{hi}
6	Red Banana	6.000^{n}	19.000^{hi}	25.667^{cd}	24.000^{cdef}	0.154^{j}	0.290^{h}	0.270^{hi}	0.254^{hi}
7	BRS-I	4.667^{n}	11.000^{m}	22.000^{fg}	20.667^{ghi}	0.377^{fg}	0.793^{a}	0.779^{a}	0.724^{ab}
8	BRS-II	4.667^{n}	15.333^{kl}	23.000^{defg}	21.333^{fgh}	0.233^{hi}	0.792^{a}	0.735^{ab}	0.679^{bc}

Values with same superscripts do not differ significantly

Contd.

Table 9. Continued

Sl. No.	Varieties	Total sugars (%)				Reducing sugars (%)			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	3.093^{jk}	11.343^{i}	23.030^{b}	19.550^{cd}	2.167^{l}	8.193^{k}	20.420^{cd}	16.410^{fg}
2	Njalipoovan	4.370^{j}	16.520^{efg}	23.270^{b}	18.767^{cde}	2.497^{l}	12.733^{hi}	19.353^{de}	16.067^{fg}
3	Chengalikodan	2.143^{jk}	11.163^{i}	32.260^{a}	30.100^{a}	1.197^{l}	8.083^{k}	26.850^{a}	23.577^{b}
4	Grand Naine	2.240^{jk}	11.637^{i}	17.097^{defg}	15.240^{gh}	1.297^{l}	10.503^{ij}	16.030^{fg}	14.443^{gh}
5	Robusta	2.183^{jk}	12.283^{i}	23.323^{b}	17.483^{defg}	1.550^{l}	10.760^{ij}	22.400^{bc}	16.307^{fg}
6	Red Banana	2.447^{jk}	12.487^{i}	18.453^{cdef}	17.163^{defg}	1.963^{l}	11.850^{i}	17.413^{ef}	15.393^{fg}
7	BRS-I	1.183^{k}	13.650^{hi}	20.603^{c}	18.323^{cdef}	0.793^{l}	10.597^{ij}	14.410^{gh}	16.200^{fg}
8	BRS-II	1.677^{k}	11.960^{i}	18.667^{cdef}	16.110^{fg}	1.170^{l}	8.917^{jk}	14.133^{gh}	11.423^{i}

Values with same superscripts do not differ significantly

Contd.

Table 9. Continued

Sl. No.	Varieties	Non-reducing sugars (%)				Moisture (%)			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	0.943^{c}	3.150^{abc}	2.610^{abc}	4.790^{abc}	60.990^{j}	65.427^{i}	70.123^{fg}	70.847^{efg}
2	Njalipoovan	1.840^{abc}	3.787^{abc}	3.917^{abc}	2.433^{abc}	51.667^{o}	54.647^{mn}	64.257^{i}	66.193^{hi}
3	Chengalikodan	0.947^{c}	3.053^{abc}	5.410^{abc}	6.523^{a}	47.787^{p}	57.453^{kl}	64.180^{i}	66.270^{hi}
4	Grand Naine	0.943^{c}	1.133^{bc}	1.067^{bc}	0.797^{c}	44.823^{q}	48.080^{p}	68.400^{gh}	69.017^{g}
5	Robusta	0.633^{c}	1.527^{abc}	0.923^{c}	1.177^{bc}	56.593^{lm}	59.620^{jk}	78.813^{ab}	79.730^{a}
6	Red Banana	0.483^{c}	0.637^{c}	1.040^{bc}	1.770^{abc}	54.713^{mn}	58.980^{jkl}	75.417^{cd}	76.417^{bc}
7	BRS-I	0.390^{c}	3.053^{abc}	6.197^{ab}	2.120^{abc}	53.343^{no}	57.750^{kl}	71.967^{ef}	73.497^{de}
8	BRS-II	0.507^{c}	3.043^{abc}	4.593^{abc}	4.687^{abc}	54.520^{mn}	58.190^{kl}	70.570^{fg}	71.843^{ef}

Values with same superscripts do not differ significantly

Contd.

Table 9. Continued

Sl. No.	Varieties	Tannin (%)				Pectin (%)			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	1.480^{b}	1.270^{c}	0.421^{ij}	0.366^{jklm}	2.060^{a}	1.467^{def}	1.157^{ijk}	1.087^{jkl}
2	Njalipoovan	1.130^{d}	0.980^{ef}	0.297^{jklmn}	0.274^{klmn}	1.640^{cd}	1.343^{fgh}	0.887^{mnop}	0.777^{opq}
3	Chengalikodan	1.610^{a}	1.547^{ab}	0.558^{h}	0.499^{hi}	1.780^{bc}	1.560^{de}	0.980^{klmn}	0.937^{lmno}
4	Grand Naine	1.023^{def}	0.680^{g}	0.266^{lmn}	0.216^{n}	1.550^{de}	1.220^{hij}	0.850^{nopq}	0.713^{pqrs}
5	Robusta	0.943^{f}	0.750^{g}	0.235^{mn}	0.213^{n}	1.273^{ghi}	0.983^{klmn}	0.583^{rs}	0.547^{s}
6	Red Banana	1.026^{def}	0.788^{g}	0.276^{klmn}	0.245^{mn}	1.437^{efg}	1.050^{jklm}	0.740^{pqr}	0.673^{qrs}
7	BRS-I	1.330^{c}	1.097^{de}	0.404^{ijk}	0.334^{jklmn}	1.910^{ab}	1.483^{def}	0.887^{mnop}	0.730^{pqr}
8	BRS-II	1.293^{c}	1.093^{de}	0.392^{ijkl}	0.382^{ijkl}	1.747^{bc}	1.280^{ghi}	1.007^{klmn}	0.900^{lmnop}

Values with same superscripts do not differ significantly

Contd.

Table 9. Continued

Sl. No.	Varieties	Starch (%)				Chlorophyll 'a' ($mg\ g^{-1}$)			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	22.753^{ab}	17.650^{e}	1.943^{i}	1.117^{i}	0.158^{a}	0.061^{f}	0.011^{i}	0.003^{i}
2	Njalipoovan	20.527^{bcd}	14.620^{f}	1.520^{i}	0.850^{i}	0.146^{a}	0.093^{de}	0.010^{i}	0.002^{i}
3	Chengalikodan	24.400^{a}	13.083^{fg}	2.353^{i}	1.573^{i}	0.126^{b}	0.052^{f}	0.005^{i}	0.003^{i}
4	Grand Naine	18.323^{de}	12.257^{fgh}	1.010^{i}	0.663^{i}	0.119^{bc}	0.063^{f}	0.031^{i}	0.013^{hi}
5	Robusta	18.957^{cde}	9.870^{h}	1.120^{i}	0.933^{i}	0.124^{b}	0.059^{f}	0.032^{i}	0.015^{ghi}
6	Red Banana	18.603^{cde}	11.443^{gh}	1.141^{i}	0.977^{i}	0.084^{e}	0.016^{ghi}	0.005^{i}	0.002^{i}
7	BRS-I	19.220^{cde}	13.113^{fg}	1.444^{i}	1.453^{i}	0.103^{cd}	0.033^{g}	0.010^{i}	0.004^{i}
8	BRS-II	20.993^{bc}	14.660^{f}	1.335^{i}	1.137^{i}	0.110^{bc}	0.030^{gh}	0.009^{i}	0.004^{i}

Values with same superscripts do not differ significantly

Contd.

Table 9. Continued

Sl. No.	Varieties	Chlorophyll 'b' ($mg\ g^{-1}$)				Total chlorophyll ($mg\ g^{-1}$)			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	0.091	0.059	0.008	0.001	0.251	0.130	0.022	0.006
2	Njalipoovan	0.132	0.047	0.010	0.002	0.244	0.144	0.024	0.005
3	Chengalikodan	0.123	0.027	0.007	0.002	0.256	0.086	0.017	0.006
4	Grand Naine	0.057	0.033	0.021	0.014	0.180	0.102	0.054	0.027
5	Robusta	0.062	0.036	0.017	0.008	0.195	0.099	0.055	0.032
6	Red Banana	0.043	0.023	0.005	0.002	0.134	0.044	0.010	0.006
7	BRS-I	0.058	0.015	0.004	0.001	0.167	0.053	0.016	0.007
8	BRS-II	0.064	0.057	0.037	0.002	0.183	0.376	0.083	0.008
	CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

NS - Not significant

4.2.2.3 Total, reducing and non reducing sugars

Total sugars in the various varieties increased from harvest to ripening. In stage I total sugars was highest in Njalipoovan (4.37%) and lowest in BRS I (1.18%). In stage IV highest and lowest values were recorded in Chengalikodan (30.1%) and BRS II (16.11%) respectively.

Reducing sugars also showed an increasing trend on ripening. The values for reducing sugars ranged between 0.79 per cent in BRS I to 2.50 per cent in Njalipoovan in stage I.

Maximum and minimum values for reducing sugars was registered by Chengalikodan (23.58%) and BRS II (11.42%) in stage IV.

Non reducing sugars showed an increasing trend in the various varieties over different stages.

Maximum value for non reducing sugars was registered by Njalipoovan (1.84%) and minimum by BRS I (0.39%) in stage I. In stage IV maximum value was recorded by Chengalikodan (6.52%) and minimum by Grand Naine (0.80%).

4.2.2.4 Moisture (%)

Moisture content of the fruit increased on ripening in the various varieties. In stage I moisture content ranged between 44.82 per cent in Grand Naine to 60.99 per cent in Palayankodan.

Maximum moisture content in stage IV was registered by Robusta (79.73%) and minimum by Njalipoovan and Chengalikodan (66.2% and 66.3% respectively).

4.2.2.5 Tannin (%)

Tannin content showed a decreasing trend on ripening in different varieties. Highest values were observed in stage I and lowest in stage IV. Chengalikodan recorded the highest value (1.61%) in stage I and Robusta recorded the lowest value (0.213%) in stage IV.

4.2.2.6 Pectin (%)

Higher values for pectin content was observed in stage I and lower values in stage IV. Palayankodan in stage I recorded the highest value (2.06) followed by BRS I (1.91%) and Chengalikodan (1.78%). Robusta recorded the lowest value for pectin content (0.547%) in stage IV.

4.2.2.7 Starch (%)

On ripening starch is hydrolysed to sugars and starch content decreases.

Maximum starch content in stage I was noticed in the variety Chengalikodan (24.4%) followed by Palayankodan (22.75%) and minimum value in stage I was noticed in Grand Naine (18.32%). In stage IV maximum and minimum values for starch content was noticed in Chengalikodan (1.57%) and Grand Naine (0.663%) respectively.

4.2.2.8 Chlorophyll

The values for chlorophyll a, b and total chlorophyll are presented in the Table 6. Chlorophyll content decreased from stage I to stage IV in the various varieties and on ripening it was almost zero. Chlorophyll 'a' content varied from 0.084 mg g^{-1} in Red banana to 0.158 in Palayankodan and total chlorophyll content 0.134 mg g^{-1} in Red banana to 0.256 in Chengalikodan in stage I.

4.2.3 Physiological changes

4.2.3.1 Enzyme activity

4.2.3.1.1 α-amylase

The activity of α-amylase increased with ripening from stage I to stage IV in all the varieties. Minimum activity in stage I was registered in Red Banana (0.015 mg g^{-1}) and maximum in Njalipoovan (0.084 mg g^{-1}). In stage IV maximum activity was recorded by Palayankodan (3.76 mg g^{-1}) (Table 10).

4.2.3.1.2 β-amylase

β-amylase activity increased with the advance of ripening in all the varieties. The maximum value for β-amylase was registered in stage IV by the variety Chengalikodan (1.69 mg g^{-1}) and minimum in BRS I (0.37 mg.g^{-1}).

Table 10. Physiological changes during ripening of banana varieties

Sl. No.	Varieties	α–amylase (mg g^{-1})				β–amylase (mg g^{-1})			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	0.030^{l}	0.429^{k}	3.540^{abc}	**3.763^{a}**	0.034^{l}	0.260^{hij}	0.645^{f}	0.669^{ef}
2	Njalipoovan	0.084^{l}	3.080^{def}	3.403^{bcd}	**3.642^{ab}**	0.019^{l}	0.167^{jkl}	0.376^{gh}	1.087^{c}
3	Chengalikodan	0.037^{l}	1.670^{j}	2.867^{fg}	**3.067^{ef}**	0.019^{l}	0.230^{hij}	0.623^{f}	1.690^{a}
4	Grand Naine	0.025^{l}	0.459^{k}	0.493^{k}	**0.756^{k}**	0.038^{l}	0.227^{hij}	0.629^{f}	0.727^{def}
5	Robusta	0.018^{l}	1.387^{j}	2.123^{i}	**2.593^{gh}**	0.023^{l}	0.652^{f}	0.813^{de}	0.811^{de}
6	Red Banana	0.015^{l}	0.442^{k}	2.175^{i}	**2.325^{hi}**	0.043^{l}	0.156^{jkl}	0.198^{ijk}	0.448^{g}
7	BRS-I	0.048^{l}	2.413^{hi}	3.091^{def}	**3.227^{cde}**	0.039^{l}	0.248^{hij}	0.341^{ghi}	0.373^{gh}
8	BRS-II	0.064^{l}	0.552^{k}	3.283^{cde}	**3.620^{ab}**	0.052^{kl}	0.229^{hij}	0.835^{d}	1.320^{b}

Values with same superscripts do not differ significantly

Contd.

Table 10. Continued

Sl. No.	Varieties	Invertase (mg g^{-1})				Co_2 (mg kg^{-1} hr^{-1})			
		S_1	S_2	S_3	S_4	S_1	S_2	S_3	S_4
1	Palayankodan	0.254^{defg}	0.291^{def}	0.604^{c}	**0.656^{c}**	13.873	74.990	87.000	77.400
2	Njalipoovan	0.061^{gh}	0.397^{d}	0.837^{ab}	**0.855^{ab}**	17.617	76.210	95.920	87.603
3	Chengalikodan	0.132^{fgh}	0.171^{efgh}	0.615^{c}	**0.947^{a}**	23.857	83.667	110.267	100.533
4	Grand Naine	0.111^{fgh}	0.139^{fgh}	0.234^{defgh}	**0.389^{d}**	19.223	87.633	108.567	97.837
5	Robusta	0.146^{fgh}	0.210^{defgh}	0.386^{d}	**0.681^{bc}**	20.193	78.200	88.867	83.627
6	Red Banana	0.136^{fgh}	0.228^{defgh}	0.356^{de}	**0.657^{c}**	18.880	90.54	112.190	100.123
7	BRS-I	0.042^{h}	0.132^{fgh}	0.260^{def}	**0.755^{bc}**	16.400	68.287	90.710	90.343
8	BRS-II	0.139^{fgh}	0.176^{efgh}	0.245^{defg}	**0.266^{def}**	15.673	63.437	82.883	78.720

Values with same superscripts do not differ significantly

4.2.3.1.3 Invertase

The activity of invertase enzyme increased on ripening from stage I to stage IV. Maximum value was registered by Chengalikodan (0.95 mg g^{-1}) and minimum by BRS II (0.27 mg g^{-1}) in stage IV (Table 10).

4.2.3.2 Respiration

The rate of respiration as measured by evolution of CO_2 was recorded from the stage I to stage IV in the various varieties. As ripening progressed the CO_2 produced also increased in the different varieties. Evolution of CO_2 was maximum in full ripe stage and after full ripening it slightly decreased. At full ripe stage maximum **CO_2 was produced by Red Banana (112.19 mg kg^{-1} hr^{-1})** followed by Chengalikodan (110.27 mg kg^{-1} hr^{-1}) (Table 10).

EXPERIMENT III

4.3 STANDARDISATION OF METHODS TO ENHANCE SHELF LIFE OF VARIETIES

4.3.1 Effect of postharvest treatments on extension of shelf life of banana

4.3.1.1 Palayankodan

4.3.1.1.1 PLW (%)

The PLW was recorded cumulatively at three days interval for all the postharvest treatments and control.

The treatments differed significantly with respect to PLW on the 6th and 9th day after storage (Table 11).

Physiological loss in weight after 3 days of storage was not significant between the various treatments. Minimum value for PLW was recorded by precooling treatment with cold water (10°C) (2.95%).

The treatments differed significantly with respect to PLW six days after storage. Minimum PLW was noticed for hot water treatment (9.0%) followed by precooling with cold water (9.55%) and maximum value for control (T_8) (15.15%).

Table 11. Effect of postharvest treatments on PLW in Palayankodan

Treatment	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)
T_1	4.325	9.000	13.950	28.100	ND
T_2	3.100	10.950	11.650	22.050	28.5
T_3	2.950	9.550	15.400	26.100	ND
T_4	3.150	10.800	15.750	26.950	29.95
T_5	4.300	13.100	16.450	29.000	ND
T_6	4.750	14.300	21.950	33.400	37.65
T_7	3.750	12.250	21.550	30.750	ND
T_8	3.800	15.150	18.500	ND	ND
CD (0.05)	NS	2.280*	2.7780*	NS	NA

* - Significant at 5% level; NS - Not significant; ND - Not determined due to spoilage; NA - Not analysed statistically

Table 12. Influence of postharvest treatments on days to 50% and 100% yellowing and shelf life in Palayankodan

Treatment	Days to 50% yellowing	Days to 100% yellowing	Shelf life
T_1	6.0 (2.550)^{c}	8.0 (2.915)^{d}	14.0 (3.808)^{h}
T_2	9.0 (3.082)^{ab}	11.0 (3.391)^{b}	16.0 (4.060)^{ef}
T_3	7.0 (2.739)^{bc}	9.0 (3.082)^{c}	14.5 (3.872)^{gh}
T_4	9.5 (3.153)^{a}	12.5 (3.605)^{a}	17.0 (4.183)^{de}
T_5	7.0 (2.732)^{bc}	9.5 (3.161)^{c}	13.5 (3.741)^{hi}
T_6	6.0 (2.550)^{c}	9.5 (3.161)^{c}	15.5 (4.000)^{fg}
T_7	6.0 (2.550)^{c}	8.0 (2.915)^{d}	14.0 (3.808)^{h}
T_8	6.0 (2.550)^{c}	8.0 (2.915)^{d}	11.0 (3.391)^{k}

Figures in parenthesis are transformed values; Values with same superscripts do not differ significantly

Minimum PLW was observed in T_2 (precooling with tap water) (11.65%) after nine days of storage whereas T_6 (Vacuum infiltration with 1% $CaCl_2$) recorded the maximum PLW (21.95%).

Since the control fruits were rejected due to spoilage, for further estimation of PLW only seven treatments were there. Minimum PLW was registered for hands precooled with tap water (22.05%) and maximum for T_6 (33.4%) on 12th day of storage.

On 15th day after storage only three treatments were available for comparison *viz.* T_2, T_4 and T_6. All the other treatments were discarded. Of the three treatments minimum PLW was registered by T_2 (28.5%) and maximum by T_6 (37.65%).

4.3.1.1.2 Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand

The treatments differed significantly in days to attain more than 50 per cent yellowing on more than 50 per cent fingers of the hand. Maximum days to reach more than 50 per cent yellowing was noticed for T_4 (9.5 days) followed by T_2 (9.0 days), whereas T_1, T_6, T_7 and T_8 were on par (6.0 days) (Table 12).

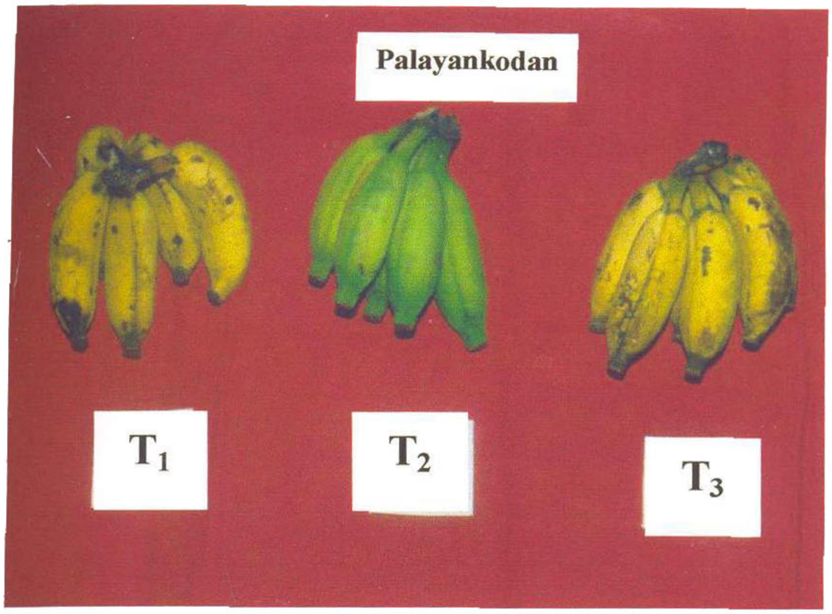
4.3.1.1.3 Days to 100 per cent yellowing on all the fingers of the hand

Significant difference was noticed for days to reach to 100 per cent yellowing. Maximum days was recorded by T_4 (12.5 days) and minimum by T_1, T_7 and T_8 (8 days) (Table 12).

4.3.1.1.4 Shelf life

Shelf life of a fruit is the number of days a fruit is in edible or consumable stage. The postharvest treatments are expected to aid in increasing the shelf life of the fruit.

The treatments T_4, showed an increased shelf life upto 17.0 days followed by T_2 (16.0 days) whereas the control fruits recorded the minimum shelf life (11.0 days) (Table 12) (Plate 33).



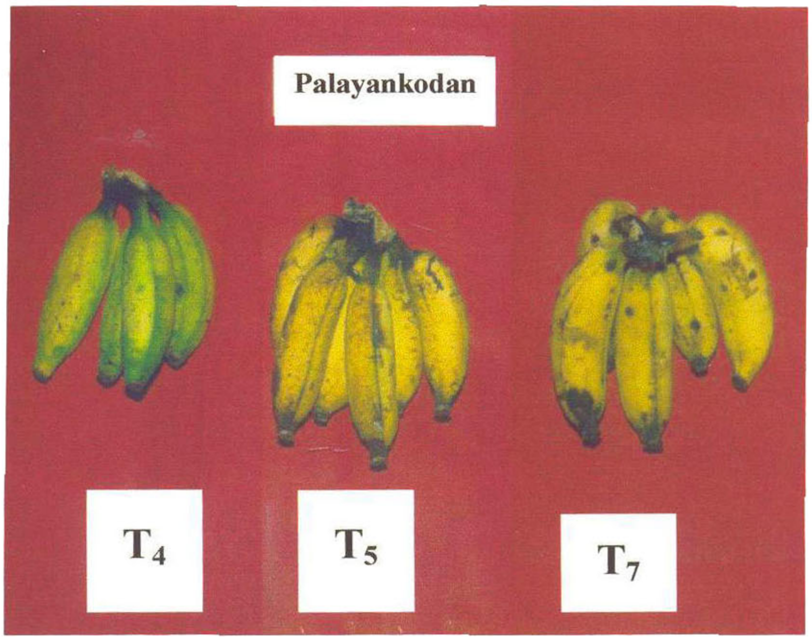


Plate 33. Palayankodan fruits 12 DAS

4.3.1.1.5 Chemical composition on ripening

4.3.1.1.5.1 Total soluble solids (TSS)

There was no significant variation with respect to TSS between various treatments on ripening in variety Palayankodan. Maximum value for TSS was recorded in T_6 (Vacuum infiltration with 1% $CaCl_2$) (26.1°brix) and minimum in T_1 and T_7 (25.1°brix) (Table 13).

4.3.1.1.5.2 Acidity (%)

Difference in acidity was not significant on ripening. However, the values for acidity ranged from 0.37 per cent (T_4) to 0.43 per cent (T_8).

4.3.1.1.5.3 Total, reducing and non reducing sugars

Total, reducing and non reducing sugars of Palayankodan fruits did not show significant variation on ripening between various treatments. Maximum values for total sugars and reducing sugar was recorded in T_8 (23.47% and 20.45 % respectively) and minimum in T_5 (20.2%) and T_7 (18.23%).

Maximum value for non reducing sugar was noticed in T_4 (3.33%) and minimum T_5 (1.84%).

4.3.1.2 Njalipoovan

4.3.1.2.1 PLW (%)

PLW showed significant variation between the different postharvest treatments on 3rd and 6th day after storage (Table 14).

On the 3rd day after storage minimum PLW was registered for T_6 (3.1%) (vacuum infiltration with one per cent $CaCl_2$) followed by T_2 (i.e., precooling with tap water) (10.1%) and maximum in T_1 (15.6%) (hot water treatment) followed by control fruits (15.45%).

Minimum PLW on the 6th day after storage was registered by T_6 (Vacuum infiltration with 1% $CaCl_2$) (4.6%) and maximum by control fruits (T_8) (28.6%).

Table 13. Effect of postharvest treatments on chemical composition of ripe fruits of Palayankodan

Treatment	TSS (° Brix)	Acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1	25.100	0.419	22.260	19.195	3.065
T_2	25.700	0.405	21.085	18.330	2.755
T_3	25.800	0.420	22.590	20.410	2.180
T_4	25.900	0.370	21.660	18.335	3.325
T_5	25.700	0.394	20.200	18.360	1.840
T_6	26.050	0.398	22.160	18.880	3.280
T_7	25.100	0.380	20.750	18.230	2.525
T_8	25.500	0.430	23.465	20.445	3.020
CD (0.05)	NS	NS	NS	NS	NS

NS - Not significant

Table 14. Effect of postharvest treatments on PLW during ripening in Njalipoovan under ambient conditions

Treatment	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)	18 DAS (%)
T_1	15.600	22.750	29.500	34.600	ND	ND
T_2	10.100	15.950	19.750	22.400	26.00	ND
T_3	10.450	16.600	19.350	23.200	25.05	ND
T_4	12.050	18.600	20.350	31.500	ND	ND
T_5	12.150	16.250	19.100	22.550	ND	ND
T_6	3.100	4.600	7.100	9.350	15.85	23.15
T_7	12.000	21.150	23.550	27.900	30.20	ND
T_8	15.450	28.600	33.900	42.900	ND	ND
CD (0.05)	3.234	3.191	NS	NS	NA	NA

ND - Not determined due to spoilage of fruits; NA - Not analysed statistically

There was no significant variation between the various treatments for PLW on the 9th and 12th day after storage.

On 15th day after storage four treatments *viz.* T_2, T_3, T_6 and T_7 were available for further estimation of PLW as the rest of the treatments were discarded due to spoilage. T_6 recorded minimum PLW (15.85%) and maximum by T_7 ($CaCl_2$ dip) (30.2%).

On the 18th day after storage only T_6 was available for PLW estimation and it recorded 23.15 per cent.

Throughout the storage period T_6 recorded the minimum PLW whereas control fruits recorded the maximum value for PLW.

4.3.1.2.2 Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand

Significant variation was observed between various postharvest treatments for the days to reach 50 per cent yellowing. Maximum number of days was seen in T_6 and T_3 (9 days) and minimum in control fruits (5.5 days) (Table 15).

4.3.1.2.3 Days to 100 per cent yellowing on all the fingers of the hand

Significant variation between the treatments was not observed for days to reach 100 per cent yellowing. However, maximum days was observed in T_6 (11.0 days) and minimum in T_4 (7.0 days) i.e., precooling with ice flakes (Table 15).

4.3.1.2.4 Shelf life

Significant difference was observed between the various postharvest treatments for shelf life. Maximum shelf life was obtained for the treatments T_6 (vacuum infiltration with 1% $CaCl_2$) (17.5 days) and T_2 (precooling with tap water) (17.0 days) and minimum for control fruits (11.0 days) (Table 15) (Plate 34).

4.3.1.2.5 Chemical composition on ripening

TSS, total sugars and reducing sugars showed no significant variation for the different postharvest treatments in Njalipoovan (Table 16).

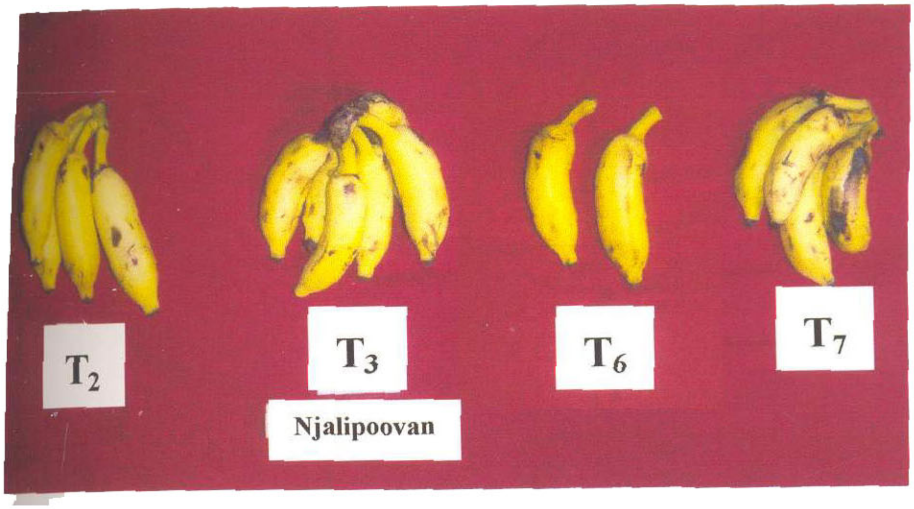


Plate 34. Njalipoovan fruits 15 DAS

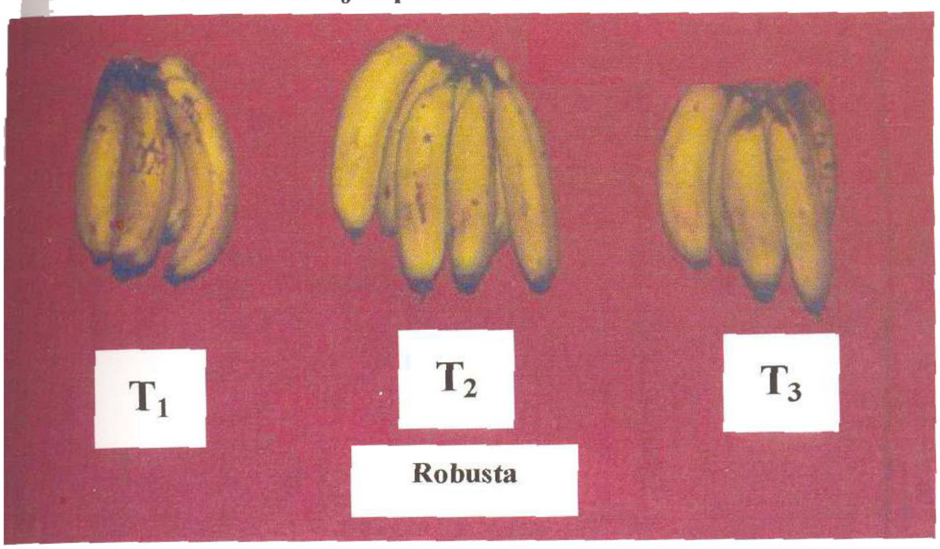


Plate 35. Robusta fruits 15 DAS

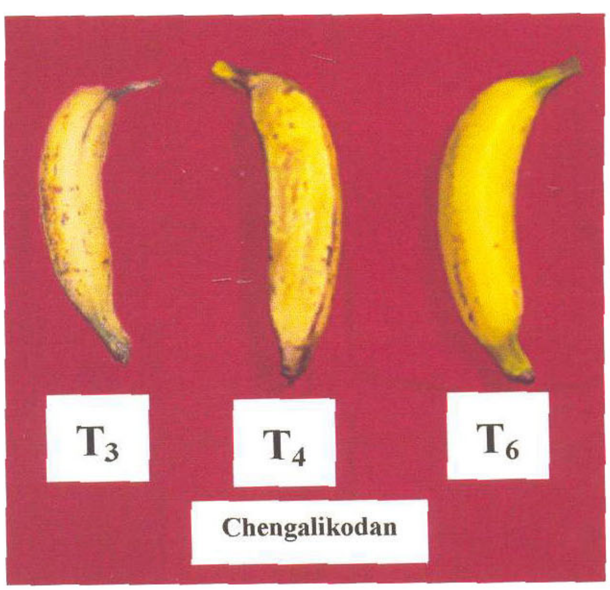


Plate 36. Chengalikodan fruits 20 DAS

Table 15. Influence of postharvest treatments on days to 50% and 100% yellowing and shelf life in Njalipoovan

Treatment	Days to 50% yellowing	Days to 100% yellowing	Shelf life
T_1	6.0 (2.550)^{c}	8.0 (2.910)^{bc}	12.5 (3.605)^{ij}
T_2	8.5 (2.999)^{ab}	10.5 (3.316)^{ab}	17.0 (4.183)^{de}
T_3	9.0 (3.078)^{a}	10.5 (3.309)^{ab}	16.0 (4.060)^{ef}
T_4	7.0 (2.732)^{abc}	7.0 (2.732)^{c}	12.0 (3.536)^{jk}
T_5	6.5 (2.644)^{bc}	8.5 (2.999)^{abc}	12.5 (3.605)^{ij}
T_6	9.0 (3.082)^{a}	11.0 (3.391)^{a}	17.5 (2.242)^{cd}
T_7	7.0 (2.732)^{abc}	9.5 (3.161)^{abc}	15.5 (4.000)^{fg}
T_8	5.5 (2.447)^{c}	8.5 (2.999)^{abc}	11.0 (3.391)^{k}

Figures in parenthesis are transformed values; Values with same superscripts do not differ significantly

Table 16. Effect of postharvest treatments on chemical composition of ripe fruits of Njalipoovan

Treatment	TSS (° Brix)	Acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1	27.500	0.545	19.880	18.550	1.330
T_2	27.500	0.590	19.600	18.060	1.540
T_3	27.500	0.390	20.930	19.410	1.520
T_4	30.500	0.420	22.450	19.925	2.525
T_5	30.000	0.530	21.990	19.235	2.755
T_6	29.000	0.600	21.000	19.140	1.860
T_7	28.500	0.570	22.150	20.725	1.425
T_8	30.500	0.640	23.800	22.845	0.955
CD (0.05)	NS	0.41*	NS	NS	1.21*

* - Significant at 5% level; NS - Not significant

4.3.1.2.5.1 Total soluble solids

Although the variation in TSS was not significant between the various treatments, maximum TSS was registered in T_4 and control fruits (30.5°brix) and minimum in T_1, T_2 and T_3 (27.5°brix).

4.3.1.2.5.2 Acidity

Acidity varied significantly between the various treatments and maximum acidity was noticed in T_8 (control fruits) (0.64%) and minimum in T_3 (Precooling with cold water) (0.39%).

4.3.1.2.5.3 Total, reducing and non-reducing sugars

The difference in total sugars and reducing sugars was not found to be significant between the various treatments. However the values for total and reducing sugars ranged from 19.6 per cent and 18.06 per cent in T_2 to 23.8 per cent and 22.85 per cent in T_8.

The values for non reducing sugars ranged from 1.33 per cent (T_1) to 2.78 per cent in T_5.

4.3.1.3 Robusta

4.3.1.3.1 PLW (%)

Significant variation in PLW was observed only on 9th and 12th day of storage (Table 17).

Minimum values for PLW on the 9th and 12th days of storage was registered by T_2 (Precooling with tap water) (10.95% and 14.95% respectively) whereas the maximum values recorded in control on 9th day (15.65%) and in T_6 (Vacuum infiltration with 1% $CaCl_2$) on 12th day of storage (24.3%).

On 15th day of storage five treatments were available for estimation of PLW as T_4, T_6 and T_8 were discarded due to spoilage. Maximum PLW was noticed in T_7 (26.85%) and minimum in T_2 i.e., precooling with tap water (19.25%).

Table 17. Effect of postharvest treatments on PLW during ripening in Rubsta under ambient conditions

Treatment	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)
T_1	2.10	8.45	11.85	17.50	22.65
T_2	4.15	8.40	10.95	14.95	19.25
T_3	4.55	9.40	13.35	17.30	21.30
T_4	3.05	10.75	14.70	20.10	ND
T_5	3.75	8.50	12.65	17.65	25.25
T_6	3.70	11.90	18.00	24.30	ND
T_7	3.20	8.55	12.55	18.75	26.85
T_8	4.30	12.50	15.65	22.00	ND
CD (0.05)	NS	NS	1.986*	2.886*	NS

* - Significant at 5% level; NS - Not significant; ND - Not determined due to spoilage of fruits

Table 18. Influence of postharvest treatments on days to 50% and 100% yellowing and shelf life in Robusta

Treatment	Days to 50% yellowing	Days to 100% yellowing	Shelf life
T_1	7.0 (2.732)^{c}	10.5 (3.316)^{bc}	16.5 (4.123)^{def}
T_2	7.0 (2.732)^{c}	11.0 (3.391)^{ab}	16.0 (4.062)^{ef}
T_3	9.5 (3.161)^{ab}	12.0 (3.536)^{a}	17.0 (4.183)^{de}
T_4	8.0 (2.915)^{bc}	11.5 (3.463)^{ab}	13.5 (3.741)^{hi}
T_5	11.0 (3.391)^{a}	12.0 (3.536)^{a}	17.0 (4.183)^{de}
T_6	7.5 (2.827)^{bc}	9.5 (3.161)^{c}	12.0 (3.536)^{jk}
T_7	8.5 (2.999)^{bc}	11.0 (3.391)^{ab}	16.5 (4.123)^{def}
T_8	8.0 (2.915)^{bc}	11.5 (3.463)^{ab}	13.5 (3.741)^{hi}

Figures in parenthesis are transformed values; Values with same superscripts do not differ significantly

4.3.1.3.2 Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand

Significant difference was noticed between the treatments for days to reach more than 50 per cent yellowing. Treatment T_5 registered maximum days (11.0 days) to reach more than 50 per cent yellowing whereas T_1 and T_2 registered minimum days (7.0 days) (Table 18).

4.3.1.3.3 Days to 100 per cent yellowing on all the fingers of the hand

Different treatments exhibited significant variation for days to reach 100 per cent yellowing in Robusta. Maximum days was registered by the treatments T_3 and T_5 (12 days) and minimum by T_6 (9.5 days) (Table 18).

4.3.1.3.4 Shelf life

Analysis of variance showed significant variation for shelf life and longer shelf life was recorded by T_3 and T_5 (17 days) as compared to 13.5 days in control (Table 18) (Plate 35).

4.3.1.3.5 Chemical composition on ripening

Total sugars and reducing sugars showed significant variation between the treatments whereas the variation in TSS, acidity and non reducing sugars was non significant (Table 19).

4.3.1.3.5.1 TSS

Although no significant variation was observed between the various treatments for TSS, the values ranged between 20.5°brix in T_7 to 24.5°brix in T_8 in Robusta.

4.3.1.3.5.2 Acidity

The values for acidity ranged from 0.068 per cent in T_1 to 0.148 per cent in T_8.

4.3.1.3.5.3 Total, reducing and non reducing sugars

Significant difference was observed for total and reducing sugars between the treatments and highest values for total sugars and reducing sugars was observed in

Table 19. Effect of postharvest treatments on chemical composition of ripe fruits of Robusta

Treatment	TSS (° Brix)	Acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1	23.500	0.068	23.785	23.205	0.580
T_2	23.500	0.109	23.030	21.595	1.435
T_3	22.500	0.114	23.960	22.575	1.385
T_4	22.000	0.133	22.205	20.425	1.810
T_5	21.000	0.122	21.100	19.590	1.510
T_6	21.250	0.087	19.240	18.230	1.010
T_7	20.500	0.123	21.075	19.755	1.320
T_8	24.500	0.148	23.520	21.585	1.935
CD (0.05)	NS	NS	1.638*	1.475*	NS

* - Significant at 5% level; NS - Not significant

Table 20. Effect of postharvest treatments on PLW during ripening in Chengalikodan

Treatment	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)	18 DAS (%)	21 DAS (%)
T_1	11.55	16.10	20.95	27.00	30.60	34.90	46.75
T_2	8.95	13.25	19.05	21.90	25.10	27.50	28.00
T_3	9.75	13.00	17.65	18.75	19.70	23.05	24.80
T_4	7.55	13.25	19.15	22.60	25.45	30.50	32.90
T_5	11.20	13.65	18.35	23.40	28.40	32.50	ND
T_6	7.25	14.15	19.30	21.45	21.40	27.70	28.25
T_7	5.95	9.95	19.55	22.75	ND	ND	ND
T_8	13.60	23.35	28.80	31.39	ND	ND	ND
CD (0.05)	NS	NS	3.065*	2.944*	NS	NS	NS

* - Significant at 5% level; NS - Not significant; ND - Not determined due to spoilage of fruits

T_3 (23.96%) and T_1 (23.21%) respectively whereas minimum values were observed in T_6 (19.24% and 18.23%) respectively.

The values for non-reducing sugars ranged between 0.58 per cent in T_1 to 1.94 per cent in T_8.

4.3.1.4 Chengalikodan

4.3.1.4.1 PLW (%)

Significant variation in PLW was observed on 9th and 12th day after storage whereas for the remaining period of storage, PLW showed no significant variation between the treatments (Table 20). .

Minimum PLW was registered by the precooling treatment with cold water (17.65 and 18.75%) and maximum values by T_8 i.e., control fruits (28.8 and 31.39%) on 9th and 12th day of storage respectively.

On 15th day of storage T_7 and T_8 were discarded due to spoilage. Minimum PLW was registered for T_3 (Precooling with cold water) (19.7 and 23.05%) and maximum value by T_1 (hot water treatment) on 15th day and 18th day of storage (30.6% and 34.9%) respectively.

Treatments T_5, T_7 and T_8 were unmarketable by 18th day of storage and hence discarded and PLW was compared between the rest of treatments. Maximum PLW was noticed in T_1 (46.75%) on 21st day and minimum in T_3 (24.8%).

It was observed that minimum PLW was registered by T_3 throughout the storage period.

4.3.1.4.2 Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand

Significant variation was noticed for days to reach more than 50 per cent yellowing between the various treatments in Chengalikodan (Table 21).

Maximum days was registered by the treatment T_6 (12.5 days) followed by T_2 (11.0 days). Minimum days was registered by control fruits (4.5 days).

Table 21. Influence of postharvest treatments on days to 50% and 100% yellowing and shelf life in Chengalikodan

Treatment	Days to 50% yellowing	Days to 100% yellowing	Shelf life
T_1	6.0 (2.550)^{cd}	12.5 (3.605)^{b}	21.0 (4.637)^{b}
T_2	11.0 (3.388)^{ab}	13.5 (3.741)^{ab}	21.0 (4.637)^{b}
T_3	6.5 (2.644)^{c}	13.5 (3.741)^{ab}	22.0 (4.743)^{ab}
T_4	7.0 (2.732)^{c}	12.0 (3.533)^{b}	22.5 (4.796)^{a}
T_5	9.0 (3.082)^{b}	11.5 (3.463)^{b}	18.5 (4.359)^{c}
T_6	12.5 (3.605)^{a}	15.5 (4.000)^{a}	22.5 (4.796)^{a}
T_7	5.5 (2.447)^{cd}	9.0 (3.078)^{c}	12.5 (3.605)^{ij}
T_8	4.5 (2.233)^{d}	8.0 (2.915)^{c}	13.5 (3.741)^{hi}

Figures in parenthesis are transformed values; Values with same superscripts do not differ significantly

Table 22. Effect of postharvest treatments on chemical composition of ripe fruits of Chengalikodan

Treatment	TSS (° Brix)	Acidity (%)	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)
T_1	27.500	0.523	26.635	22.790	3.845
T_2	25.500	0.505	26.910	22.760	3.945
T_3	30.000	0.507	30.605	26.115	4.490
T_4	29.500	0.511	29.580	23.720	5.860
T_5	29.000	0.461	28.885	23.070	5.700
T_6	28.500	0.546	27.585	23.385	4.200
T_7	27.500	0.506	27.050	22.910	4.140
T_8	32.000	0.468	31.785	26.250	5.535
CD (0.05)	NS	NS	2.128*	NS	NS

* - Significant at 5% level; NS - Not significant

4.3.1.4.3 Days to 100 per cent yellowing on all the fingers of the hand

Different treatments showed significant variation with respect to days to reach 100 per cent yellowing.

Treatment T_6 took more days to reach 100 per cent yellowing (15.5 days) whereas control fruits reached in less days (8.0 days) (Table 21).

4.3.1.4.4 Shelf life

Shelf life showed significant variation between the various postharvest treatments. T_4 (Precooling with iceflakes) and T_6 (Vacuum infiltration with 1% $CaCl_2$) was found to be the most effective in prolonging shelf life of Chengalikodan (22.5 days) and T_7 ($CaCl_2$ dip) the least (12.5 days) followed by control fruits (13.5 days) (Table 21) (Plate 36).

4.3.1.4.5 Chemical composition on ripening

No significant variation was observed for the chemical constituents like TSS, acidity, reducing sugars and non reducing sugars whereas total sugars exhibited significant difference between the treatments (Table 22).

4.3.1.4.5.1 TSS

Eventhough TSS showed no significant difference between the treatments, maximum TSS was recorded by T_8 (32°brix) and minimum by T_2 (25.5°brix).

4.3.1.4.5.2 Acidity

Values for acidity ranged from 0.468 per cent in T_8 to 0.546 per cent in T_6.

4.3.1.4.5.3 Total, reducing and non reducing sugars

Total sugar differed significantly between the treatments and maximum value was registered by T_8 (31.79%) and minimum by T_2 (26.91%).

Maximum values for reducing and non reducing sugars were registered by T_8 and T_4 with 26.25 per cent and 5.85 per cent respectively and minimum values were registered by T_2 (22.76%) and T_1 (3.85%) respectively.

4.3.1.5 *Organoleptic evaluation*

4.3.1.5.1 *Palayankodan*

Precooling treatments in general were found to improve the appearance of fruits. Highest score for this parameter was registered by fruits precooled with tap water (7.5) followed by ice flakes (7.2) (Table 23).

Taste and sweetness were also found to be better for fruits precooled with ice flakes (6.7 and 7.1) followed by those subjected to precooling with tap water (6.6 and 6.8). Overall acceptance was better for fruits precooled with tap water followed by those precooled with ice flakes (7.4 and 6.5 respectively). Control fruits registered minimum scores for appearance, taste, sweetness and overall acceptance.

4.3.1.5.2 *Njalipoovan*

In the case of Njalipoovan vacuum infiltration with 1 per cent $CaCl_2$ registered maximum scores for appearance (7.7) taste (6.9) sweetness (7.5) and overall acceptance (7.0) whereas control fruits registered minimum scores for these characters compared to the other treatments (Table 24).

4.3.1.5.3 *Robusta*

In the case of Robusta, fruits precooled with tap water registered maximum scores for appearance (7.9), taste (7.8), sweetness and overall acceptance (8.0). This was followed by fruits treated with hot water whereas the control fruits registered least scores (Table 25).

4.3.1.5.4 *Chengalikodan*

In the variety Chengalikodan the scores for appearance and taste was higher for fruits precooled with ice flakes (7.9 and 6.9 respectively), whereas sweetness was higher for hot water treated fruits (7.6) followed by fruits precooled with tap water (6.2). Overall acceptance was higher for fruits precooled with cold water (6.9) followed by fruits precooled with ice flakes (6.5). The control fruits registered minimum scores for all the sensory attributes (Table 26).

Table 23. Influence of postharvest treatments on sensory attributes of ripe fruits of Palayankodan

Postharvest treatments	Appearance	Taste	Sweetness	Overall acceptance
T_1	4.3 (19.30)	3.6 (25.80)	3.5 (25.85)	3.8 (23.30)
T_2	7.5 (65.25)	6.6 (68.40)	6.8 (67.80)	7.4 (70.75)
T_3	6.8 (54.60)	4.6 (43.00)	5.1 (47.80)	5.4 (45.30)
T_4	7.2 (63.61)	6.7 (70.78)	7.1 (70.78)	6.5 (60.67)
T_5	5.9 (41.69)	4.1 (37.68)	3.8 (33.27)	5.3 (46.50)
T_6	4.9 (25.75)	3.9 (31.40)	5.1 (47.95)	5.8 (48.70)
T_7	6.5 (49.80)	4.5 (41.20)	3.3 (22.30)	3.6 (23.00)
T_8	2.7 (6.30)	2.3 (9.05)	2.4 (12.00)	2.1 (7.20)
Kruskal Wallis Statistics	61.556*	56.101*	58.957*	59.433*

* - Significant at 5% level

Table 24. Influence of postharvest treatments on sensory attributes of ripe fruits of Njalipoovan

Postharvest treatments	Appearance	Taste	Sweetness	Overall acceptance
T_1	4.1 (29.26)	2.9 (18.80)	3.2 (24.00)	3.3 (24.65)
T_2	5.9 (54.70)	3.1 (22.85)	2.8 (17.50)	2.8 (16.70)
T_3	6.7 (63.20)	4.3 (38.05)	4.5 (43.30)	4.6 (43.25)
T_4	4.8 (40.89)	7.4 (70.39)	7.0 (68.11)	6.7 (62.78)
T_5	3.7 (24.18)	6.5 (59.95)	4.8 (48.32)	6.9 (65.09)
T_6	7.7 (72.35)	6.9 (64.35)	7.5 (72.50)	7.0 (67.05)
T_7	4.5 (34.55)	4.6 (40.65)	4.1 (37.85)	3.8 (32.45)
T_8	1.9 (6.55)	2.1 (10.00)	2.4 (14.40)	2.5 (11.80)
Kruskal Wallis Statistics	63.475*	66.355*	62.411*	67.312*

* - Significant at 5% level

Table 25. Influence of postharvest treatments on sensory attributes of ripe fruits of Robusta

Postharvest treatments	Appearance	Taste	Sweetness	Overall acceptance
T_1	6.5 (62.10)	6.5 (58.35)	6.8 (64.70)	6.9 (64.45)
T_2	7.9 (73.90)	7.8 (73.50)	7.7 (72.10)	8.0 (73.70)
T_3	5.8 (55.10)	4.8 (26.10)	5.9 (54.05)	6.0 (55.70)
T_4	2.6 (9.17)	5.9 (47.83)	4.0 (24.33)	3.3 (15.56)
T_5	4.0 (25.32)	5.5 (41.23)	4.1 (25.86)	4.9 (41.23)
T_6	4.4 (33.85)	4.8 (26.10)	4.8 (37.40)	4.0 (28.30)
T_7	4.1 (29.10)	4.9 (28.05)	4.5 (32.65)	3.8 (24.80)
T_8	4.4 (33.86)	4.6 (23.50)	3.1 (12.75)	3.3 (17.70)
Kruskal Wallis Statistics	60.346*	45.300*	59.029*	64.834*

* - Significant at 5% level

Table 26. Influence of postharvest treatments on sensory attributes of ripe fruits of Chengalikodan

Postharvest treatments	Appearance	Taste	Sweetness	Overall acceptance
T_1	4.3 (26.45)	6.5 (60.75)	7.6 (70.10)	4.7 (34.80)
T_2	4.9 (36.85)	5.3 (37.75)	6.2 (54.30)	4.4 (30.30)
T_3	6.5 (62.50)	6.6 (61.65)	5.3 (41.65)	6.9 (68.55)
T_4	7.9 (74.22)	6.9 (64.39)	4.7 (34.67)	6.5 (62.83)
T_5	5.1 (43.82)	4.4 (25.77)	3.8 (15.59)	5.4 (47.68)
T_6	5.1 (40.90)	4.9 (30.05)	7.3 (67.50)	4.3 (35.75)
T_7	4.7 (32.80)	4.4 (22.40)	4.2 (23.60)	4.7 (36.30)
T_8	3.0 (9.50)	4.6 (25.10)	3.9 (18.60)	2.9 (10.30)
Kruskal Wallis Statistics	53.450*	44.603*	62.888*	45.983*

* - Significant at 5% level

4.3.2 Effect of packaging on shelf life of banana varieties

4.3.2.1 Palayankodan

4.3.2.1.1 PLW (%)

Physiological loss in weight was found to be significant on 6th, 9th, 12th, 15th and 21st day of storage (Table 27).

On 3rd day after storage lowest PLW was noticed in vacuum packed fruits (P_8) (0.0%) and highest in P_7 (CFB + polyethylene lining + ethylene absorbent (6.7%) followed by control fruits (5.7%).

On 6th, 9th and 12th day after storage vacuum packed fruits registered minimum PLW (0.0%) whereas control fruits registered maximum PLW (30.75%) on 12th day of storage.

On 15th day of storage control fruits were discarded. Out of the remaining treatments maximum PLW was registered by CFB packed (P_5) fruits (27.5%) and minimum by vacuum packed fruits. On 18th day of storage fruits in ventilated package was discarded due to spoilage and fruits in CFB recorded maximum PLW on 18th and 21st day (30.35% and 39.15% respectively) and vacuum packed fruits (0.45% and 0.65% respectively).

On 24th day of storage only P_3, P_4, P_6 and P_8 were available for comparison, all the others had to be rejected due to spoilage. P_6 had to be discarded on 27th day of storage. Statistical analysis of data was done only upto 21 days of storage, since fruits of most of the treatments were spoiled by that time. Maximum PLW was registered by P_6 (27.05%) on 24th day of storage whereas on 27th day it was for P_3 (9.85%). Vacuum packaged fruits recorded the minimum PLW (%) throughout the period of storage.

4.3.2.1.2 Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand

Banana hands in different packages showed significant difference for the days to reach 50 per cent yellowing. Vacuum packed fruits recorded maximum days to

Table 27. Effect of packaging on PLW during storage in fruits of Palayankodan under ambient conditions

Treatments	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)	18 DAS (%)	21 DAS (%)	24 DAS (%)	27 DAS (%)	30 DAS (%)	33 DAS (%)
P_1	4.05	5.45	6.35	7.50	8.05	11.60	14.30	ND	ND	ND	ND
P_2	4.95	8.15	10.25	16.45	19.15	ND	ND	ND	ND	ND	ND
P_3	4.15	5.20	7.25	8.00	8.00	8.55	9.05	9.05	9.85	10.60	ND
P_4	2.35	5.30	6.00	6.00	6.45	6.95	6.95	7.40	7.40	ND	ND
P_5	5.40	12.50	16.10	19.15	27.50	30.35	39.15	ND	ND	ND	ND
P_6	1.20	5.30	8.90	14.15	16.05	17.90	25.10	27.05	ND	ND	ND
P_7	6.70	9.45	12.80	17.60	20.20	23.75	28.60	ND	ND	ND	ND
P_8	0.00	0.00	0.00	0.00	0.45	0.45	0.65	0.65	1.10	2.40	2.80
P_9	5.70	19.25	23.60	30.75	ND	ND	ND	ND	ND	ND	ND
CD (0.05)	NS	3.63	3.631	3.181	3.325	NS	3.782	NA	NA	NA	NA

* - Significant at 5% level; NS - Not significant; ND - Not determined due to spoilage of fruits; NA - Not analysed statistically

reach 50 per cent yellowing (29.5 days). Unventilated package was effective in extending the green life upto 25.5 days whereas with ethylene absorbent the green life was extended upto 27 days. Fruits in CFB box with polyethylene lining extended the green life upto 17.5 days whereas in CFB box (P_5) and CFB box + polyethylene lining + ethylene absorbent (P_7) it was 13.5 days (Table 28).

Fruits wrapped in cling film extended the green life upto 15.5 days and ventilated polyethylene cover ten days over the control fruits (8.5 days).

4.3.2.1.3 Days to 100 per cent yellowing on all the fingers of the hands

Analysis of variance revealed significant variation between packages for days to reach 100 per cent yellowing (Table 28).

Maximum days to reach 100 per cent yellowing was registered by vacuum packed fruits (31.5 days) followed by fruits in unventilated package with ethylene absorbent (28 days). Minimum days to reach 100 per cent yellowing was recorded in control fruits.

4.3.2.1.4 Shelf life

The packaging materials had a significant influence on shelf life of fruits. Maximum shelf life was recorded in P_8 (vacuum packed fruits) (33.0 days) followed by fruits packaged in unventilated polyethylene with and without ethylene absorbent (30 days). Minimum shelf life was for control fruits (12.5 days) (Table 28) (Plate 37).

4.3.2.1.5 Changes in chemical composition during ripening

Significant variation for different chemical constituents like TSS, acidity, total and reducing sugars were observed in different packages (Table 29).

4.3.2.1.5.1 TSS

Maximum value for TSS was registered in CFB packaged fruits (P_5) (27.0°brix) whereas minimum value was registered in P_3 (16.5°brix) followed by vacuum packed fruits (17.5°brix).

Table 28. Effect of packaging on green life and shelf life of selected banana varieties

Treatment	Palayankodan			Njalipoovan			Chengalikodan		
	Days to 50% yellowing	Days to 100% yellowing	Shelf life	Days to 50% yellowing	Days to 100% yellowing	Shelf life	Days to 50% yellowing	Days to 100% yellowing	Shelf life
P_1	15.5 (3.996)^{bc}	18.5 (4.355)^{c}	21.5 (4.690)^{j}	19.5 (4.469)^{b}	21.0 (4.636)^{b}	24.0 (4.950)^{ij}	22.5 (4.793)^{d}	23.5 (4.897)	30.5 (5.568)^{def}
P_2	10.0 (3.237)^{d}	12.5 (3.605)^{e}	16.5 (4.119)^{kl}	12.0 (3.510)^{c}	15.0 (3.918)^{c}	18.0 (4.287)^{k}	12.0 (3.533)^{e}	16.0 (4.062)	24.5 (5.000)^{hi}
P_3	25.5 (5.099)^{a}	27.5 (5.291)^{b}	30.0 (5.523)^{efg}	21.0 (4.632)^{b}	25.0 (5.049)^{b}	28.5 (5.385)^{fg}	24.5 (4.998)^{c}	29.0 (5.431)	33.5 (5.830)^{cd}
P_4	27.0 (5.243)^{a}	28.0 (5.338)^{ab}	30.0 (5.522)^{efg}	21.0 (4.636)^{b}	24.5 (5.000)^{b}	27.0 (5.244)^{gh}	29.5 (5.477)^{b}	33.5 (5.830)	37.0 (6.123)^{ab}
P_5	13.5 (3.727)^{c}	15.05 (3.996)^{d}	22.0 (4.742)^{ij}	8.5 (2.999)^{cd}	11.5 (3.463)^{cd}	15.5 (4.000)^{l}	12.5 (3.605)^{e}	15.5 (4.000)	21.5 (4.690)^{j}
P_6	17.5 (4.242)^{b}	20.5 (4.582)^{c}	24.0 (4.950)^{ij}	12.0 (3.533)^{c}	14.5 (3.872)^{c}	18.5 (4.359)^{k}	12.5 (3.605)^{e}	15.0 (3.937)	24.0 (4.950)^{ij}
P_7	13.5 (3.741)^{c}	15.5 (4.000)^{d}	21.5 (4.690)^{j}	10.5 (3.316)^{c}	12.0 (3.536)^{cd}	16.5 (4.123)^{kl}	12.5 (3.605)^{e}	16.5 (4.123)	24.0 (4.950)^{ij}
P_8	29.5 (5.470)^{a}	31.5 (5.657)^{a}	33.0 (5.788)^{cde}	31.0 (5.612)^{a}	32.5 (5.744)^{a}	34.0 (5.874)^{bc}	34.5 (5.915)^{a}	37.0 (6.123)	39.5 (6.323)^{a}
P_9	8.5 (2.999)^{d}	10.5 (3.316)^{e}	12.5 (3.605)^{m}	6.0 (2.550)^{d}	9.0 (3.082)^{d}	11.0 (3.391)^{m}	6.5 (2.644)^{f}	9.5 (3.161)	15.0 (3.937)^{l}

Figures in parenthesis are transformed values; Values with same superscripts do not differ significantly

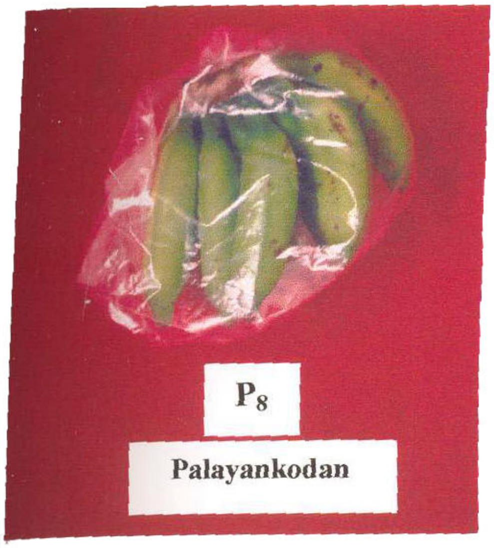


Plate 37. Vacuum packed fruits of Palayankodan 25 DAS

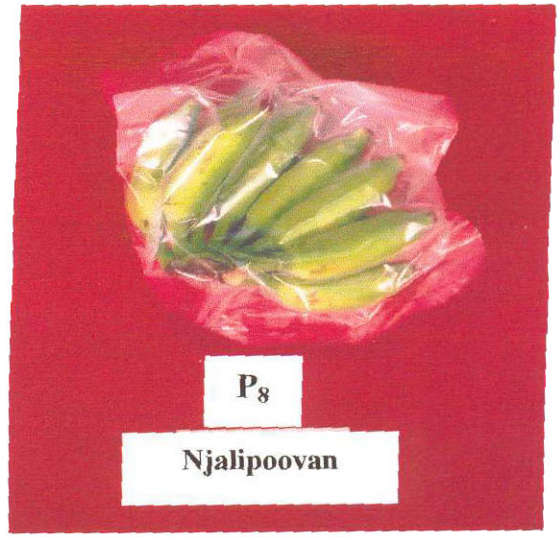


Plate 38. Vacuum packed fruits of Njalipoovan 25 DAS

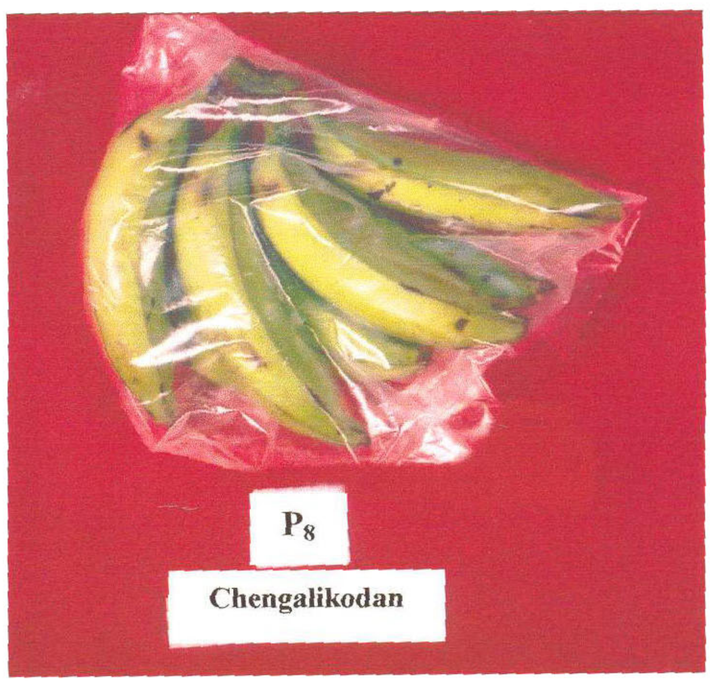


Plate 39. Vacuum packed fruits of Chengalikodan 30 DAS

Table 29. Effect of packaging on chemical composition of ripe fruits of Palayankodan

Treatments	TSS (° Brix)	Acidity (%)	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)
P_1	21.0	0.516	18.955	15.655	3.300
P_2	20.0	0.484	19.570	17.460	2.105
P_3	16.5	0.464	16.620	13.115	3.500
P_4	18.5	0.424	17.165	13.810	3.355
P_5	27.0	0.413	24.585	22.795	1.790
P_6	24.5	0.395	23.240	21.310	1.930
P_7	23.0	0.424	21.885	19.235	2.650
P_8	17.5	0.497	17.185	13.555	3.630
P_9	25.5	0.427	23.150	20.970	2.180
CD (0.05)	2.44*	0.326*	1.901*	2.306*	NS

* - Significant at 5% level; NS - Not significant

Table 30. Effect of packaging on PLW during storage in fruits of Njalipoovan under ambient conditions

Treatments	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)	18 DAS (%)	21 DAS (%)	24 DAS (%)	27 DAS (%)	30 DAS (%)	33 DAS (%)
P_1	4.60	4.60	4.60	4.60	5.35	5.35	6.15	10.1	ND	ND	ND
P_2	6.10	7.60	12.40	15.50	21.75	23.05	24.7	ND	ND	ND	ND
P_3	1.75	1.75	1.75	2.05	2.05	2.85	2.85	4.0	5.9	ND	ND
P_4	2.55	2.85	2.85	3.70	3.70	4.55	4.55	4.85	ND	ND	ND
P_5	4.70	8.45	12.15	24.20	30.45	ND	ND	ND	ND	ND	ND
P_6	6.60	5.55	8.05	13.75	17.75	20.30	ND	ND	ND	ND	ND
P_7	6.00	6.10	8.85	15.05	20.80	ND	ND	ND	ND	ND	ND
P_8	0.00	0.00	0.00	0.30	0.30	0.85	0.85	1.4	2.45	2.8	3.3
P_9	27.20	13.60	26.25	ND	ND	ND	ND	ND	ND	ND	ND
CD (0.05)	2.483*	2.88*	3.646*	3.394*	3.62*	4.889*	NA	NA	NA	NA	NA

* - Significant at 5% level; NA - Not analysed statistically; ND - Not determined due to spoilage of fruits

4.3.2.1.5.2 Acidity

Higher acid content was noticed in cling film wrapped fruits (P_1) (0.516%) and lower acid content in fruits packaged in CFB + polyethylene lining (P_6) (0.395%).

4.3.2.1.5.3 Total, reducing and non reducing sugars

Total sugars was found to be highest in P_5 (24.59%) and lowest in P_3 (16.62%).

Higher values for reducing sugars was noticed in P_5 (22.80%) and lower values in P_3 (13.12%).

Non reducing sugars were highest in P_8 (3.63%) and lowest in P_5 (1.79%).

4.3.2.2 Njalipoovan

4.3.2.2.1 PLW (%)

Significant difference in PLW was observed in different packages (Table 30).

Third day after storage, loss in weight was found to be highest in unpacked control fruits (P_9) (27.2%) whereas there was no weight loss in vacuum packed fruits (P_8).

Control fruits registered maximum PLW on 6^{th} and 9^{th} day of storage whereas no weight loss was observed in vacuum packed fruits (P_8).

Twelfth day after storage control fruits were in an unacceptable condition. On comparing the different packages PLW was minimum in vacuum packed fruits (P_8) (0.3%) and maximum in P_5 (CFB box) (24.2%).

Fifteenth day after storage CFB (P_5) packed fruits registered maximum PLW (30.45%) and vacuum packed fruits the minimum (0.3%).

P_5 and P_7 were discarded on 18^{th} day after storage and the other packages were compared. Fruits packed in ventilated polyethylene cover registered maximum PLW (23.05%) and vacuum packed fruits the minimum (0.85%).

4.3.2.2.2 Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand

Significant difference was noticed between different packages for the days to reach 50 per cent yellowing. Vacuum packed fruits registered maximum days to reach 50 per cent yellowing (31 days) and control fruits registered minimum days (6.0 days) (Table 28).

4.3.2.2.3 Days to 100 per cent yellowing on all the fingers of the hand

Banana hands in various packages differed significantly for the days to reach 100 per cent yellowing. Maximum days to reach 100 per cent yellowing was recorded by vacuum packed fruits (32.5 days) and minimum by control fruits (9.0 days) (Table 28).

4.3.2.2.4 Shelf life

Significant difference was noticed between different packages with respect to shelf life. Longest shelf life was recorded by vacuum packed fruits (34.0 days) and shortest by control fruits (11.0 days) (Table 28) (Plate 38).

4.3.2.2.5 Chemical composition on ripening

Chemical composition on ripening showed significant difference in various packages (Table 31).

4.3.2.2.5.1 TSS

Highest values for TSS was recorded in P_5 (CFB box) and control fruits (P_9)(30.5°brix) and lowest for vacuum packed fruits P_8 (20.5°brix).

4.3.2.2.5.2 Acidity

Acidity in different packages ranged between 0.615 per cent (control fruits) to 0.4 per cent (vacuum packed fruits).

4.3.2.2.5.3 Total, reducing and non reducing sugars

Total sugars in different packages ranged between 18.85 per cent (cling film package P_1) to 25.05 per cent (CFB box P_5), whereas reducing sugars ranged between 14.84 per cent in vacuum packed fruits to 22.55 per cent in P_2 (fruits packed in ventilated polyethylene cover):

Table 31. Effect of packaging on chemical composition of ripe fruits of Njalipoovan

Treatments	TSS (° Brix)	Acidity (%)	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)
P_1	24.0	0.545	18.850	16.105	2.745
P_2	28.0	0.445	24.650	22.550	2.100
P_3	24.5	0.490	21.580	17.850	3.730
P_4	26.5	0.470	20.700	15.970	4.730
P_5	30.5	0.595	25.050	22.445	2.605
P_6	29.5	0.565	23.050	20.975	2.075
P_7	30.0	0.600	22.000	19.175	2.735
P_8	20.5	0.400	19.200	14.835	4.365
P_9	30.5	0.615	22.450	19.945	2.505
CD (0.05)	2.036*	0.326*	NS	2.340*	1.476*

* - Significant at 5% level; NS - Not significant

Table 32. Effect of packaging on PLW during storage in fruits of Chengalikodan under ambient conditions

Treatment	3 DAS (%)	6 DAS (%)	9 DAS (%)	12 DAS (%)	15 DAS (%)	18 DAS (%)	21 DAS (%)	24 DAS (%)	27 DAS (%)	30 DAS (%)	33 DAS (%)	35 DAS (%)	38 DAS (%)
P_1	2.25	2.55	2.95	3.60	3.60	3.60	4.00	4.00	5.1	5.35	ND	ND	ND
P_2	7.40	9.20	9.20	14.85	15.25	17.05	18.65	19.65	ND	ND	ND	ND	ND
P_3	1.80	2.05	2.05	2.40	2.90	3.90	4.25	4.25	4.45	4.45	ND	ND	ND
P_4	1.55	1.55	1.55	2.30	2.70	3.20	3.60	3.75	4.00	4.00	2.90	4.15	
P_5	7.50	11.00	11.00	23.35	25.70	27.40	30.30	ND	ND	ND	ND	ND	ND
P_6	3.65	5.35	5.35	15.30	16.50	17.95	21.55	22.95	ND	ND	ND	ND	ND
P_7	4.60	5.75	5.75	14.05	15.95	18.65	20.60	21.25	ND	ND	ND	ND	ND
P_8	0.65	0.65	0.65	0.65	1.10	1.10	1.35	1.35	2.05	2.05	4.15	4.35	4.6
P_9	12.55	12.55	18.10	27.75	30.80	ND	ND	ND	ND	ND	ND	ND	ND
CD (0.05)	2.776*	2.767*	2.619*	3.143*	3.024*	2.867*	1.001*	1.641*	NA	NA	NA	NA	NA

* - Significant at 5% level; NA - Not analysed statistically; ND - Not determined due to spoilage

Non reducing sugars ranged between 2.1 per cent (P_2) to 4.73 per cent (P_4).

4.3.2.3 *Chengalikodan*

4.3.2.3.1 *PLW (%)*

Significant difference in PLW was noticed between the different packages on 3rd, 6th, 9th, 12th, 15th, 18th, 21st and 24th days of storage (Table 32).

Physiological loss in weight was found to be lowest in vacuum packed fruits (P_8) through out the storage period.

Maximum PLW was noticed in control fruits P_9 up to 15th day of storage.

On 18th day of storage control fruits were discarded and maximum PLW was registered by P_5 (CFB box) upto 21 days of storage.

Twenty four days after storage P_5 was discarded and maximum PLW was observed in P_6 (CFB + polyethylene lining) (22.95%).

Twenty seven days after storage only P_1, P_3, P_4 and P_8 were available for comparing the PLW as the rest of the treatments were rejected due to spoilage. So statistical analysis was not done and the mean values were compared. Maximum PLW was recorded by cling film package (P_1) on 27 and 30th day of storage and minimum PLW was recorded in P_8 (vacuum packed fruits) (2.05%).

4.3.2.3.2 *Days to more than 50 per cent yellowing on more than 50 per cent fingers of the hand*

Vacuum packed (P_8) fruits recorded maximum number of days to reach 50 per cent yellowing (34.5 days) and control fruits the minimum (6.5 days).(Table 28).

4.3.2.3.3 *Days to 100 per cent yellowing on all the fingers of the hand*

Different packages varied significantly for days to reach 100 per cent yellowing. Maximum days to reach 100 per cent yellowing was registered by vacuum packed fruits (37 days) and minimum in control fruits (9.5 days) (Table 28).

4.3.2.3.4 Shelf life

Analysis of variance showed significant difference for shelf life between different packages. Maximum shelf life was recorded in vacuum packed fruits (39.5 days) followed by fruits packed in polyethylene with ethylene absorbent (37.0 days). Minimum shelf life was for control fruits (15.0 days) (Table 28) (Plate 39).

4.3.2.3.5 Chemical composition on ripening

Significant difference was noticed for TSS, total, reducing and non reducing sugars between different packages on ripening (Table 33).

4.3.2.3.5.1 TSS

Control fruits registered highest TSS (31.5°brix) and cling film wrapped fruits the lowest (23.5°brix).

4.3.2.3.5.2 Acidity

The values for acidity ranged from 0.42 per cent in P_5 to 0.51 per cent in P_4 (unventilated polyethylene cover with ethylene absorbent).

4.3.2.3.5.3 Total, reducing and non-reducing sugars

Maximum values for total and reducing sugars were registered by control fruits (32% and 26.05% respectively and minimum total sugar in cling film wrapped fruits (21.54%) and reducing sugar in vacuum packed fruits (14.74%). Non reducing sugars was highest in P_3 (unventilated polyethylene cover) (7.97%) and lowest in P_2 (ventilated polyethylene cover) (4.76%).

4.3.2.4 Organoleptic evaluation

4.3.2.4.1 Palayankodan

Highest score for appearance was obtained for vacuum packed fruits (7.6) (Table 34) and superior scores for taste and sweetness was registered by fruits packed in CFB box with polyethylene lining (6.9 and 7.1 respectively) followed by fruits

Table 33. Effect of packaging on chemical composition of ripe fruits of Chengalikodan

Treatments	TSS (° Brix)	Acidity (%)	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)
P_1	23.5	0.465	21.540	15.215	6.375
P_2	28.0	0.457	24.155	17.580	4.755
P_3	26.5	0.458	23.165	15.195	7.970
P_4	27.5	0.509	22.335	16.670	7.485
P_5	26.5	0.420	25.650	20.115	5.535
P_6	27.0	0.483	28.860	23.130	5.730
P_7	28.5	0.500	27.015	21.145	5.870
P_8	25.0	0.470	21.855	14.735	7.120
P_9	31.5	0.496	32.000	26.050	6.000
CD (0.05)	2.151*	NS	1.315*	2.775*	1.529*

* - Significant at 5% level; NS - Not significant

Table 34. Influence of packaging on sensory attributes of ripe fruits of Palayankodan

Treatment	Appearance	Taste	Sweetness	Overall acceptance
P_1	7.4 (59.95)	5.4 (51.80)	7.1 (65.40)	6.2 (49.70)
P_2	6.4 (36.30)	6.2 (62.40)	7.1 (64.15)	7.1 (67.90)
P_3	7.3 (57.30)	4.1 (24.30)	5.0 (32.05)	5.0 (30.90)
P_4	7.4 (59.95)	4.3 (25.28)	4.4 (24.17)	5.2 (36.39)
P_5	6.3 (39.05)	6.3 (61.36)	7.0 (59.50)	6.8 (58.05)
P_6	7.3 (57.25)	6.9 (70.05)	7.1 (64.70)	7.0 (66.66)
P_7	6.2 (32.50)	6.8 (73.35)	7.0 (63.40)	7.1 (67.90)
P_8	7.6 (63.94)	3.8 (18.90)	3.5 (12.85)	3.9 (14.75)
P_9	3.2 (5.75)	3.9 (18.45)	4.2 (19.75)	4.0 (16.10)
Kruskalwallis statistic	45.99*	64.696*	60.295*	56.562*

* - Significant at 5% level

Table 35. Influence of packaging on sensory attributes of ripe fruits of Njalipoovan

Treatment	Appearance	Taste	Sweetness	Overall acceptance
P_1	7.1 (60.35)	6.4 (52.65)	6.4 (54.85)	6.1 (50.50)
P_2	7.1 (59.16)	6.8 (58.20)	6.6 (66.85)	6.9 (61.30)
P_3	7.0 (58.20)	4.1 (24.95)	3.9 (19.80)	4.4 (27.15)
P_4	7.1 (60.50)	3.6 (16.89)	3.9 (21.17)	4.4 (26.72)
P_5	6.0 (37.36)	7.8 (65.77)	7.8 (68.91)	7.9 (70.09)
P_6	4.9 (18.60)	8.1 (76.05)	7.9 (77.45)	8.3 (80.00)
P_7	6.4 (44.15)	7.5 (67.40)	6.8 (60.05)	6.7 (56.10)
P_8	7.4 (65.55)	4.3 (27.40)	3.4 (14.60)	3.3 (14.30)
P_9	4.0 (8.55)	3.4 (15.30)	4.6 (31.05)	3.9 (19.90)
Kruskalwallis statistic	52.155*	67.351*	66.336*	68.507*

* - Significant at 5% level

Table 36. Influence of packaging on sensory attributes of ripe fruits of Chengalikodan

Treatment	Appearance	Taste	Sweetness	Overall acceptance
P_1	7.30 (64.45)	6.9 (65.65)	6.7 (61.15)	6.7 (63.95)
P_2	7.2 (59.45)	7.0 (64.85)	7.0 (67.00)	6.0 (53.50)
P_3	5.3 (34.45)	3.9 (18.20)	3.7 (24.70)	3.9 (24.55)
P_4	6.7 (63.17)	4.0 (19.56)	3.6 (24.06)	3.6 (20.61)
P_5	5.4 (37.77)	6.9 (59.45)	6.6 (56.00)	6.8 (60.41)
P_6	3.6 (19.45)	7.1 (66.55)	6.9 (64.55)	6.7 (64.16)
P_7	6.9 (55.55)	7.0 (64.25)	7.6 (74.30)	7.8 (79.30)
P_8	8.1 (76.40)	3.7 (17.55)	2.8 (13.85)	3.3 (15.85)
P_9	3.2 (10.35)	4.7 (29.45)	3.6 (20.70)	3.8 (23.20)
Kruskalwallis statistic	56.896*	63.125*	67.628*	68.043*

* - Significant at 5% level

packed in CFB box + polyethylene lining + ethylene absorbent (6.8 and 7.0). Overall acceptability was better for fruits packed in CFB box + polyethylene lining + ethylene absorbent and fruits packed in ventilated polyethylene cover (7.1).

4.3.2.4.2 Njalipoovan

Vacuum packed fruits registered superior scores for appearance in Njalipoovan (7.4) whereas highest scores for taste, sweetness and overall acceptability was registered by fruits packed in CFB box + polyethylene lining (8.1, 7.9 and 8.3 respectively) (Table 35).

4.3.2.4.3 Chengalikodan

In the case of Chengalikodan fruits also higher scores for appearance was registered by vacuum packed fruits (8.1). Higher score for taste was obtained by fruits packed in CFB box + polyethylene lining (7.1) whereas scores for sweetness and overall acceptance was higher for fruits packed in CFB box + polyethylene lining + ethylene absorbent (7.6 and 7.8 respectively) (Table 36).

Discussion

5. DISCUSSION

The postharvest losses of fruits like banana are 30-40 per cent in the tropical countries like India. Postharvest losses occur on account of various reasons such as lack of proper storage facilities, improper handling, long distance transport, rapid ripening and microbial spoilage owing to high temperatures in the country. The difficulties associated with the short storage life of plantain are worsened by the marketing system. Transport is often delayed, and can fail altogether, because of poor conditions of vehicles and roads. A combination of high perishability, high ambient temperatures, slow marketing systems and poor market conditions lead to losses in fruit quality and ultimately to postharvest losses (Singh, 2002). Hence there is a need to develop inexpensive methods for delaying ripening and extending the shelf life under ambient conditions without affecting the eating quality of the fruit which can help both in internal trade and export. Low temperature is one of the most widely used methods adopted all over the world for storage as well as during transport of fruits to reduce their postharvest losses, but it is not an economical and feasible method for bananas. Effective methods followed to extend shelf life include different postharvest treatments, use of polyethylene bags and different forms of ethylene absorbents for the storage and transport of bananas (Sarkar *et al.*, 1994).

Inspite of having a rich wealth of genetic diversity, the postharvest characterisation of banana varieties grown in Kerala is limited. Hence the present study was taken up for evaluation of twenty five banana varieties belonging to six genomic groups and to study their ripening behaviour, effect of various postharvest treatments and packaging treatments on shelf life in selected varieties. The results of the experiments conducted are discussed in this chapter.

5.1 EVALUATION OF BANANA VARIETIES FOR POSTHARVEST ATTRIBUTES

5.1.1 Fruit morphological characters

Twenty five banana accessions belonging to six genomic groups were morphologically described as per INIBAP/IPGRI (*Musa* descriptors). The accessions exhibited considerable variation for fruit characters. Of the accessions studied the fruit position was curved upward in 68 per cent, curved towards stalk in 16 per cent, parallel to stalk in 12 per cent and pendant in 4 per cent (Fig. 1). Fifty two per cent of the accessions studied were with 13-16 fruits per hand, 40 per cent with $\leq$ 12 fruits and 8 per cent with $\geq$ 17 fruits per hand (Fig. 2). Fruit length in 24 per cent of the accessions were $\leq$ 15 cm, 16-20 cm in 28 per cent, 21-25 cm in 28 per cent, 26-30 cm in 16 per cent and $\geq$ 31 cm in 4 per cent (Fig. 3). The finger characters like number of fingers, number of fruits and fruit length were higher for the triploids and tetraploids than the diploids confirming to the reports of Simmonds (1966), DeLanghe (1969) and Valsalakumari (1984). Shape of the fruit was slightly curved in 32 per cent, straight in 36 per cent and straight in the distal part in 32 per cent (Fig. 4). Among the accessions studied slightly ridged transverse section was observed in 44 per cent, rounded in 28 per cent and pronounced ridged in 28 per cent. Varieties Matti, Kadali, Njalipoovan, Koompillakannan, Poomkalli, Red Banana and Poovan had rounded transverse section of fruit (Fig. 5). Blunt tipped fruit apex was seen in 44 per cent of the accessions, lengthily pointed in 28 per cent and bottle necked fruit apex in 28 per cent (Fig. 6). In *Musa acuminata* blunt tipped fruit apex is generally present (Salunkhe and Desai, 1984). Base of the style was prominent at the fruit apex in 44 per cent of the accessions, persistent style in 28 per cent and without any floral relicts in 28 per cent (Fig. 7).

The fruit pedicel length was $\geq$ 21 mm in 52 per cent, 11 to 20 mm in 36 per cent and $\leq$ 10 mm in 12 per cent of the accessions studied. The *Musa acuminata* groups (AA, AAA and AAAA) recorded lower values for pedicel length compared to other groups. The short pedicel is a characteristic feature of *Musa acuminata* (Simmonds and Shepherd, 1955). Partially fused pedicel was observed in 16 per cent whereas no visible sign of fusion was observed in 84 per cent of the accessions studied (Fig. 8). In 68 per cent of the accessions studied immature fruit peel colour was light green and mature fruit peel colour in 48 per cent of the accessions was bright yellow. In Red Banana immature fruit peel colour was brown or rusty brown which turned to orangish red on maturity. The peel thickness was comparatively less for diploids than the triploids. Sixty per cent of the accessions studied had $\geq$ 3 mm peel thickness and 40 per cent $\leq$ 2 mm peel thickness. Ninety six per cent of the accessions were without

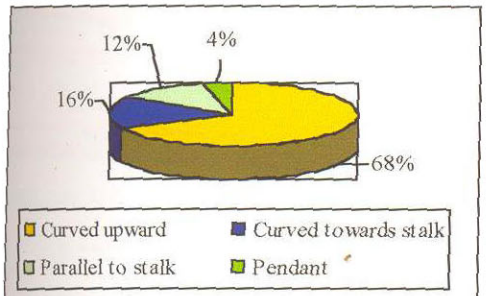


Fig. 1. Fruit position

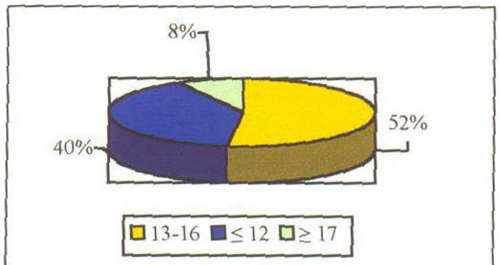


Fig. 2. Number of fruits per hand

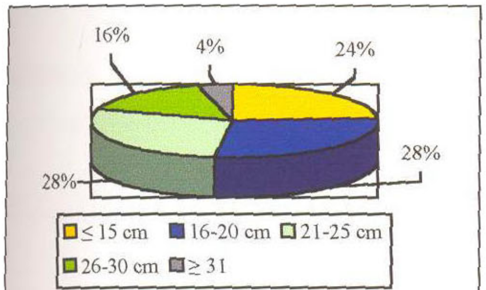


Fig. 3. Fruit length

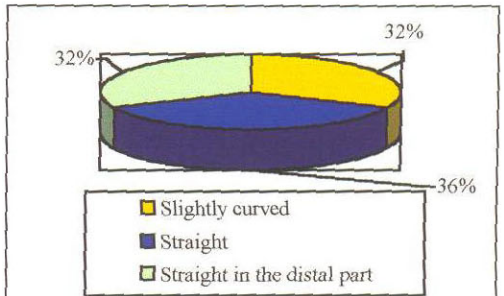


Fig. 4. Fruit shape

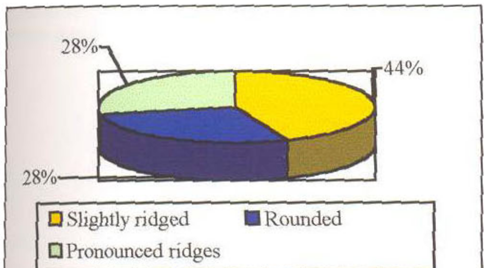


Fig. 5. Transverse section of fruit

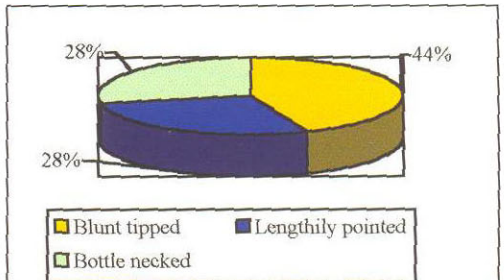


Fig. 6. Fruit apex

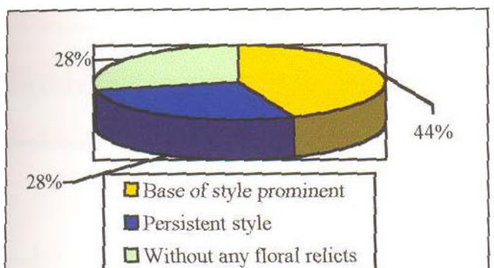


Fig. 7. Remains of flower relicts at fruit apex

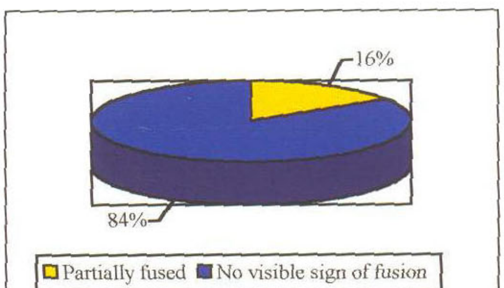


Fig. 8. Fusion of pedicels

any cracks in the fruit peel and four per cent with cracks. Cracks on fruit peel was observed in Poovan. Before maturity the pulp colour was white in 48 per cent and cream, ivory or beige in 52 per cent. Firm flesh texture was noticed in 20 per cent and soft in 80 per cent of the accessions. The predominant taste was sweet and acidic in 48 per cent and sweet in 40 per cent and astringent in 12 per cent. The quality characters were influenced more by the genomic constitution than by the ploidy level. The fruits of *Musa acuminata* groups (AA, AAA and AAAA) had sweet taste. Though the hybrid cultivars, especially of the genomic group, ABB had higher sugar content the disappearance of acidity at ripening proceeds at a lower rate and they have a lower sugar/acid ratio which contributes to their inferior quality (Simmonds, 1966).

5.1.2 Physical characters

Twenty five varieties of banana were evaluated for physical characters, chemical constituents and shelf life. Physical characters studied include finger weight, length of finger, volume of finger, pulp weight, peel weight, pulp/peel ratio, peel thickness and specific gravity.

Significant difference with respect to physical characters were observed in various varieties. Tripathi *et al.* (1981) also reported that the physical characters of the fruit varied widely among banana varieties. It is evident because of the fact that varieties covered under the study belonged to different genomic group under the genes *Musa* with varying ploidy levels (Fig. 9, 10, 11 and 12).

In the present investigation variety Zanzibar recorded the highest values for physical characters like finger weight, length of finger, volume of finger, pulp weight and peel weight. Variety Matti recorded the lowest values for these parameters. The values for finger weight ranged between 36.5 g to 202.5 g, length 10.85 cm to 30.80 cm, volume 53 ml to 295 ml, pulp weight 21.5 g to 160 g and peel weight 15 g to 102.5 g among the different varieties. Pulp/peel ratio ranged from 0.97 (Monthan) to 3.15 (Poomkalli), peel thickness 1.06 mm (Matti) to 4.13 mm (Monthan) and specific gravity 0.69 (Matti) to 1.08 (Grand Naine). Higher fruit weight, pulp weight and low peel weight are desirable attributes for processing, which was observed in varieties

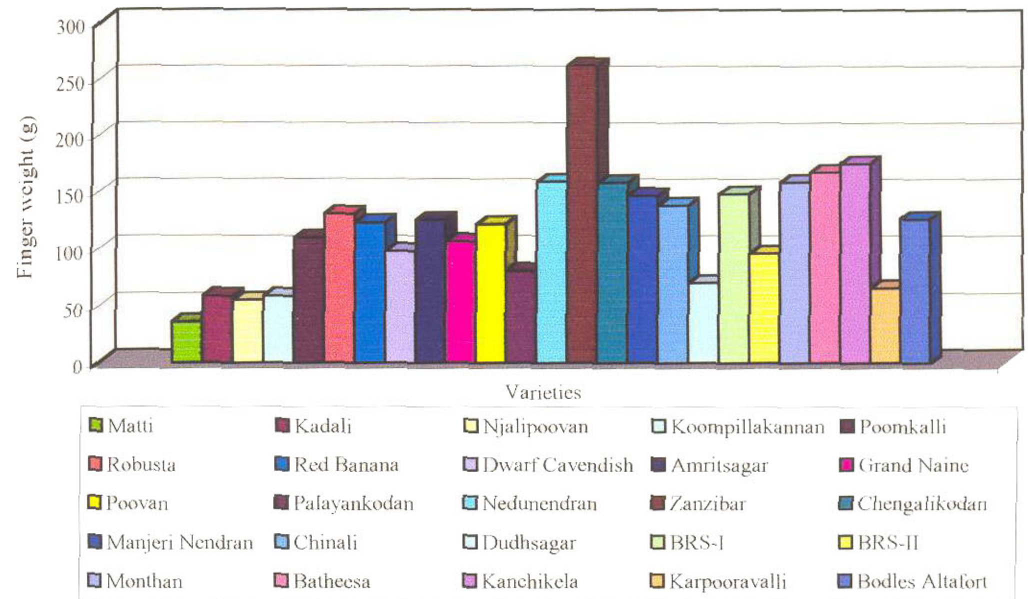


Fig. 9. Finger weight of selected banana varieties

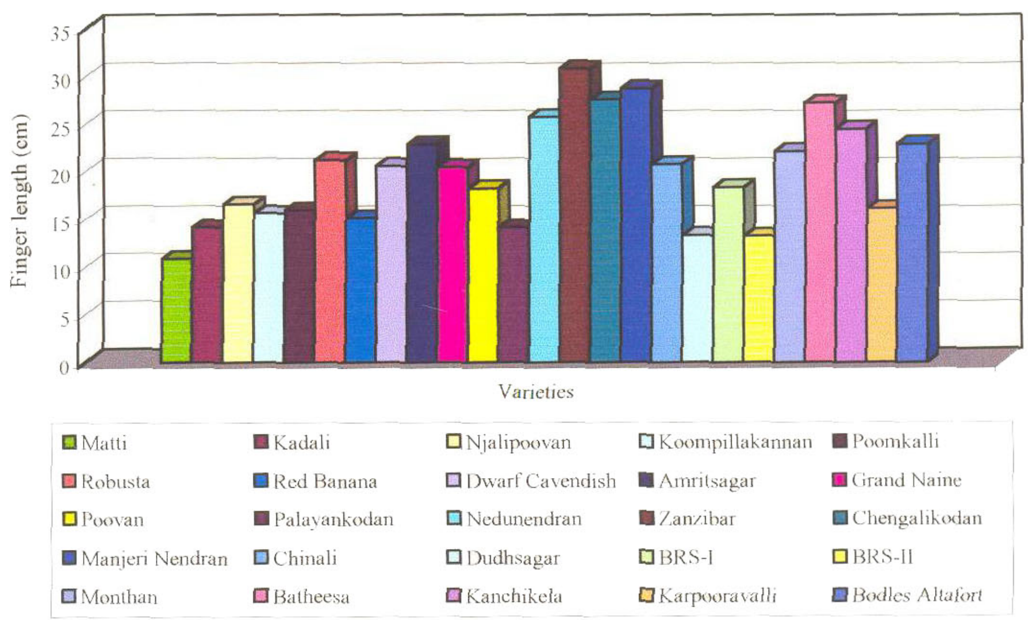


Fig. 10. Finger length of selected banana varieties

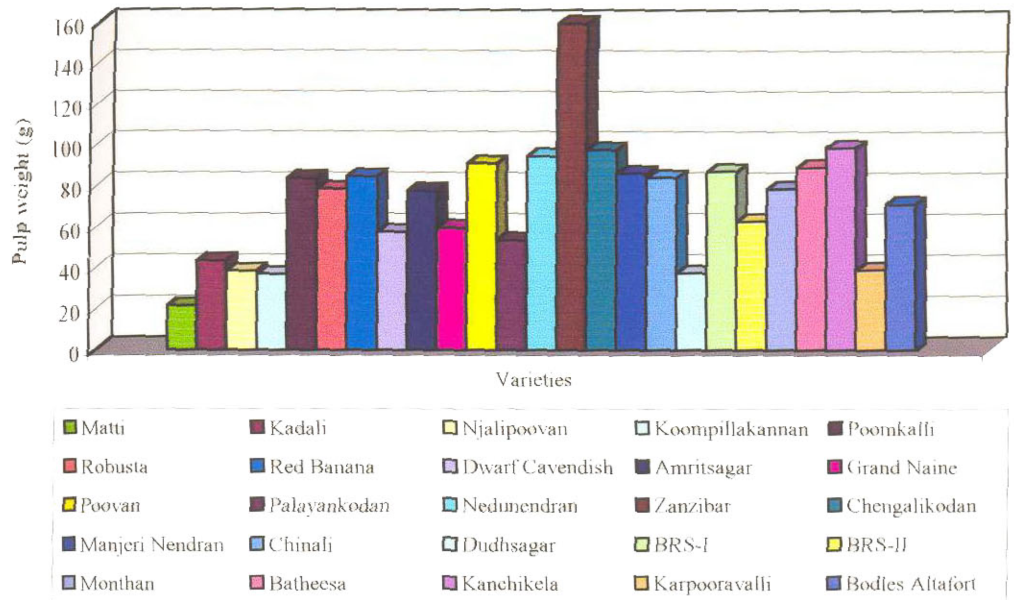


Fig. 11. Pulp weight of selected banana varieties

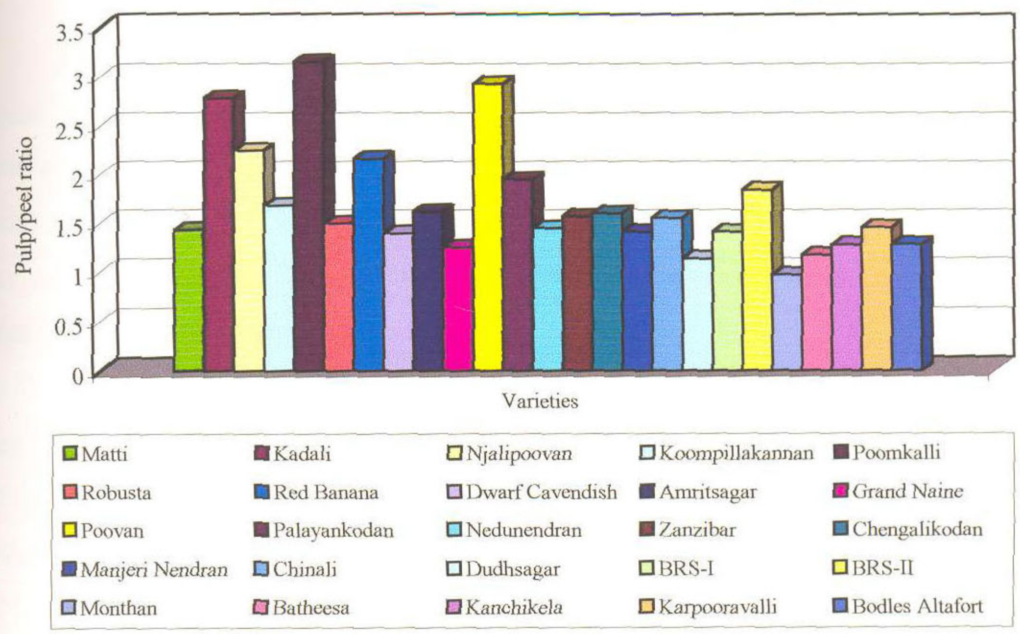


Fig. 12. Pulp/peel ratio of selected banana varieties

Poovan, Red banana, Poomkalli, Chinali, BRS-I, Zanzibar and Nendran clones. Peel weight was lower in the varieties Matti, Kadali and Njalipoovan. Higher pulp/peel ratio was seen in the varieties Kadali, Njalipoovan, Poomkalli, Red Banana, Poovan, Palayankodan, Chinali, BRS-II, Karpooravalli, Zanzibar and Nendran clones indicating the pulp recovery would be high and the processing waste less in these varieties. Varieties Matti, Kadali, Njalipoovan, Koompillakannan, Poomkalli, Poovan (Rasthali), Palayankodan, Dudhsagar and Karpooravalli had lower peel thickness. The finger weight of Monthan reported by Sabeena (2000) is in confirmation with the present study. The values obtained for pulp/peel ratio in the present study is in general agreement with that of Burdon *et al.* (1993), Ngalani *et al.* (1998) and Sabeena (2000).

5.1.3 Chemical constituents

Chemical constituents like TSS, acidity, pH, total, reducing and non-reducing sugars, moisture, vitamin C, β-carotene, tannin, pectin and starch were assessed at full ripe stage in the table varieties and at the mature green stage in culinary varieties.

The total soluble solids (TSS) content of the screened varieties showed significant differences. Maximum values for TSS was observed in the varieties Zanzibar and Chinali (32.5°brix) and minimum in the culinary variety Kanchikela (6.5°brix) (Fig. 13). Most of the accessions had a TSS more than 25°brix. Only culinary varieties Monthan, Batheesa and Kanchikela recorded lower TSS (< 10°brix). Varieties Matti, Njalipoovan, Koompillakannan, Nedunendran, Zanzibar, Chengalikodan, Manjeri Nendran and Chinali had TSS above 30°brix. Majority of the varieties (twenty) had TSS above 25°brix. Banana hybrids BRS-I and II had TSS less than 25°brix. Since sugars form the main component of soluble solids in banana, the data indicate that most of the table varieties are comparatively richer in sugars, which is one of the most important factors contributing to fruit quality.

The titrable acidity values of the varieties ranged from 0.192 per cent to 0.794 per cent (Fig. 14). The acidity was more than 0.4 per cent in fifteen varieties and highest acidity were recorded in the hybrids BRS-I and BRS-II (0.794% and 0.743%

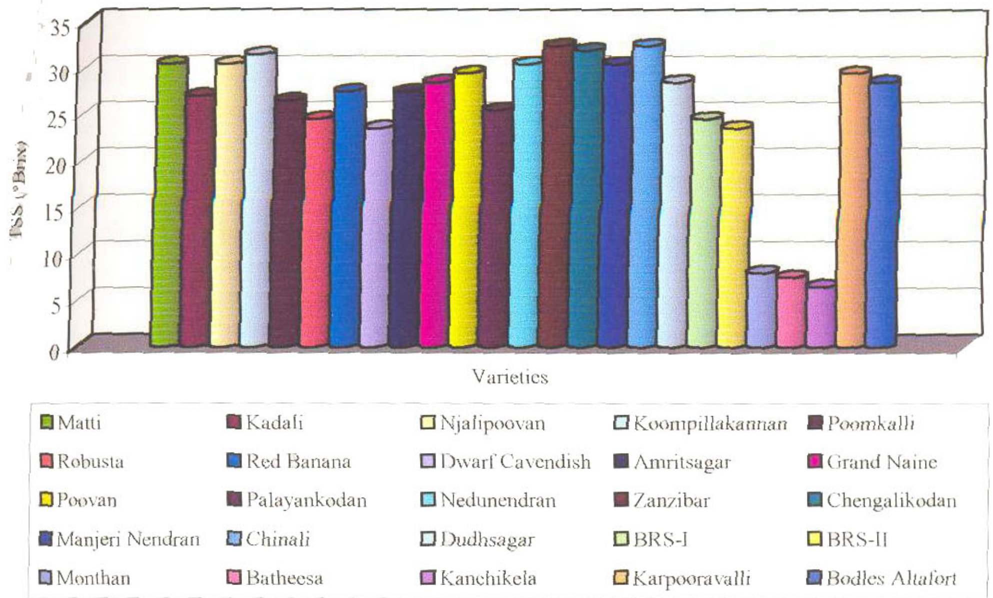


Fig. 13. TSS of selected banana varieties

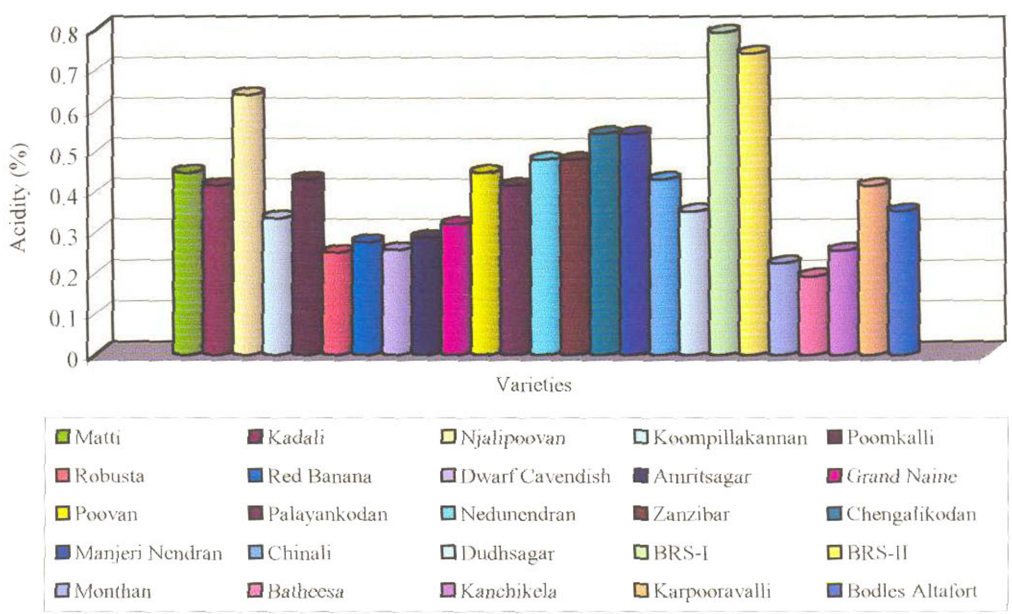


Fig. 14. Acidity of selected banana varieties

respectively). The varieties belonging to AAA genomic group such as Robusta, Red Banana, Dwarf Cavendish, Amritsagar and Grand Naine showed comparatively lower acidity. Acidity is an important determinant of the eating quality of the fruit as the fruit taste is decided by the balance between sugar and acid contents. Hence, varieties with the right mix of sweetness and acidity would have highly agreeable taste (Shivasankar, 1999).

The values for pH in the different varieties varied between 5.7 to 3.0. High values of pH corresponds to low acidity and vice versa. Most of the varieties had a pH between 4.0 and 5.0. Banana hybrids BRS-I and II had high acidity and low pH.

The TSS/Acid ratio in the present investigation ranged between 25.39 to 96.0. High values for TSS/acid ratio corresponds to higher TSS and lower acidity. Varieties belonging to AAA genomic group had higher TSS/acid ratio of more than 85 as the acid content was found to be less in these varieties. In seventeen varieties TSS/acid ratio was more than 60. The culinary varieties Monthan, Batheesa and Kanchikela had lower TSS/acid ratio as TSS content was low in these varieties.

Thirteen varieties had a total sugar content of more than 20 and in nine varieties the total sugars ranged between 15 to 20 (Fig. 15). Higher values for total sugars was observed in the varieties Chengalikodan, Zanzibar, Nedunendran, Manjeri Nendran, Njalipoovan, Koompillakannan, Dwarf Cavenidsh, Robusta, Poovan (Rasthali), Palayankodan and Karpooravalli. The three culinary varieties viz., Monthan, Batheesa and Kanchikela registered lower total sugar content (1.43%). Even though the ABB genomic group had higher total sugar content, acidity was higher imparting lower sugar acid ratio in these groups.

The reducing sugar content ranged between 0.73 per cent to 27.08 per cent. In sixteen varieties reducing sugar content was more than 15 per cent. The values for non reducing sugar content varied between 0.39 per cent to 6.37 per cent. Zanzibar and nendran clones like Nedunendran, Chengalikodan and Manjeri Nendran had high TSS, total sugars and reducing sugars.

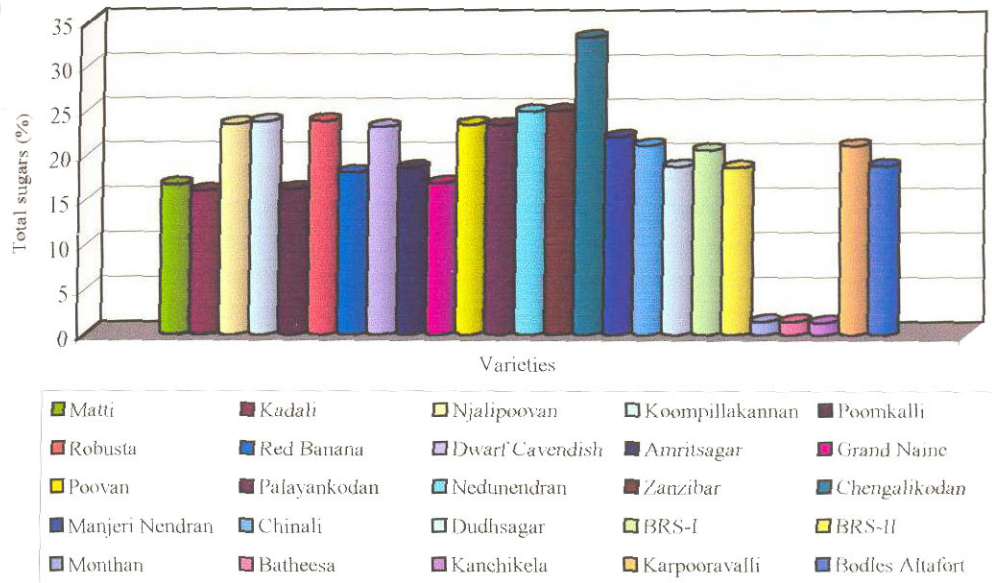


Fig. 15. Total sugars of selected banana varieties

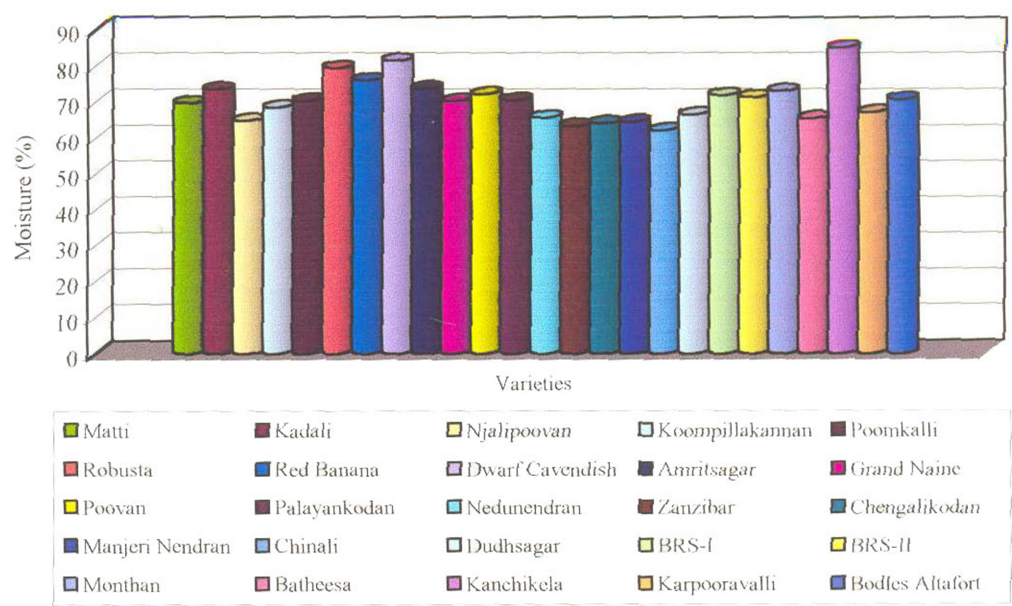


Fig. 16. Moisture content of selected banana varieties

In the present investigation the moisture content of the different varieties ranged between 62.16 per cent (Chinali) to 85.04 per cent (Kanchikela). In fourteen varieties moisture content was more than 70 per cent (Fig. 16). Chadha (1992) reported a moisture content of 70 per cent in ripe banana. The moisture content reported by Sabeena (2000) in Njalipoovan and Red Banana is in confirmation with the present result.

Compared to other tropical fruits like mango, guava etc., a low vitamin C content is observed in banana. In most of the varieties the vitamin C content was more than 2.0 mg 100 g^{-1} (Fig. 17). In Nendran clones the mean vitamin C content was 5.38 mg 100 g^{-1} in the present study. Anil (1994), Deepa (1997) and Sabeena (2000) reported a vitamin C content of 9.37 mg 100 g^{-1}, 3.07 mg 100 g^{-1} and 6.8 mg 100 g^{-1} respectively in Nendran banana. Comparatively higher vitamin C content was observed in the varieties Matti, Kadali, Red Banana, Amritsagar, Nedunendran, Zanzibar, Chengalikodan, Manjeri Nendran and BRS-I.

Content of β-carotene ranged from 52.3 μg 100 g^{-1} to 266.61 μg 100 g^{-1} in the various varieties. Highest β-carotene was reported in the variety Chengalikodan (266.61 μg 100 g^{-1}). Nendran clones and Zanzibar had higher β-carotene evidenced by yellowish orange flesh colour (Fig. 18). This results are in confirmation with that obtained by Sabeena (2000). β-carotene content was lower in the culinary varieties. From the nutritional point of view Nendran clones were found superior with higher β-carotene and vitamin C content.

Tannins are water-soluble phenolics found in the peel and pulp of bananas. In partially ripened fruit they impart an astringent taste. Ripening polymerizes the tannins, resulting in loss of astringency (Turner, 1997). Tannin content in the different varieties varied between 0.10 per cent to 1.64 per cent (Fig. 19). In table varieties it was lower whereas in culinary varieties higher tannin content was observed. In sixteen varieties the tannin content ranged between 0.2 per cent to 0.5 per cent. The varieties belonging to AA and AAA genomic group had lower tannin content compared to ABB

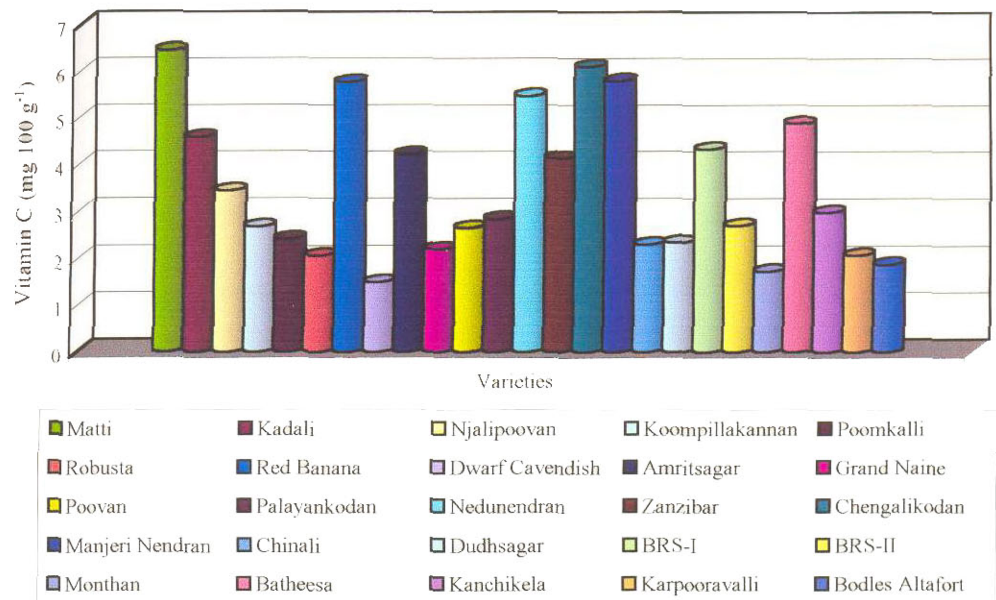


Fig. 17. Vitamin C content of selected banana varieties

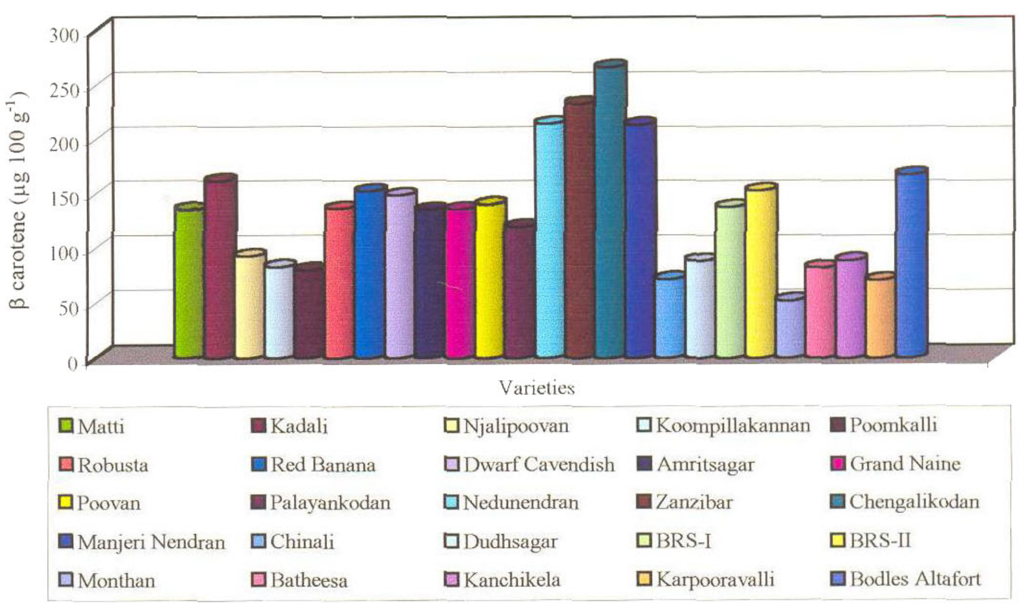


Fig. 18. β carotene content of selected banana varieties

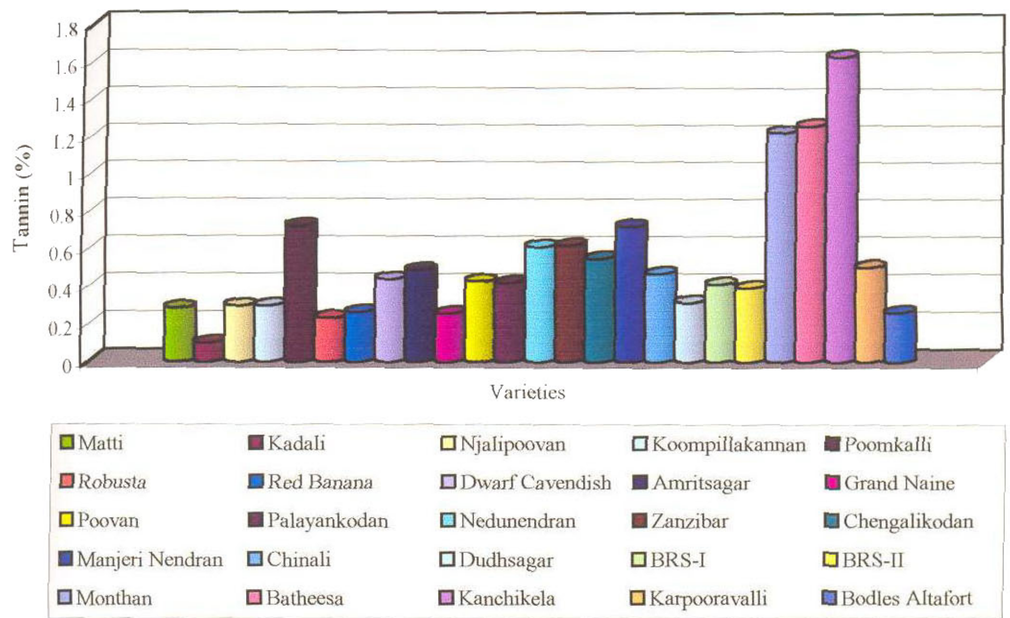


Fig. 19. Tannin content of selected banana varieties

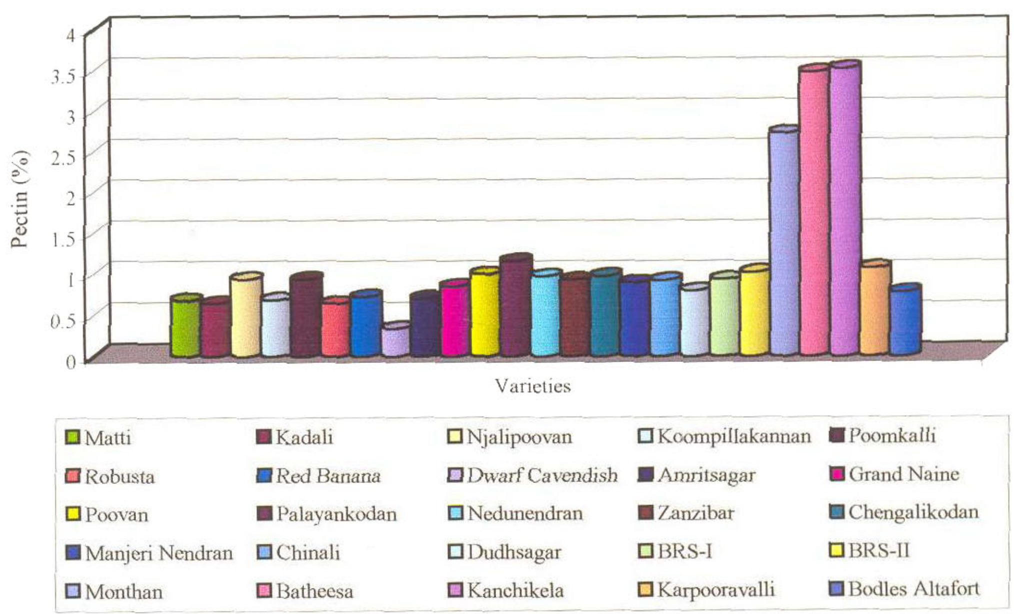


Fig. 20. Pectin content of selected banana varieties

genomic group. Better palatability of varieties can be attributed to their lower tannin content. Varieties Matti, Kadali, Njalipoovan, Koompillakannan, Robusta, Red Banana, Grand Naine and Bodles Altafort had lower tannin content (below 0.3%).

Pectin content ranged between 0.34 per cent to 3.54 per cent in the various varieties. In the table varieties pectin content was found to be lower whereas the culinary varieties recorded higher values of pectin (Fig. 20). Palayankodan and Karpooravalli registered higher values of pectin content among the table varieties (1.16% and 1.08% respectively) and Kanchikela among the culinary varieties (3.54%). Among the various genomic groups lower pectin content was observed in pure acuminata group. During ripening the insoluble pectin content in fruits gets converted to water soluble pectin by the action of pectin methyl esterase.

Among the table varieties higher starch content was reported in Zanzibar and nendran clones (2.15%). The starch content in culinary varieties ranged from 22.46 per cent to 25.39 per cent (Fig. 21). During ripening starch is hydrolysed to sugars which account for the lower starch content in table varieties.

5.1.4 Shelf life

Shelf life of 25 accessions of banana was evaluated under ambient conditions.

5.1.4.1 Physiological loss in weight

PLW is one of the most important factors that affect shelf life of harvested fruits and vegetables. Loss of water through transpiration appears to be the most important component accounting for the loss of weight. A higher PLW is therefore an undesirable feature commercially, as it leads to large reduction in bunch weight during ripening. PLW varied considerably among varieties. When a variety has a high PLW, its shelf life will be low.

On the sixth day of storage minimum PLW was registered in Zanzibar and in Red Banana on 15th day of storage. In general physiological loss in weight was

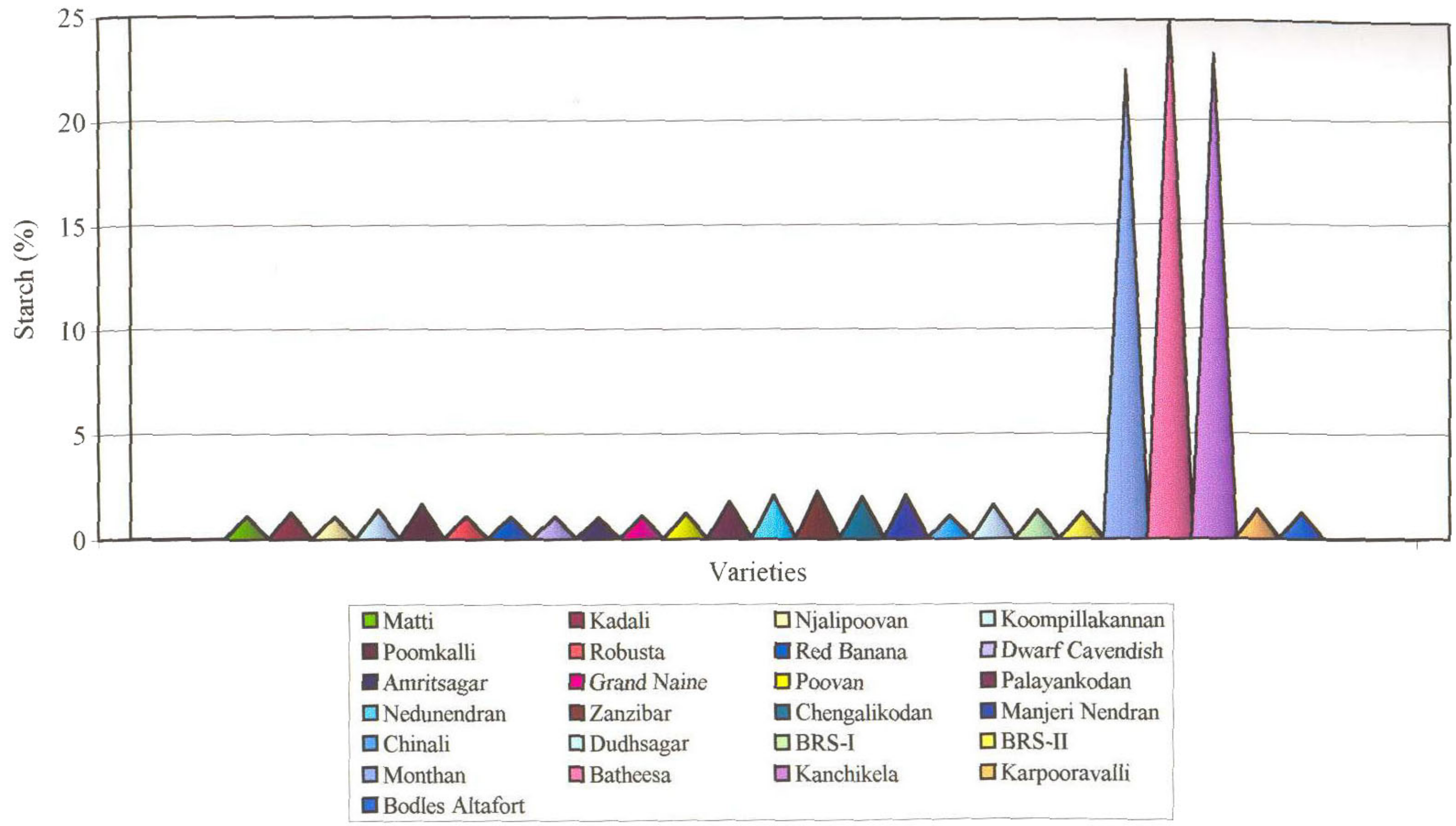


Fig. 21. Starch content of selected banana varieties

comparatively less in Nendran clones. Only seven varieties were left on the 15th day of storage.

The loss in weight was at a higher rate in the earlier period than at later period of storage. This is in agreement with the results of Sen *et al.* (1982) and Sarkar *et al.* (1995). The PLW ranged from 4.07 per cent (Zanzibar) to 20.38 per cent (Koompillakannan) at six days after storage in the present study. Shivasankar (1999) reported that the PLW varied from 1.81 per cent (Gros Michel) to 22.26 per cent (Chenkadali).

Higher loss in weight was reported in Dwarf Cavendish banana than in Robusta by Wasker and Roy (1992) which is in confirmation with the present result.

Cumulative PLW at the end of storage period was highest for Grand Naine (26.46%) in the present study where the total shelf life was 15.5 days and minimum PLW was for Batheesa (9.63%) where the total shelf life was only seven days (Fig. 22).

5.1.4.2 Shelf life

The shelf life was calculated as number of days till the fruit remained marketable. Unmarketability was attributed when more than 50 per cent of fruits in a banana hand showed more than 50 per cent blackening as spots, specks and lesions.

The long shelf life potential is a highly useful attribute, especially in storage, handling and marketing of fruits. Shelf life is a function of several distinct processes in the ripening fruit, and it is not a definable physiological event comparable to the commencement of the climacteric. Its components are the rate at which senescent spotting develops, the rate of softening of pulp and peel with respect to their susceptibility to bruising, the rate of weakening of the fruit pedicel which ultimately gives rise to 'finger drop' and the rate of development of fungal disorders which are normally controllable by treatment with fungicide soon after harvesting (Marriott, 1980).

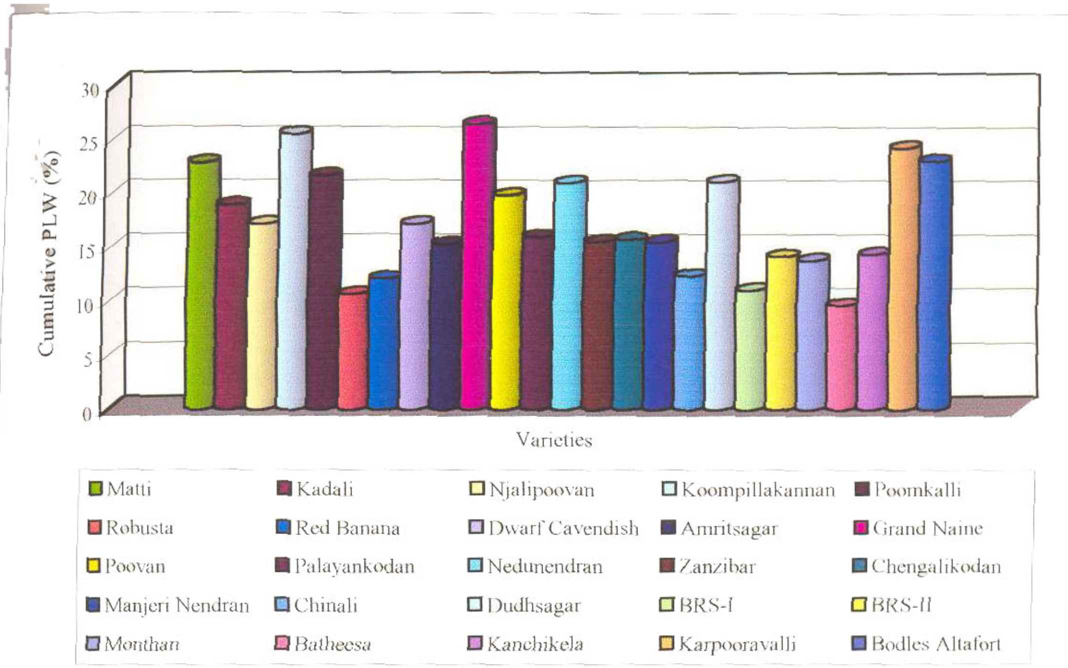


Fig. 22. Cumulative PLW of selected banana varieties

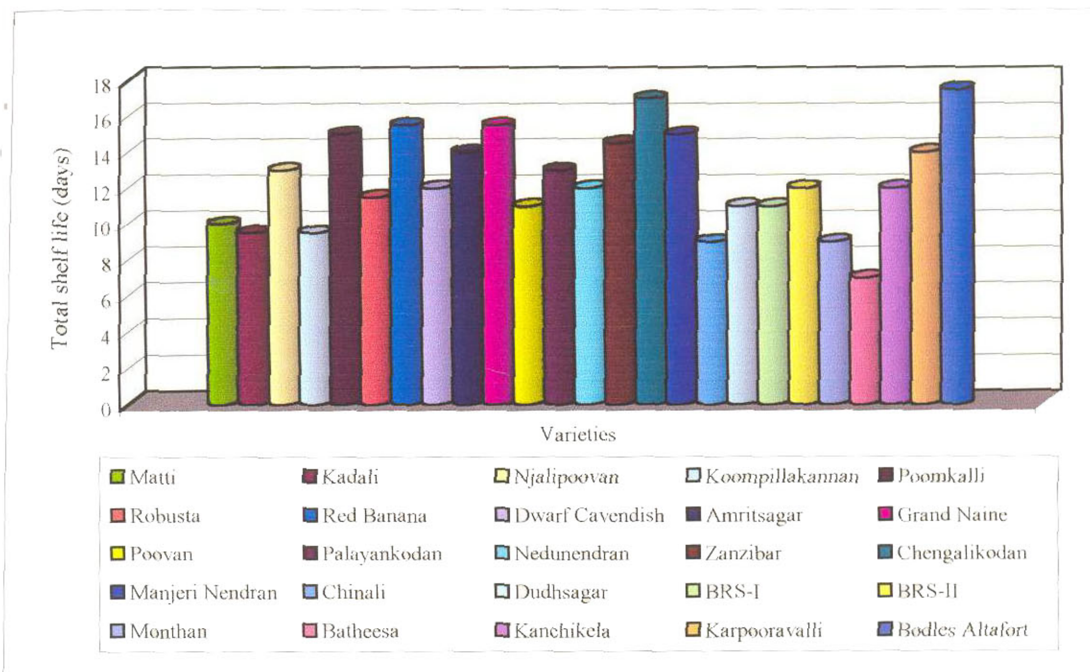


Fig. 23. Total shelf life of selected banana varieties

Maximum shelf life was observed in the varieties Bodles Altafort (17.5 days) and Chengalikodan (17 days) in the present study and minimum in Chinali (9.0 days) among the table varieties (Fig. 23). Other varieties with longer shelf life were Red Banana, Grand Naine (15.5 days), Manjeri Nendran, Poomkalli (15.0 days), Zanzibar (14.5 days), Amritsagar and Karpooravalli (14.0 days). Among the culinary varieties the shortest shelf life was for Batheesa (7.0 days).

In Robusta banana a shelf life of 17.83 days was reported by Rao and Rao (1979) as against 11.5 days in the present study. Shivashankar (1999) reported that the shelf life of the various accessions varied from 2 to 10 days.

5.1.4.3 Finger retention

Maximum days upto which fingers were retained on the hand without dehiscence was considered for finger retention. Fruits of varieties Koompillakannan, Robusta, Dwarf Cavendish, Amritsagar, Poovan (Rasthali), Palayankodan and BRS-I showed dehiscence. In Koompillakannan onset of dehiscence was observed on 7th day of storage, in BRS-I on 9th day, in Robusta and Poovan on the 10th day of storage.

The fingers were intact on the hands upto the last day of storage in varieties Njalipoovan, Poomkalli, Red Banana, Karpooravalli, Bodles Altafort and Nendran clones Nedunendran, Zanzibar, Chengalikodan and Manjeri Nendran. Finger retention is a desirable attribute as it helps in better marketing and transportation and have better acceptability by the consumers.

Finger drop occurs after ripening due to excessive weakening of the fruit pedicel due to formation of abscission layer as senescence advances. Susceptibility to finger drop also varies between cultivars and there are indications that high clonal contribution to preclimacteric period is correlated with increased resistance to finger drop (Marriott, 1980).

5.1.4.4 Spoilage

The following pathogens were found in the spoiled fruits on microscopic examination. *Colletotrichum musae, Botrydiplodia theobromae* and *Rhizopus* species.

Colletotrichum musae causes crown rot and anthracnose (Stover, 1972; Stover and Simmonds, 1987). Anthracnose is a latent infection that occurs while the bunch is developing in the plantation, while the crown rot organisms enter after harvest, usually as a result of mechanical injury to the fruit (Simmonds, 1966). *Botrydiplodia* causes stalk and fruit rot in banana (Stover and Simmonds, 1987). In most cases, the incidence of postharvest spoilage in banana is due to microbial infection. This might be either due to latent field infection or infection at postharvest stages.

5.1.5 Organoleptic evaluation

Sensory evaluation is an important test of fruit quality.

Appearance is probably the most important quality factor determining the market value of produce, as people 'buy with their eyes'. A rapid, visual assessment can be made on the criteria of size, shape, colour, condition and the presence of defects on blemishes (Wills *et al.*, 1989). The highest score for appearance was recorded by the varieties Njalipoovan and Dwarf Cavendish.

Good banana flavour and sweetness were the main characters found in acceptable varieties. A positive correlation between sweetness and soluble solids and between texture and alcohol insoluble solids has been reported by Marriott (1980). In bananas, flavour is due to amylesters and the fruitness is attributable to butylesters (Turner, 1997). The flavour components cause combinations of the sensations of taste and smell. In the present study varieties Kadali, Koompillakannan and Dwarf Cavendish registered maximum values for sweetness and Kadali and Koompillakannan registered top scores for taste. Kadali registered the maximum values for flavour followed by Robusta and Dwarf Cavendish.

Higher scores with respect to overall acceptability was recorded by the varieties Kadali, Matti, Robusta, Red Banana, Dwarf Cavendish, Amritsagar, Grand Naine, Poovan and Zanzibar in the present study.

5.2 PHYSICAL, CHEMICAL AND PHYSIOLOGICAL CHANGES DURING POSTHARVEST PERIOD IN BANANA

The three stages in the postharvest life of banana are preclimacteric or green life, the ripening phase and a senescent phase during which metabolism slows and the quality of the fruit declines. These developmental changes take place during the postharvest journey from plantation to consumer (John and Marchal, 1995).

5.2.1 Physical changes

During ripening the pulp percentage showed an increasing trend whereas the peel percentage showed a decreasing trend from unripe green stage to senescence (Fig. 24 and 25). Pulp/peel ratio also increased in the various stages in the present study (Fig. 26). Highest pulp percentage and pulp/peel ratio was observed in the variety Njalipoovan in the senescent stage. The percentage difference in pulp weight, peel weight and pulp/peel ratio between the green stage and senescent stage was found to be highest in BRS-I in the present study.

The most abundant constituent of banana fruit is water. The peel of green bananas has 90 per cent water and that of unripe plantains slightly less (86%). As the fruit ripens water is lost from the peel because of a three fold increase in evaporation rate, and water is believed to flow from the peel to the pulp in response to changes in the osmotic potential of each. The water movement from the peel to the pulp during ripening is supported by the change in the pulp:peel ratio which increases as the fruit ripens (Simmonds, 1966, John and Marchal, 1995).

The rise in pulp-peel ratio is related to change in sugar concentrations in the two tissues. Sugar increases more rapidly in the pulp than in the skin and this difference is reflected in a differential change in osmotic pressure. The consequence is that water is withdrawn from the skin by the pulp and the pulp:peel weight ratio changes accordingly. The osmotic pressure of all parts of the unripe banana bunch is sensibly constant and that ripening is accompanied by the establishment of osmotic gradients tending to cause the movement of water from stem to fruit and within the fruit, from skin to pulp (Simmonds, 1966).

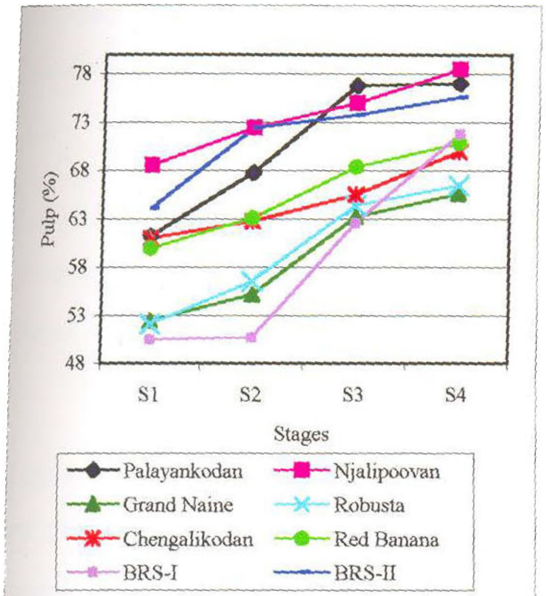


Fig. 24. Pulp per cent during ripening of banana varieties

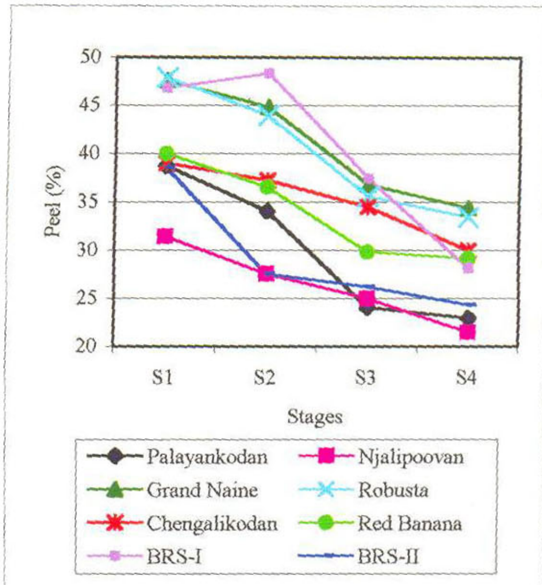


Fig. 25. Peel per cent during ripening of banana varieties

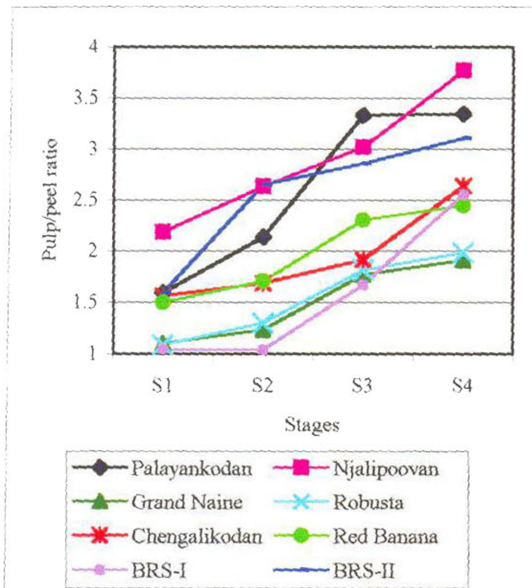


Fig. 26. Pulp/peel ratio during ripening of banana varieties

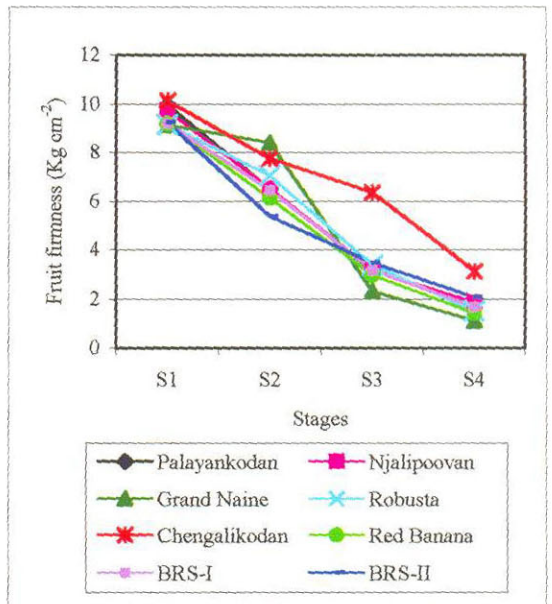


Fig. 27. Fruit firmness during ripening of banana varieties

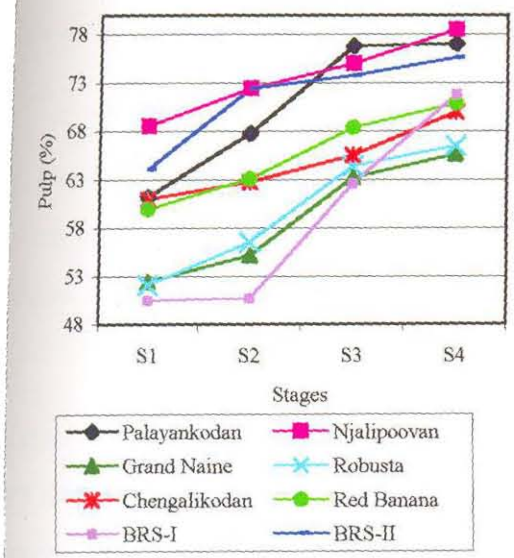


Fig. 24. Pulp per cent during ripening of banana varieties

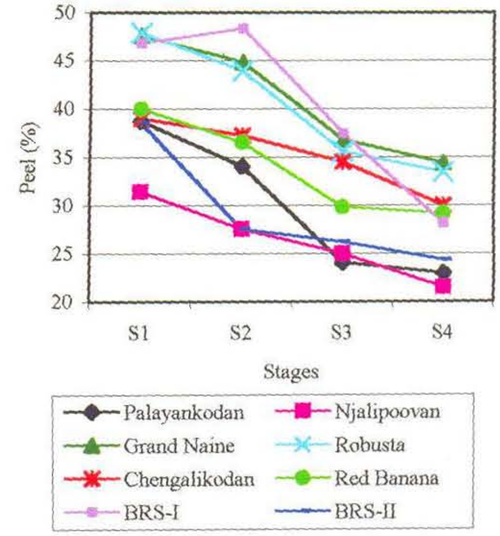


Fig. 25. Peel per cent during ripening of banana varieties

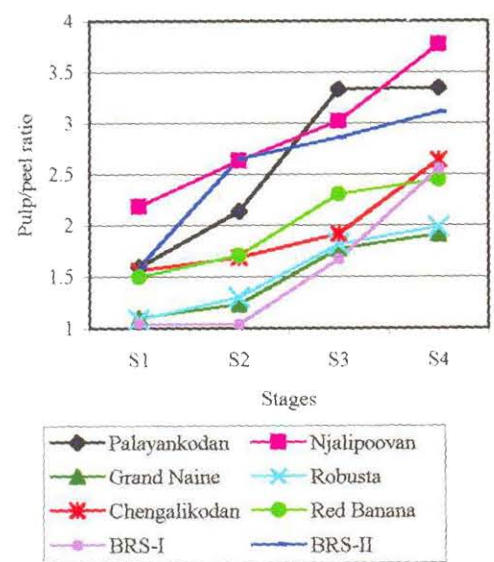


Fig. 26. Pulp/peel ratio during ripening of banana varieties

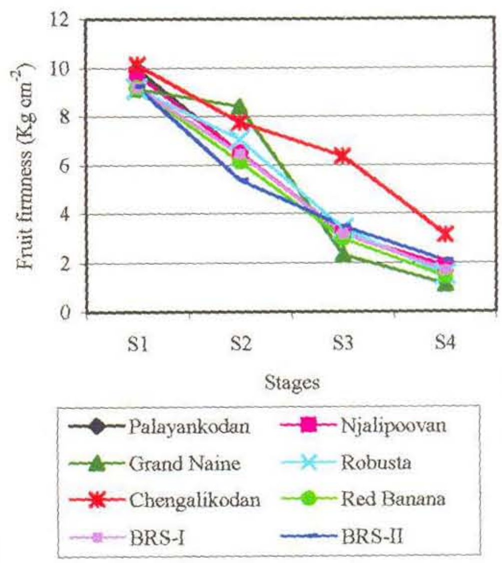


Fig. 27. Fruit firmness during ripening of banana varieties

According to Palmer (1971), the ratio of pulp to peel was related to accumulation of moisture in the pulp which was derived from carbohydrate breakdown and the osmotic transfer of water from peel to pulp.

The firmness of the fruit decreased with ripening in all the varieties (Fig. 27). Maximum value for firmness was recorded by Chengalikodan in green and senescent stage. The percentage difference in fruit firmness between the green and senescent stage was most significant in Grand Naine.

Softening in fruits appears to be closely linked with changes in their cell wall structure. In bananas, the changes in texture of the fruit during ripening probably result from alterations in both cell wall structure and the degradation of starch (Seymour, 1993).

According to Leopold (1964) the decrease in firmness during storage of fruits was due to the changes in the nature of pectic substances cementing the cell wall and hydrolysis of starch, hemicellulose and cellulose during ripening of fruit.

Wasker and Roy (1992) opined that flesh softening of banana after harvest was related to the production of compounds in alcohol i.e., cellulose, hemicellulose and pectin. Desai and Deshpande (1975) also reported that the firmness of banana fruits decreased progressively during ripening and this decrease was attributed to the concomitant decrease in their starch content, cellulose and hemicellulose and increase in soluble pectin.

5.2.2 Chemical changes

5.2.2.1 TSS, total, reducing, non reducing sugars and starch

The most striking chemical change which occur during the postharvest ripening of banana is the hydrolysis of starch and accumulation of sugars (Loesecke, 1950). About 20 to 25 per cent of the pulp of the fresh green fruit is starch. From initiation to completion of ripening, the starch is almost completely hydrolysed, only 1 to 2 per cent remaining in the fully ripe fruit. Sugars normally 1 to 2 per cent in the pulp of green fruit increases to 15 to 20 per cent in the ripe pulp (Wasker and Roy, 1992). Desai and Deshpande (1975) also reported that the sugars increased during ripening.

In the present study TSS, total sugars, reducing sugars and non-reducing sugars increased as ripening advanced and starch content decreased (Fig. 28, 29 and 30). This corroborates with findings of Simmonds (1966), Marriott (1980) and Seymour (1993).

During ripening the starch is degraded rapidly and the sugars, sucrose, glucose and fructose accumulate; traces of maltose may also be present (Palmer, 1971). In the banana pulp sucrose is the predominant sugar, at the start of ripening, and its formation precedes the accumulation of glucose and fructose (Areas and Lajolo, 1981; Marriott *et al.*, 1981; Hubbard *et al.*, 1990).

The percentage difference in TSS, total and reducing sugars and starch between the green and full ripe stage was found to be higher in Palayankodan, BRS-1 and Grand Naine respectively. The percentage difference for starch was higher in the variety Grand Naine.

5.2.2.2 Acidity

In the present investigation acid content of the fruit increased in the initial stage of ripening and on full ripening the acidity decreased in the various varieties (Fig. 31). The percentage increase in acidity between the green stage and colour break stage was higher in the variety Njalipoovan followed by BRS-II. During the full ripe stage the acid content decreased in all the varieties. Loesecke (1950) reported that the acidity of the pulp rises to a maximum at or soon after the climacteric and then usually shows a slight fall as ripening progresses. Wyman and Palmer (1963) reported that oxalic acid exceeded malic and citric in the green fruit but declined at ripening so that malic became the principal component. They also found traces of glyceric, glycolic, succinic and keto-acids. Hulme (1958) recorded the presence of quinic and shikinic acids. Turner also reported that malic, citric and oxalic acids are the main acids of

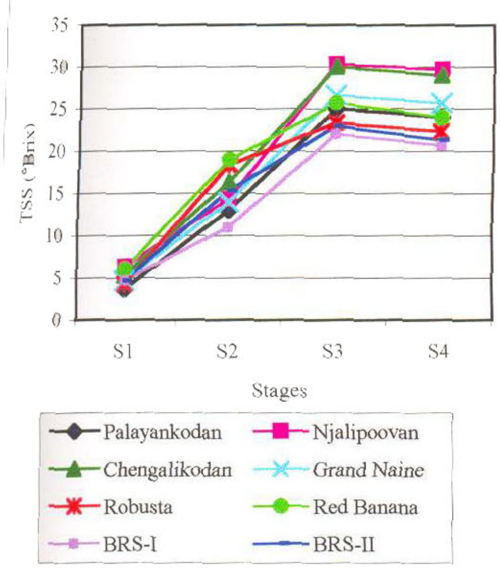


Fig. 28. TSS during ripening of banana varieties

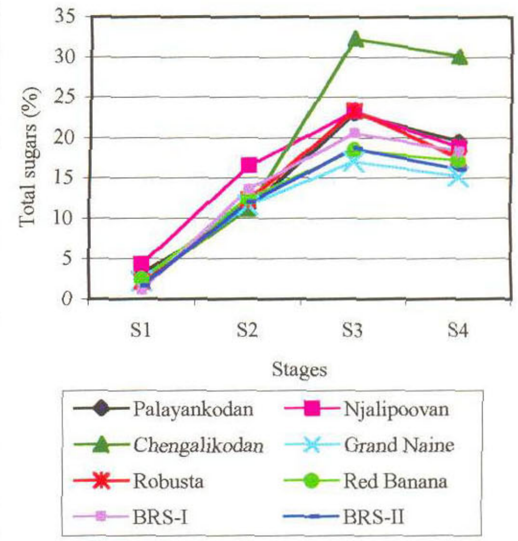


Fig. 29. Total sugars during ripening of banana varieties

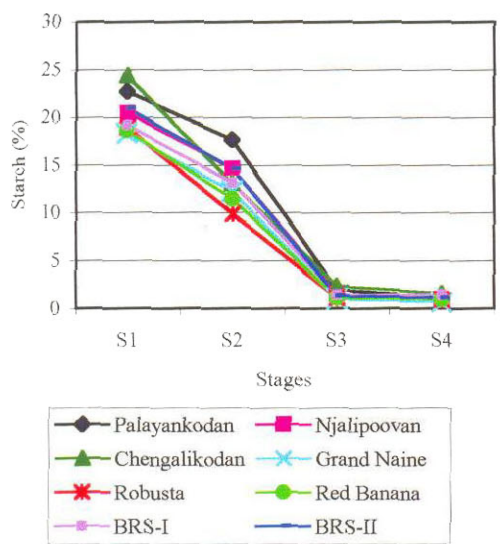


Fig. 30. Starch content during ripening of banana varieties

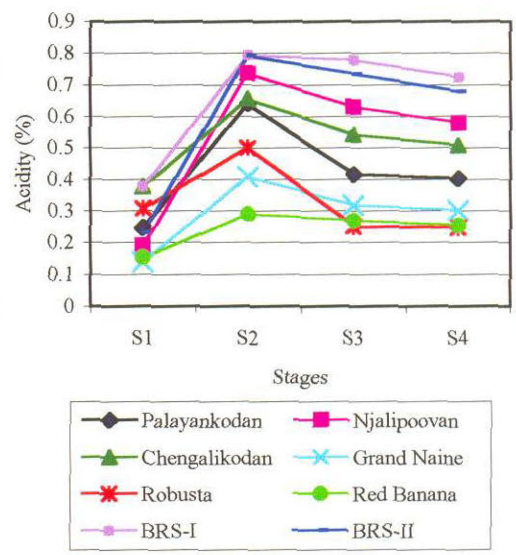


Fig. 31. Acidity during ripening of banana varieties

ripening bananas. Ripening doubles, in some cases trebles, fruit acidity in certain cultivars containing A and B genomes. In the present study the acidity was trebled in the varieties Njalipoovan and BRS-II whereas in Palayankodan, Chengalikodan, Grand Naine, Robusta, Red Banana and BRS-I it was doubled.

According to Shimokawa *et al.* (1972) the pulp shows an increase in acidity during ripening and the astringent taste of unripe bananas is probably attributable at least partly to their oxalic acid content, which undergoes significant decarboxylation during ripening probably by the action of oxalate oxidase.

Despite the increase in acid with ripening the increase in sugar is greater and the sugar:acid ratio, which is an important component of flavour increases.

5.2.2.3 Moisture

In the present investigation moisture content increased on ripening. The moisture content varied from 44.82 per cent in green unripe fruit to 79.73 per cent in over ripe fruit. Water is the most abundant constituent in the pulp and peel of banana and the pulp of banana has a higher water content than that of plantain. Water percentage increases in the pulp during ripening due to respiratory break down of starch and osmotic movement of water from peel to pulp (Robinson, 1996). Water is also lost from the peel externally due to transpiration, until ripening processes degrade the peel tissue preventing further water loss. In a fully ripe banana, water occupies about 75 per cent of the pulp mass and for a plantain it is about 66 per cent.

The percentage increase in moisture content from green stage to senescent stage was higher in Grand Naine followed by Robusta and lowest in Palayankodan.

According to Simmonds (1966), the trend of water content in the banana pulp at ripening was a net result of at least four processes, where two of them *viz.*, transpiration and starch hydrolysis caused decrease in water content whereas other two *viz.*, osmotic withdrawal of water from skin and stem and the production of water by respiration caused increase in it. The latter processes predominated and the net result was a slight increase in moisture content of ripe fruit to the fully ripe stage.

Sen *et al.* (1982) reported that the moisture content in banana pulp increased during ripening whereas it decreased in the peel tissues. Wills *et al.* (1989) also reported a steady increase in moisture during ripening of 'Cavendish' banana fruits from about 72 to 76 per cent due to its accumulation as an end product of respiration and also due to the movement of water from peel to pulp.

5.2.2.4 Tannin

Tannins are water soluble phenolics found in the peel and pulp of bananas. In partially ripened fruit they impart an astringent taste. The pulp of green banana fruit is markedly astringent but this astringency is reduced during ripening.

The tannin content showed a decreasing trend on ripening in different varieties in the present study (Fig. 32). Higher tannin content was observed in the variety Chengalikodan in the green stage and over ripe stage. The percentage decrease in tannin content was highest in Grand Naine and Robusta and lowest in Chengalikodan.

Barnell and Barnell (1945) observed that banana pulp tannins decreased in the ripe fruit to about one-fifth of their value in the green, preclimacteric fruit. The peel contains three to five times more active tannins than the pulp; these were also sharply reduced during ripening. The decrease correlated well with the observed loss of astringency. Chang and Hwang (1990a) also reported that tannin concentration decreased on ripening.

The loss of astringency of banana during ripening may result from increased polymerization of tannins (Palmer, 1971; Haslam, 1981; Turner, 1997). The ability of tannins to bind proteins has long been recognized as a major problem to be overcome when extracting active enzymes from banana tissue (Young, 1965).

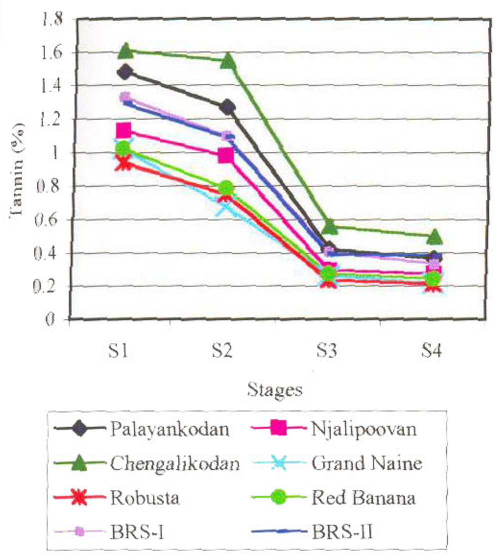


Fig. 32. Tannin content during ripening of banana varieties

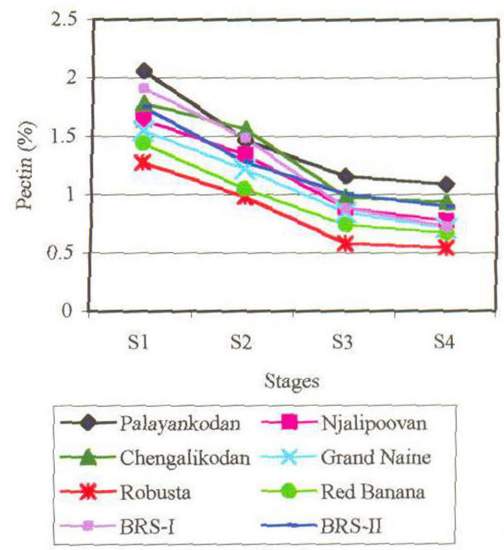


Fig. 33. Pectin content during ripening of banana varieties

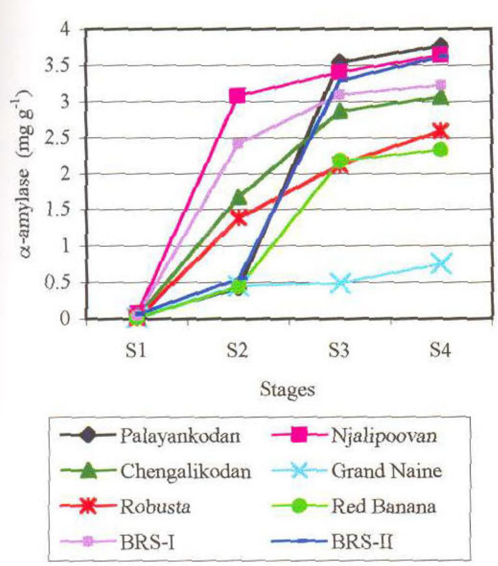


Fig. 34. α-amylase activity during ripening of banana varieties

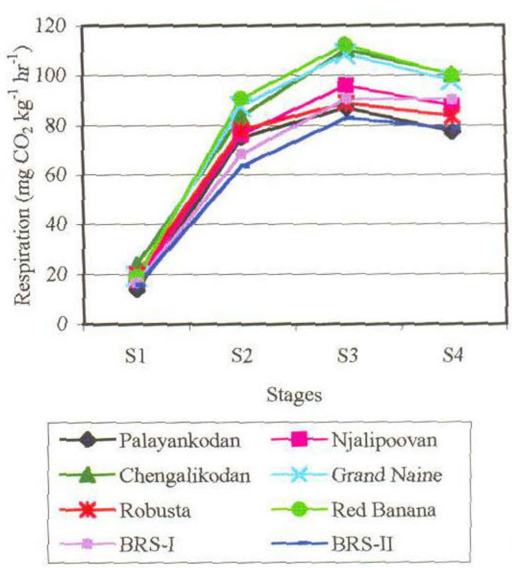


Fig. 35. Respiration rate during ripening of banana varieties

5.2.2.5 *Pectin*

The pectin content of fruit decreased with the advance of ripening in the various varieties (Fig. 33). In the unripe green fruit Palayankodan registered the highest value. The lowest value for pectin was recorded by Robusta in the over ripe stage in the present study. The percentage decrease in pectin content from green to senescent stage was highest in the variety BRS-I and lowest in Chengalikodan. This may account for the high degree of firmness observed in fruits of Chengalikodan and other Nendran clones at ripe stage.

Robinson (1996) reported that ripe pulp contains 0.5 to 0.7 per cent pectin. As ripening progresses, the water soluble pectins increase and the insoluble pectins decrease which is associated with pulp softening. These changes are catalysed by pectin methyl esterase whose activity remains constant during ripening.

5.2.2.6 *Chlorophyll*

The change in the colour of the banana peel from green to yellow is the most obvious change which occurs during postharvest life of a fruit. Yellowing begin at or shortly after the climacteric peak and the fruit becomes full yellow within three to seven days at normal ripening temperatures. During ripening, the peel colour changes from dark green to bright yellow and this is due to the destruction of chlorophyll which process gradually unmasks the carotenoid pigments also present in the unripe peel.

In the present study also the chlorophyll content decreased as ripening progressed and on full ripening it reached almost zero. Chengalikodan registered highest total chlorophyll content at the green stage. At senescence stage the chlorophyll content decreased and in Robusta it was 0.032 mg g^{-1} followed by Grand Naine 0.027 mg g^{-1}. The percentage decrease in total chlorophyll content was highest in Njalipoovan. The reduction in chlorophyll was the lowest in Robusta which justifies the retention of green colour even at the ripening stage.

Wasker and Roy (1992) reported that green banana peel contains about 50 to 100 μg g^{-1} chlorophyll and during ripening all the chlorophyll is lost. The reduction in chlorophyll during ripening may be due to action of enzyme chlorophyllase, the activity of which was found to increase sharply at the onset of climacteric.

Biale (1960) obtained a close inverse correlation between sugar formation and chlorophyll content and detected no chlorophyll in the fully ripe bananas. Decrease in chlorophyll content with ripening was also reported by Simmonds (1966), Desai and Deshpande (1975), Patil and Magan (1976), Marriott (1980), Seymour (1993) and Turner, 1997).

5.2.3 Physiological changes

5.2.3.1 Enzyme activity

Enzymes for both hydrolytic and phosphorolytic breakdown of starch in bananas include α-amylase, β-amylase and α--1-6-glucosidase.

The activity of enzymes α-amylase, β-amylase and invertase were found to increase on ripening in the various varieties studied. In the green unripe stage the values for α-amylase ranged between 0.015 mg g^{-1} (Red banana) to 0.084 mg g^{-1} (Njalipoovan). In the senescence stage it varied from 0.756 mg g^{-1} (Grand Naine) to 3.763 mg g^{-1} (Palayankodan) (Fig. 34).

β-amylase ranged between 0.019 mg g^{-1} (Njalipoovan and Chengalikodan) and 0.052 mg g^{-1} (BRS II) in the green unripe stage and in senescence stage 0.373 mg g^{-1} (BRS I) to 1.69 mg g^{-1} (Chengalikodan). The values for invertase varied between 0.042 mg g^{-1} (BRS I) to 0.254 mg g^{-1} (Palayankodan) in the green stage and in senescence stage 0.266 mg g^{-1} (BRS II) to 0.947 mg g^{-1} (Chengalikodan).

The activity of α-amylase and β-amylase has been reported to increase in ripening bananas (Young *et al.*, 1974; Mao and Kinsella, 1981; Garcia and Lajolo, 1988).

Seymour (1993) reported that hexose sugars arise from sucrose hydrolysis by the action of acid invertase in the vacuole. Acid invertase activity increases during ripening. The conversion of starch to sucrose and sucrose turnover creates a very substantial demand for ATP, and sugar accumulation and respired carbondioxide were highly correlated. Sucrose accumulation may contribute to the respiratory climacteric in banana fruit by creating rapid adenylate turnover (Hubbard *et al.*, 1990).

α and β-amylase and starch phosphorylase are the starch degrading enzymes in banana. The major enzyme activity in banana is associated with α-amylase although the levels of the other two enzymes are not insignificant. All three enzymes increase in activity during ripening to some extent (Tucker and Grierson, 1987). The breakdown of sucrose is mediated by the action of invertase and its activity increased during ripening (Tucker, 1993).

Associated with the carbohydrate changes during banana ripening is the increase in activity of α and β-amylase, invertase and phosphorylase (Young *et al.*, 1974; Chitarra, *et al.*, 1981; Terra *et al.*, 1983).

The findings of the present study on changes in amylase and invertase activity in ripening banana are in agreement with those reported by Palmer (1971) and Nabeesa and Unnikrishnan (1988). Amylase and invertase showed a general increase in activity in stage II with a corresponding decrease in starch and increase in sugars.

Desai and Deshpande (1978) also noticed a significant increase in the activity of α-amylase, decrease in starch and pectin with resultant increase in sugars as the fruits ripened. From the observation it can be presumed that based on the α amylase activity the varieties can be classified into two groups - low and high enzyme activity groups at full ripe stage of fruits (upto activity three is considered as high and below three low) TSS and total sugar content was found to be comparatively high in the high enzyme activity group.

5.2.3.2 Respiration

It was observed that rate of respiration increased with ripening and it increased by about five fold in fully ripe fruits (Fig. 35). The ripening of banana fruits exhibit a climacteric pattern of respiration (Wasker and Roy, 1992). They also reported a steady value of about 20 mg CO_2 kg^{-1} hr^{-1} in the hard, green fruit rises to about 125 mg CO_2 kg^{-1} hr^{-1} at the climacteric peak and then falls to about 100mg CO_2 kg^{-1} hr^{-1} as ripening proceeds. The increase in respiration from preclimacteric to climacteric varied from four to ten folds. Simmonds (1966), Peacock and Blake (1970), Palmer (1971) and Seymour (1993) also observed a similar trend in CO_2 evolution. The respiratory climax is identified by rapid oxygen uptake and CO_2 evolution to a maximum rate and the ripening process is accelerated when the respiratory maximum is attained. Subsequently the respiration rate decreased progressively to reach zero at the physiological death of the fruit (Robinson, 1996).

Simmonds (1966) suggested that the preclimacteric respiration is primarily by way of the pentose cycle and that normal glycolysis (the Embden Meyerhof-Parnas pathway) begins as the climacteric begins, becoming predominant in post climacteric fruit.

5.3 STANDARDISATION OF METHODS TO ENHANCE SHELF LIFE OF BANANA VARIETIES

The postharvest life of banana is very short and it creates problem when marketed in distant places from the production centre and bulk amount of fruit is spoiled. Therefore, suitable measures are necessary to extend the storage life to avoid postharvest loss in banana. The present study was, therefore, conducted with a view to evaluate the effect of different chemicals and packaging materials on storage and quality of banana.

5.3.1 Effect of postharvest treatments on extension of shelf life of banana

The varieties differed significantly in their response to the postharvest treatments to which they were subjected. The impact of different treatments on the postharvest behaviour of the different varieties are discussed below.

5.3.1.1 Palayankodan

Water loss results in loss of saleable weight and eventually the materials becomes unsaleable as a result of wilting.

Minimum physiological loss in weight in Palayankodan fruits was recorded by precooling with tap water followed by precooling with cold water and ice flakes. Precooling technique is mainly recommended for reducing the field heat of the harvested produce. Hydrocooling with tap water was reported to be the best precooling treatment for moisture loss reduction in okra and tomato (Sunilkumar, 1994).

Precooling with ice flakes was also effective in extending the days to reach 50 per cent yellowing and 100 per cent yellowing of the fruits. Precooling with tap water was the next best treatment in extending days to reach ripening. Maximum shelf life in Palayankodan fruits was registered by precooling with ice flakes (17.0 days) followed by precooling with tap water (16.0 days). By the precooling treatments the temperature of the harvested produce was reduced which in turn retarded the metabolic processes and extended the shelf life. Besides treatment with water helps in the removal of microbial load on the surface of the fruits resulting in a lower level of microbial spoilage. Precooling also aids in the deregistration of a number of chemical treatments. There is increased demand for produce that is chemically free or had the minimum amount of treatments. Due to the avoidance of chemicals precooling is an effective, non-damaging, ecofriendly and cheap treatment in extending the shelf life of fresh horticultural products. All the postharvest treatments was found to be better than control in extending shelf life. While the shelf life of control fruits was only 11.0 days, the postharvest treatments *viz.*, vacuum infiltration with 1 per cent $CaCl_2$ (15.5 days), precooling with cold water (14.5 days), $CaCl_2$ dip (14.0 days), hot water treatment (14.0 days), coating the cut ends of the fruit with edible wax (13.5 days), extended the shelf life of fruits (Fig. 36).

5.3.1.2 Njalipoovan

In the case of Njalipoovan minimum physiological loss in weight throughout the storage period was recorded by vacuum infiltration with 1 per cent $CaCl_2$ which was followed by precooling with tap water. Vacuum infiltration with

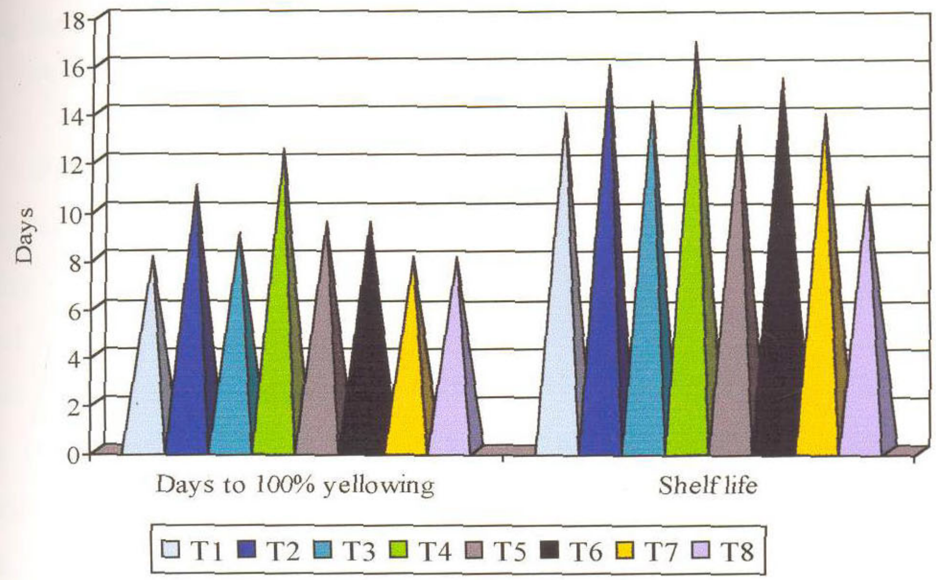


Fig. 36. Influence of postharvest treatments on days to 100% yellowing and shelf life in Palayankodan

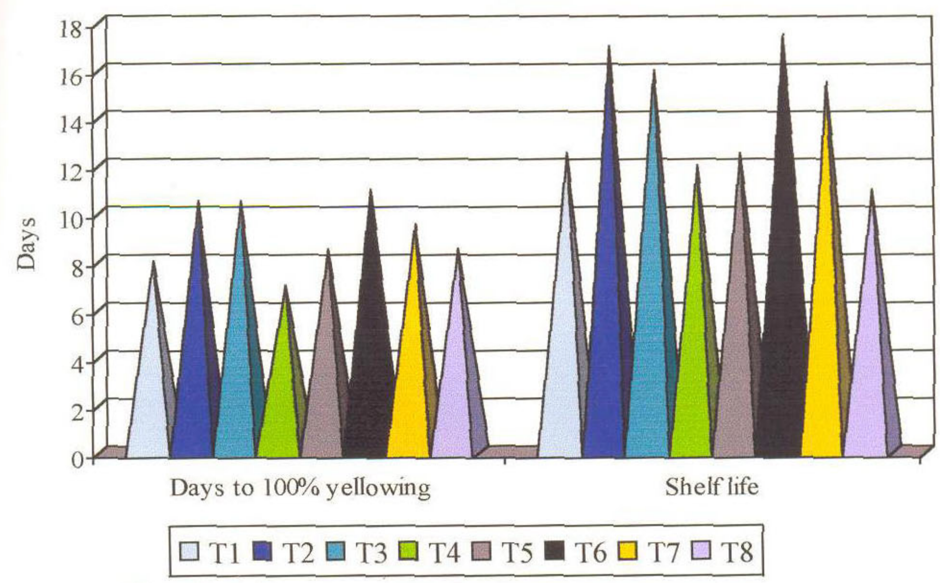


Fig. 37. Influence of postharvest treatments on days to 100% yellowing and shelf life in Njalipoovan

1 per cent $CaCl_2$ was found to be superior to the other postharvest treatments in extending the days to reach 50 per cent yellowing, 100 per cent yellowing and shelf life (Fig. 37).

Precooling with tap water and cold water were the next best treatments in extending the days to reach ripening and shelf life. Longer shelf life was obtained for precooling with tap water (17.0 days), cold water (16.0 days), $CaCl_2$ dip (15.5 days) as compared to control fruits (11.0 days). High calcium fruit stores well due to less metabolic breakdown as explained by Miklos (1980). Yuen (1994) reported that ethylene production and respiration rates were immensely related to the calcium concentration in the flesh of fruits. At higher levels, calcium counteracted the effect of nitrogen and kept the respiration low. Reduction in physiological loss in weight by $CaCl_2$ infiltration may be due to the retardation of respiration and transpiration by calcium salt. Calcium might have thickened the cell wall by bridging with the plasmalemma and prevented the increase of apparent free space in the tissue leading to lesser transpiration. The presence of calcium defers senescence by retaining the integrity of the membrane systems (Poovaiah and Leopold, 1973). By the entry of calcium, it acts at preservation of membrane integrity, better retention of ions due to specificity and selectivity brought about by change in ionic fluxes and again its protective role like overcoming the injurious effects of nascent H^+ ions by change in pH (Rains *et al.*, 1964) should have resulted in the deferral of senescence or increase in shelf life. Similar reduction in PLW by calcium was reported by Dhoot *et al.* (1984) and Singh (1988) in guava, Chukwu *et al.* (1995) in plantain, Evelin (1997), Pathak *et al.* (1999) and Sindhu (1999) in banana.

5.3.1.3 Robusta

Fruits of Robusta recorded minimum physiological loss in weight on precooling with tap water followed by cold water. Hot water treatment was also effective in reducing the physiological loss in weight. Coating the cut ends of fruit with edible wax and precooling with cold water and tap water also extended the days to reach 50 per cent yellowing, 100 per cent yellowing and shelf life (Fig. 38).

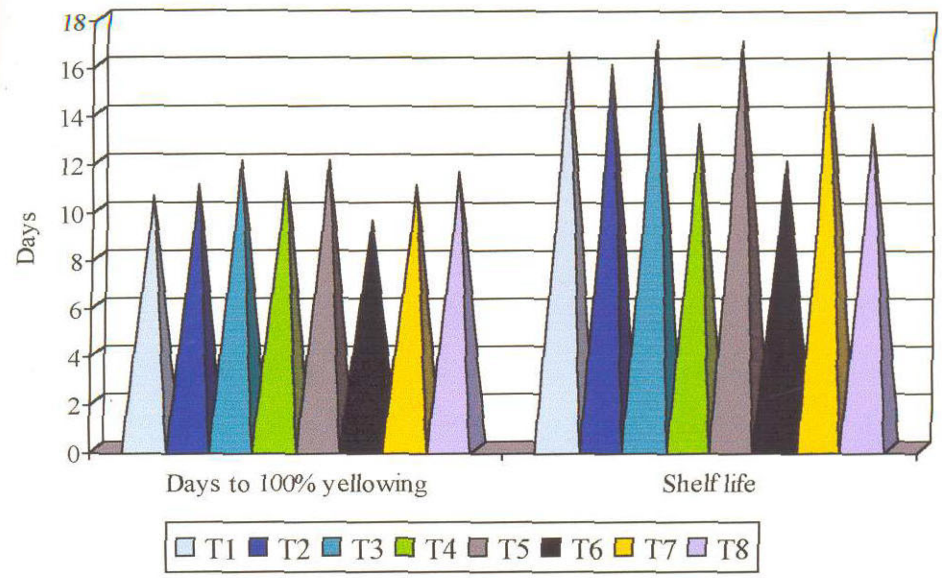


Fig. 38. Influence of postharvest treatments on days to 100% yellowing and shelf life in Robusta

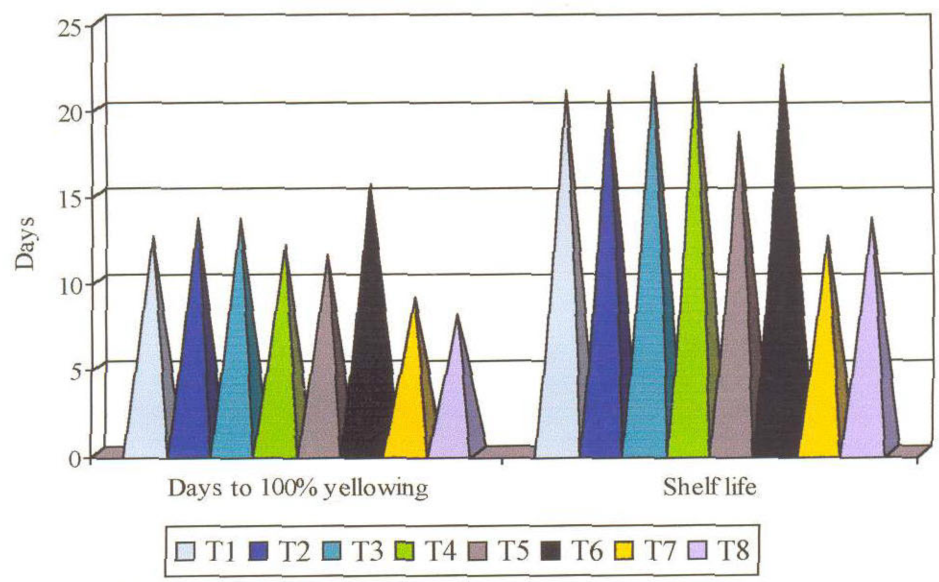


Fig. 39. Influence of postharvest treatments on days to 100% yellowing and shelf life in Chengalikodan

Maximum shelf life was attained by coating the cut ends with edible wax and precooling with cold water (17.0 days). Precooling reduced the field heat thereby reducing the physiological processes like transpiration and respiration. This resulted in reduced loss in weight during storage in fruits precooled with tap water and cold water. The reduction in loss in weight by precooling was also reported by Rodriguez *et al.* (1995).

Beneficial effects of skin coating in delaying ripening was reported by Yehoshua (1966), Dalal *et al.* (1969), Bhardwaj *et al.* (1984), Krishnaiah *et al.* (1985), Desai *et al.* (1989), Das and Medhi (1996) and James and Gregor (2000). Coating bananas with wax emulsion decreased gaseous exchange between the fruit and the outside atmosphere, thus modifying the atmosphere within the fruit without impeding the ripening process. By hot water treatment the shelf life in Robusta was extended to 16.5 days whereas the control fruits had a shelf life of 13.5 days only. Beneficial effect of hot water treatment of banana on shelf life has been reported by Armstrong (1982), Frith and Chalker (1983) and Dominguez *et al.* (1998) in banana. Hot water dips are generally used for fungal pathogen control as fungal spores and latent infections are either on the surface or in the first few cell layers under the peel of the fruit or vegetable. Heat treatment delay the breakdown and disappearance of preformed antifungal compounds that are present in unripe fruits. By hot water dips crown rot of banana was effectively controlled (Cabrera *et al.*, 1998; Reyes *et al.*, 1998). Hot water dips have also been tested for their efficiency in disinfesting insects. In bananas fruit flies were controlled by hot water treatment (Armstrong, 1982). The delay in ripening by hot water dips may have been the result of temporary cessation of the normal ripening system physiology (especially respiration and ethylene production) caused by the heat itself (Armstrong, 1982).

5.3.1.4 Chengalikodan

In the case of Chengalikodan minimum physiological loss in weight was observed in fruits precooled with cold water, followed by hydrocooling with tap water and vacuum infiltration with 1 per cent $CaCl_2$. Vacuum infiltration with 1 per cent $CaCl_2$ was effective in extending the days to attain 50 per cent yellowing, 100 per cent yellowing and shelf life (22.5 days) (Fig. 39). Calcium has been successfully used to extend storage life in many fruits by retarding ripening (Ferguson, 1984). Calcium maintains membrane integrity and influences cellular organisation and thereby controls respiration (Faust and Shear, 1972). The action of calcium in inhibiting ripening might be due to its effect on some specific key action systems leading to reduction in the enzymatic activity and ethylene evolution. There is a strong evidence that the solubilisation of cell wall fragments such as galactose and galacturonic acid induces ethylene production (Kim *et al.*, 1987). The binding action of calcium in the cell wall may suppress ethylene production and retard ripening as exemplified by lower rate of colour change, softening and carbondioxide production (Conway, 1987).

Preccoling with cold water, tap water and hot water treatment was also effective in extending the shelf life in the variety Chengalikodan.

5.3.1.5 Changes in chemical composition

The chemical composition at the ripe stage of fruits subjected to different postharvest treatments varied significantly with varieties and treatments. Precooling treatments in general improved the TSS, total sugars in Palayankodan, Njalipoovan, Robusta and Chengalikodan. Precooling results in a lowering of surface temperature and consequently a reduction in the rate of respiration. Sugars are the main substrates for respiration and hence precooling treatments had higher content of sugars and TSS compared to control fruits with higher respiration rate.

5.3.1.6 Organoleptic evaluation of fruits

From the consumer's point of view, organoleptic evaluation of fruits is very important which determines the marketability of fruits. Precooling treatments improved the sensory qualities of fruits of Palayankodan, Robusta and Chengalikodan. Vacuum infiltration with 1 per cent $CaCl_2$ resulted in maximum scores for organoleptic qualities in Njalipoovan. Calcium is effective in protecting cellular organization, preventing cell wall degradation and improving the textural quality of fruits, which would have accounted for the better appearance of fruits.

5.3.2 Effect of packaging on shelf life of banana varieties

Modified atmosphere packaging is intended to create an appropriate gaseous atmosphere around a commodity by use of selectively permeable polymeric films, to enhance shelf life and to conserve the quality of the packaged produce. MAP is known to extend the shelf life of fresh produce by retarding the physiological metabolism leading to senescence by the increased CO_2 and decreased O_2 concentration in the storage atmosphere, slowing down the rate of ethylene biosynthesis and its action subsequently helping in decreasing microbial contamination and by creating high humidity resulting in less moisture loss and better quality retention.

In Palayankodan, Njalipoovan and Chengalikodan minimum physiological loss in weight was observed for vacuum packed fruits. This was followed by fruits packed in polythene cover without ventilation and polythene cover sealed with ethylene absorbant. The control fruits recorded the maximum physiological weight loss. The higher physiological loss in weight in unpacked fruits may be due to high transpirational losses from the fruit surface (Bhullar *et al.*, 1981) while vacuum packed fruits and fruits in polythene cover with and without ethylene absorbant had lower rate of transpiration hence less moisture loss. The minimum PLW of vacuum packed fruits may also be due to slowing down of enzymatic and respiratory activity and thereby reduced water loss. The minimum PLW in vacuum packed fruits can be corroborated by the findings of Hardenburg (1971). Adsul and Tandon (1983), Nair *et al.* (1996), Rajeev and Sreenarayanan (1998) and Emerald and Sreenarayanan (1999). Throughout the study minimum PLW was observed in fruits packed in unventilated polythene cover with and without ethylene absorbant. The polyethylene acted as a controlled condition and it reduced weight loss and extended the shelf life. The low PLW is due to the high humidity created within the packages by the respiring fruits and low water vapour transmission rate of the packaging material used. These results are in conformity with the observation of various workers (Scott *et al.*, 1971; Scott and Gandanegara (1974), Scott (1975), Desai *et al.*, 1984; Carvalho *et al.* (1988b), Rao and Chundawat (1991), Nair *et al.*, 1992; Sarkar *et al.*, 1994; Rahman *et al.*, 1995; Sarkar *et al.*, 1997; Gouthami, 2001; Mustaffa *et al.*, 2002a, 2002b).

Tan *et al.* (1990) opined that modified atmosphere storage conditions created by the respiration of fruits in polyethylene bags prolonged the preclimacteric life of fruits. The physiological loss in weight increased from the inception of storage. Significant differences between packed and unpacked banana with respect to PLW were observed during storage. Nair *et al.* (1992) reported that bananas when stored in a hermetically sealed, tight polyethylene bag, the atmosphere around the fruit rapidly becomes modified and drops to 10 per cent oxygen within an hour after vacuum packaging of the fruit.

The slow colour development in polyethylene and ethylene absorbant + polyethylene was indicative of reduced rate of metabolic changes within the fruit or it may be attributed to higher accumulation of CO_2 concentration and depletion of O_2 level around the fruit (Kader *et al.*, 1989). Sisler and Wood (1988) opined that higher CO_2 accumulation counteract ethylene action and colour development. The gradual colour development may be attributed to the fact that CO_2 accumulation was not too high to restrict colour development. Similar result was also reported by Keditsu *et al.* (2003) in Mandarin.

In all the three varieties maximum days to reach 50 per cent yellowing, 100 per cent yellowing and shelf life was recorded by vacuum packed followed by polyethylene with and without ethylene absorbent packed fruits (Fig. 40, 41 and 42). Jayaraman and Raju (1992) also observed that using permanganate based ethylene scrubber extended the shelf life of banana fruits. The studies of Satyan *et al.* (1992), Lin and Zang (1993), Mohammed and Campbell (1993), Ming *et al.* (1997), Xin *et al.* (1998) and Shanmugasundaram *et al.* (2002) also supported the present findings.

Use of ethylene absorbent inside the modified atmosphere packs resulted in an additive effect along with modified atmosphere in prolonging the green life by keeping the ethylene levels low inside the sealed packs. $KMnO_4$ has been reported to oxidize ethylene to ethylene glycol, thus partly delaying the ripening process (Mahajan and Chopra, 1994).

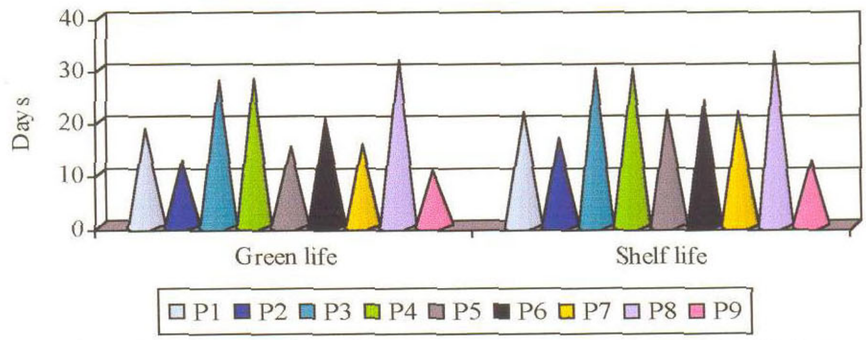


Fig. 40. Effect of packaging on green life and shelf life of Palayankodan

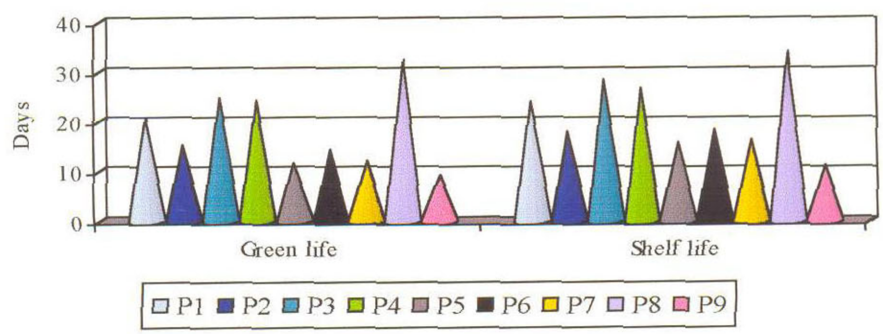


Fig. 41. Effect of packaging on green life and shelf life of Njalipoovan

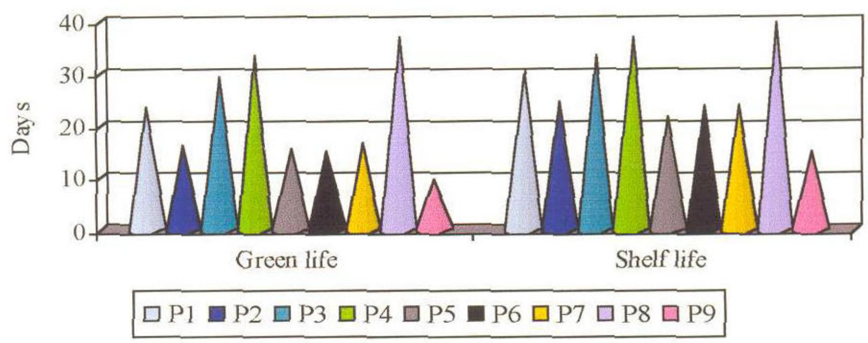


Fig. 42. Effect of packaging on green life and shelf life of Chengalikodan

Extension of storage life through vacuum packing was reported by Nair *et al.* (1992), Rajeev (1996), Gouthami (2001). This was due to the modified atmosphere developed inside the sealed polyethylene bag. Low levels of O_2 and increased CO_2 concentration might have caused reduction in respiration rate leading to low rates of most metabolic activities and thereby prolonging the green life. Decrease in oxygen concentration also could have suppressed ethylene synthesis as conversion of ACC to ethylene is an oxidative reaction. Vacuum packing slowed down the metabolic activity by limiting the oxygen supply and applying an elevated level of carbondioxide (Gorris and Peppelenbos, 1992).

High PLW in corrugated fibre board packing may be due to high rate of transpiration through uninterrupted atmospheric column and low humidity in the storage environment. Reduced green life in CFB packing could be due to early onset of climacteric resulting in high respiration and ethylene production.

In all the three varieties *viz.*, Palayankodan, Njalipoovan and Chengalikodan included in the study maximum storage life after full ripening was observed in fruits packed in corrugated fibre board boxes, CFB box + polyethylene lining + ethylene absorbent and ventilated polyethylene cover. In vacuum pack and unventilated polyethylene cover with and without ethylene absorbent the yellow life was minimum. The prolonged storage life in CFB boxes might be due to reduced incidence of spoilage in less humidified atmosphere. The vacuum packed fruits recorded less shelf life due to the spoilage by fungal growth induced by high humid condition in the package. Rotting of the fruits packed in polyethylene bag with and without $KMnO_4$ due to high CO_2 concentration was reported by Aravindakshan (1981). Rotting of banana in sealed polyethylene bag was also reported by Scott *et al.* (1971). Use of modern packaging materials such as plastic film bags, paper board boxes lined with polyethylene can help upgrade the value of produce, cost effective distribution, minimise product losses and enhance product quality so as to generate confidence among the buyers. The use of corrugated fibre board (CFB) cartons for storage instead of wooden boxes is being seriously considered in view of the adverse effects of deforestation on ecological balance. These boxes are lighter in weight, more convenient to handle, cheaper to transport, internationally acceptable and can be recycled as pulp or paper (Maini *et al.*, 1993).

Packing in CFB box would serve the primary function of packaging to protect and to contain the banana fruits safely. CFB box could be conveniently stacked without damage to the fruits in the lower most boxes where as packaging just in a polyethylene bag though serves the purpose of containing and to some extent protect from bruising will not permit stacking, which would be a problem in the transportation and storage of banana.

5.3.2.2 Chemical constituents on ripening

In the present study the total soluble solids, total sugars and reducing sugars in the three varieties Palayankodan, Njalipoovan and Chengalikodan were lower in vacuum packed, unventilated polyethylene cover with and without ethylene absorbent and cling film wrapped fruits, and higher in fruits packed in CFB box, CFB box with polyethylene lining and CFB + polyethylene lining + ethylene absorbent and ventilated polyethylene cover. The rate of increase in TSS was slower in polyethylene bag treatment (Deka, 1990). The lower TSS content of fruit in polyethylene bags may be attributed to reduced rate of metabolic activities (Rao and Krishnamurthy, 1983). A lower sugar content in fruit from polyethylene packaging was in agreement with the findings of Deka (1990) and Keditsu *et al.* (2003).

In Palayankodan acid content was highest in cling film wrapped fruits, in Njalipoovan in CFB + polyethylene lining + ethylene absorbent and in Chengalikodan unventilated polyethylene cover with ethylene absorbent. The higher content of acidity may be due to lesser availability of oxygen to fruit, thus the organic acids, which participate in respiratory processes are not oxidized and hence the level remains high (Josan *et al.*, 1983).

On organoleptic evaluation of fruits higher scores for appearance was obtained for vacuum packed fruits and taste, sweetness and overall acceptability for CFB box packed fruits. In vacuum packed fruits, as the air from the package is fully evacuated before sealing, the gaseous composition of the air would be different from the other packages, which would have affected the changes in the biochemical constituents during ripening.

General conclusion

Postharvest losses in banana, the premier fruit crop of Kerala can be minimized only by systematic and scientific postharvest management. Selection of varieties with longer shelf life, extension of shelf life by means of suitable postharvest treatments and packaging therefore assumes significance. Though our state is blessed with a large number of varieties, information on postharvest attributes is lacking even for varieties recommended for cultivation in Kerala.

The present investigation has generated information on postharvest qualities of important varieties of banana grown in Kerala for table, and culinary purposes. Varieties with better keeping and processing qualities have been identified. The study has proved the supremacy of Nendran clones with respect to postharvest qualities evidenced by high β carotene, Vitamin C, starch, TSS, total sugars and longer shelf life. Varieties Bodles Altafort, Red Banana, Grand Naine, Amritsagar and Karpooravalli also had good keeping quality. Utilization of varieties with desirable processing attributes would ensure a superior quality processed product. The varieties with ideal processing qualities identified in the present study were Palayankodan, Karpooravalli, Njalipoovan, Poomkalli and Poovan with high pectin, sugar, acid and nutritive value. Varieties ideal for table purpose were Kadali, Koompillakannan, Dwarf Cavendish, Robusta, Njalipoovan, Poovan, Red Banana and Amritsagar.

Precooling treatment can be recommended as an effective, eco-friendly and inexpensive method for prolonging shelf life of banana. Vacuum packaging of hands in polyethylene bags was found to be effective in extending shelf life of banana whereas the quality attributes were superior in fruits packaged in CFB boxes.

The response to postharvest treatments and packaging varied with varieties which indicate that these techniques have to be standardized for each variety. There is immense potential for further exploitation of the rich germplasm of banana in Kerala for selecting varieties with better postharvest attributes

Summary

6. SUMMARY

The project entitled "Evaluation of selected banana (*Musa* spp.) varieties grown in Kerala for postharvest attributes" was conducted to evaluate banana varieties for postharvest attributes, to study the physical, chemical and physiological changes during postharvest period and to standardise methods to enhance shelf life of varieties. Cataloguing of twenty five accessions of banana based on fruit characters was also envisaged. The results obtained from the experiments conducted under the project are summarised in this chapter.

1. Twenty five accessions of banana belonging to six genomic groups were catalogued as per IPGRI/INIBAP descriptors based on 21 fruit characters.

2. Maximum value for finger weight was obtained in the variety Zanzibar (262.5 g) and minimum in Matti (36.5 g). Other varieties with higher finger weight were Nedunendran (159.5 g), Chengalikodan (158.5 g), Manjeri Nendran (147 g) and BRS I (148.5 g).

3. Highest value for finger length, volume of finger, pulp weight, peel weight was recorded by Zanzibar and lowest by Matti. Pulp/peel ratio was maximum in Poomkalli (3.15) and minimum in Monthan (0.97). Peel thickness was highest in Monthan (4.13 mm) and lowest in Matti (1.06 mm).

4. Maximum values for TSS was recorded in Zanzibar and Chinali (32.5°brix). Other varieties with higher TSS were Chengalikodan (32°brix), Koompillakannan (31.5°brix), Nedunendran, Manjeri Nendran, Matti and Njalipoovan (30.5°brix). Culinary varieties Batheesa, Monthan and Kanchikela recorded lower TSS.

5. Higher values for acidity was observed in the hybrids BRS I (0.794%) and BRS II (0.743%) and lower in Batheesa (0.192%). Culinary varieties Batheesa (5.695) and Monthan (5.59) recorded higher values for pH and BRS I and BRS II (3.0) lower.

6. Total and reducing sugars were higher in Chengalikodan and lower in Kadali and Poomkalli among the table varieties. The culinary varieties registered minimum values for total, reducing and non reducing sugars.

7. Moisture content varied from 62.16 per cent in Chinali to 85.04 per cent in Kanchikela.

8. Maximum value for vitamin C was registered by the variety Matti (6.45 mg 100 g^{-1}) followed by Chengalikodan (6.1 mg 100 g^{-1}).

9. β-carotene content was highest in the variety Chengalikodan (266.6 μg 100 g^{-1}) followed by Zanzibar (233.22 μg 100 g^{-1}).

10. Culinary varieties Kanchikela, Batheesa and Monthan registered higher tannin content. Tannin content was the least in table variety Kadali.

11. Higher pectin content was observed in culinary varieties and Kanchikela recorded the highest (3.54%). Among the table varieties higher pectin content was observed in Palayankodan and Karpooravalli.

12. Among the table varieties higher starch content was observed in Zanzibar (2.29%).

13. Highest value for PLW was recorded by Grand Naine (26.46%) followed by Koompillakannan (25.54%) at the end of storage period whereas lowest value was recorded by Batheesa (9.63%).

14. Maximum shelf life was recorded by the variety Bodles Altafort (17.5 days) and Chengalikodan (17.0 days) and minimum by the variety Chinali (9 days) under ambient conditions. Red Banana, Grand Naine (15.5 days), Manjeri Nendran, Poomkalli (15 days), Zanzibar (14.5 days), Amritsagar, Karpooravalli (14.0 days) also recorded longer shelf life.

15. Pathological examination of spoiled fruits revealed the presence of microorganisms *Botrydiplodia theobromae, Colletotrichum gloeosporioides* and *Rhizopus* sp.

16. On organoleptic evaluation higher score for appearance was recorded by Njalipoovan and Dwarf Cavendish, for sweetness Kadali, Koompillakannan and Dwarf Cavendish, for taste Kadali and Koompillakannan, and for flavour Kadali, Robusta and Dwarf Cavendish. Higher scores for overall acceptability was obtained for Kadali, Matti, Robusta, Red Banana, Dwarf Cavendish, Amritsagar, Grand Naine, Poovan and Zanzibar.

17. The physical, chemical and physiological changes during ripening were recorded at four stages viz., mature green unripe stage, colour changing, full ripe and over ripe stage. Pulp percentage showed an increasing trend from stage I to stage IV in all the varieties. Percentage of peel decreased in all the varieties over different stages. Pulp/peel ratio showed an increasing trend in all the varieties. Firmness of the fruit decreased as the fruit ripened.

18. Total soluble solids showed an increasing trend in the different varieties. TSS ranged between 3.67°brix (Palayankodan) to 6.33°brix (Njalipoovan) during stage I and from 20.67°brix (BRS I) to 29.67°brix (Njalipoovan) during stage IV.

19. Acidity showed an increasing trend up to stage II and on full ripening decreased in the different varieties. In stage II the values for acidity ranged between 0.29 per cent in Red Banana to 0.793 per cent in BRS I. In stage IV the maximum and minimum values for acidity was recorded in BRS I (0.724%) and Robusta (0.247%) respectively.

20. Total, reducing and non-reducing sugars showed an increasing trend on ripening. Maximum value for total, reducing and non-reducing sugar was recorded by Njalipoovan in stage I (4.37%, 2.5% and 1.84% respectively) and in stage IV by Chengalikodan (30.1%, 23.58% and 6.52% respectively).

21. Increase in moisture content of the fruit was observed on ripening. Moisture content ranged from 44.8 per cent in Grand Naine to 60.99 per cent in Palayankodan in stage I and from 66.2 per cent in Njalipoovan and Chengalikodan to 79.73 per cent in Robusta.

22. Tannin content of the fruit decreased on ripening in the different varieties. Highest values were observed in stage I by Chengalikodan (1.61%) and lowest by Robusta (0.213%).

23. Higher values for pectin was observed in stage I by Palayankodan (20.6%) and lower values in stage IV by Robusta (0.547%).

24. On ripening starch hydrolysed to sugars and starch content decreased. During stage I starch content ranged from 18.32 per cent (Grand Naine) to 24.4 per cent (Chengalikodan) and during stage IV from 0.663 per cent in Grand Naine to 1.57 per cent in Chengalikodan.

25. Chlorophyll content decreased from stage I to stage IV in the various varieties and on ripening it was almost zero. Total chlorophyll content ranged from 0.134 mg g^{-1} in Red Banana to 0.256 mg g^{-1} in Chengalikodan during stage I.

26. The activities of enzyme, α-amylase, β-amylase and invertase increased on ripening from stage I to stage IV in all the varieties. The maximum value during stage IV for α-amylase was in Palayankodan (3.76 mg g^{-1}), β-amylase and invertase in Chengalikodan (1.69 mg g^{-1} and 0.95 mg g^{-1}) respectively).

27. CO_2 evolution showed a climacteric peak at full ripe stage and after that it slightly decreased. Maximum CO_2 evolution was by Red Banana at full ripe stage (112.12 mg kg^{-1} hr^{-1}).

28. Effect of different postharvest treatments varied in the different varieties. Precooling with ice flakes was the most effective in extending days to 50 per cent and 100 per cent yellowing and shelf life of fruits of Palayankodan. Precooling with tap water was effective in reducing PLW.

29. In the case of Njalipoovan, minimum physiological loss in weight throughout the storage period was registered by vacuum infiltration with 1 per cent $CaCl_2$ followed by precooling with tap water. Vacuum infiltration with 1 per cent $CaCl_2$ was effective in delaying 50 per cent yellowing and 100 per cent yellowing and

there by extending shelf life by 17.5 days. Longer shelf life was also obtained for precooling with tap water (17.0 days), cold water (16.0 days) and $CaCl_2$ dip (15.5 days).

30. Fruits of Robusta recorded minimum physiological loss in weight on precooling with tap water followed by cold water. Coating the cut ends of fruit with edible wax and precooling with cold water and tap water also extended the days to reach 50 per cent yellowing, 100 per cent yellowing and shelf life. Maximum shelf life was attained by coating the cut ends with edible wax and precooling with cold water (17.0 days).

31. In the case of Chengalikodan minimum physiological loss in weight was observed in fruits precooled with cold water, followed by hydrocooling with tap water and vacuum infiltration with 1 per cent $CaCl_2$. Vacuum infiltration with 1 per cent $CaCl_2$ was effective in extending the days to reach 50 per cent yellowing, 100 per cent yellowing and shelf life 22.5 days.

32. Precooling treatments in general improved the TSS, total sugars in Palayankodan, Njalipoovan, Robusta and Chengalikodan. Precooled fruits in general registered less acidity.

33. Precooling treatments improved the sensory qualities of fruits of Palayankodan, Robusta and Chengalikodan. Vacuum infiltration with 1 per cent $CaCl_2$ resulted in maximum scores for organoleptic qualities in Njalipoovan.

34. Effect of different packaging treatments varied significantly in the various varieties. In Palayankodan, Njalipoovan and Chengalikodan minimum physiological loss in weight was observed for vacuum packed fruits. This was followed by fruits packed in polyethylene cover without ventilation and polyethylene cover sealed with ethylene absorbent.

35. The maximum days to reach 50 per cent yellowing, 100 per cent yellowing and shelf life was recorded by vacuum packaged fruits followed by polyethylene with or without ethylene absorbent packed fruits in the three varieties Palayankodan, Njalipoovan and Chengalikodan.

36. Longer shelf life was recorded by vacuum packed fruits in Palayankodan (33.0 days), Njalipoovan (34.0 days) and Chengalikodan (39.5 days).

37. Maximum yellow life was observed in fruits packed in corrugated fibre board boxes and CFB box + polyethylene lining + ethylene absorbent.

38. TSS, total sugars and reducing sugars were comparatively lower in vacuum packed fruits whereas higher values were recorded in fruits packed either in CFB box, CFB box with polyethylene lining and with ethylene absorbent.

39. CFB box packed fruits recorded higher scores for taste, flavour and overall acceptability whereas as vacuum packed fruits obtained higher scores for appearance.

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EVALUATION OF SELECTED BANANA (*Musa* spp.) VARIETIES GROWN IN KERALA FOR POSTHARVEST ATTRIBUTES

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The present investigation on 'Evaluation of selected banana (*Musa* spp) varieties grown in Kerala for postharvest attributes was conducted in the Department of Processing Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala.

Twenty five accessions of banana belonging to six genomic groups were catalogued as per IPGRI description based on 21 fruit characters. Of the twenty five accessions, maximum value for finger weight, finger length, volume of finger, pulp weight and peel weight was recorded by Zanzibar and lowest by Matti. Other varieties with higher finger weight were Nedunendran, Chengalikodan, Manjeri Nendran, BRS I, Monthan, Batheesa and Kanchikela.

Varieties Zanzibar and Chinali recorded highest value for TSS (32.5°brix). Varieties Chengalikodan, Koompillakannan, Nendunendran, Manjeri Nendran, Matti and Njalipoovan also recorded higher values for TSS (TSS >30°brix). Culinary varieties recorded lower TSS. Nendran clones recorded higher values for total and reducing sugars, vitamin C, ß carotene and starch. Physiological loss in weight was highest in Grand Naine and lowest in Batheesa at the end of storage period. Longer shelf life was recorded by the varieties Bodles Altafort, Chengalikodan, Red Banana, Grand Naine, Manjeri Nendran and Poomkalli. On organoleptic evaluation higher scores for sweetness and taste was recorded by Kadali and Koompillakannan.

The physical, chemical and physiological changes during ripening were recorded in four stages *viz*., mature green unripe stage, colour changing, full ripe and over ripe stage in eight varieties. Pulp percentage and pulp/peel ratio showed an increasing trend whereas peel percentage and fruit firmness showed a decreasing trend during the postharvest period. TSS, total, reducing and non reducing sugars and moisture content increased progressively in the various varieties from stage I to stage IV, whereas starch, pectin and tannin content decreased during ripening. Acidity in the various varieties increased up to colour changing stage whereas on full ripening decreased. The activity of starch hydrolysing enzymes α-amylase, ß-amylase and

invertase increased during the postharvest period in the various varieties. The rate of respiration showed a climacteric peak at full ripe stage and after that it slightly decreased.

The effect of different postharvest treatments on enhancing the shelf life varied with different varieties. Precooling with ice flakes and tap water was effective in extending shelf life in Palayankodan fruits. In Njalipoovan and Chengalikodan longer shelf life was obtained for fruits vacuum infiltrated with 1 per cent $CaCl_2$. Maximum shelf life in the case of Robusta was for fruits coated with edible wax at cut ends and precooling with cold water.

Precooling treatments in general improved the TSS and total sugars in Palayankodan, Njalipoovan, Robusta and Chengalikodan. Higher scores for sensory qualities were obtained for precooled fruits in Palayankodan, Robusta and Chengalikodan and for fruits vacuum infiltrated with 1 per cent $CaCl_2$ in Njalipoovan.

Effect of different packaging treatments varied significantly in the various varieties. In Palayankodan, Njalipoovan and Chengalikodan minimum physiological loss in weight and maximum shelf life was observed for vacuum packed fruits. Maximum yellow life was observed in fruits packed in corrugated fibre board boxes and CFB box + polyethylene lining + ethylene absorbent. Higher values for TSS, total sugars and higher scores for taste, flavour and overall acceptability was for fruits packed in CFB boxes.