Effect of indigenous methods of ripening on shelf life and quality of banana fruits

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By

Manuranjan Roy
Roll No. 2017-AMB-12

DEPARTMENT OF HORTICULTURE
BISWANATH COLLEGE OF AGRICULTURE
FACULTY OF AGRICULTURE
ASSAM AGRICULTURAL UNIVERSITY,
BISWANATH CHARIALI-784176

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ASSAM AGRICULTURAL UNIVERSITY

Faculty of Agriculture

CERTIFICATE I

This is to certify that the thesis entitled **“Effect of Indigenous methods of ripening on shelf life and quality of banana fruits”** submitted to the Faculty of Agriculture, Assam Agricultural University in partial fulfillment for the degree of **Master of Science (Agriculture)** in **Horticulture** is a record of research work carried out by **Manuranjan Roy** under my personal supervision and guidance.

All kind of helps received by him have been duly acknowledged.

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Dated : ___ July, 2019

Dr. (Mrs.) Supriya Langthasa
Professor & Major Adviser
Department of Horticulture
Biswanath College of Agriculture
Assam Agricultural University
Biswanath Chariali
Biswanath- 784176 (Assam)

CERTIFICATE II

This is to certify that the thesis entitled, **"Effect of Indigenous methods of ripening on shelf life and quality of banana fruits"** submitted by **Mr. Manuranjan Roy**, Roll No. 2017-AMB-12 to Assam Agricultural University in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Horticulture** has been examined and approved by the student's Advisory Committee after Viva-voce.

____
Dr.(Mrs) Supriya Langthasa
Major Adviser

____
Chairman
Board of Examiners

Members of the Advisory Committee

1.________________________
Dr. Dharindra Nath Hazarika

2.________________________
Dr. Ratna Kinkor Goswami

3. ____________________
Dr. Manoj Kumar Kalita

____
Dr. B.P. Gautam
Professor & Head (Horticulture)
Biswanath College of Agriculture
Assam Agricultural University
Biswanath Chariali- 784176
Assam

____
Director, Post Graduate Studies
Assam Agricultural University
Jorhat- 785013, Assam

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Place: Biswanath Chariali

Date:……..July 2019 *(The Author)*

ABSTRACT

The present investigation entitled "Effect of indigenous methods of ripening on shelf life and quality of Banana fruits" was carried out during 2017-2019 in thelaboratories, Department of Horticulture, B.N. College of Agriculture, AAU, Biswanath Chariali. The experiment was conducted with six different ripening methods with two varieties (Amritsagar and Chenichampa). The treatments were: ripening in covered pit with smoke (T_1), ripening with ripe tomato (T_2), ripening with paddy straw (T_3), ripening in covered pit without smoke (T_4), ripening with Calcium carbide(T_5) and ripening naturally at room temperature (T_6). The study was laid out in factorial CRD with three replications.

Result of the study revealed marked variation in quality characters among the different treatments on ripening. Among the indigenous ripening methods, fruit ripenedwithripe tomato (T_2) retained maximum TSS (21.75%), reducing sugar (5.12 %),total sugar (6.15%), moisture content (73.85%), calcium content (17.38 mg/100g), magnesium content (58.47 mg/100g) and potassium content (427.28 mg/100g). Similarly, fruit ripened with calcium carbide (T_5) recorded highest acidity (0.347%) and phosphorous (74.81 mg/100g). The fruits ripened in covered pit without smoke exhibited maximum ash content (1.84%) and specific gravity (1.21%). The retention of ascorbic acid (5.19 mg/100g) was highest in T_3 (paddy straw) treatment.

Banana fruits ripened withcalcium carbideshowed rapid colour initiation within 2 days and full colour development stage in 2.5 days and followed by smoke which required 5 days for full colour development.

Significant differences in terms of biochemical characters were observed among the banana varieties. The shelf life of Chenichampa banana was found to be 11.61 days as compared to Amritsagar (8.48 days). But among the treatment combinations, fruit of Chenichampa variety ripened naturally (control) showed maximum shelf life of 14.33 days. Aprogressive increase in PLW of banana fruit was observed with an increase in ripening period. The overall preferential score (23.93)with aroma (8.01) and taste (7.88) were highest in fruits ripened with tomato (T_2) than the rest of the ripening methods.Chemically treated Banana showed highest score for colour 8.89.

In case of ripening of fruits calcium carbide, colour change in peel was faster with bright yellow colour but with short shelf life and inferior taste. The use of calcium carbide is known to be carcinogenic as reported earlier; thus an alternative method to induce ripening of fruits with ripe tomato or ripening of banana in covered pits with smoke might be used for ripening of bananas with desirable quality in terms of colour, days require for ripening, biochemical characters and shelf life. Naturally ripened fruit develop poor colour, which might reduce the market price but they had longest shelf life.

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CHAPTER I
INTRODUCTION

Banana is a member of musaceae family and provides a desert fruit in the world (Gowen, 1994). There are many varieties of bananas, all differing in flavour and appearance (Robinson, 1996) and are eaten when ripe (Dadzie and Orchard, 1997). Banana is unique due to its high calorie and nutritive value and plays significant role in human diet by supplying vitamins, minerals and dietary fibre (Khader *et al*., 1990). It stood second to citrus in world fruit trade. In commercial production, the fruit is harvested still green and transported to market where, in some countries, it is ripened under controlled condition. There is usually a need to transport the fruit in green state. Therefore, harvesting time represents a compromise between leaving the fruit on the plant for long period to maximize yield but harvesting it soon enough so that sufficient green life remains to market the fruit in acceptable manner (Mitra, 1997).

In recent times, there is much concern about artificial ripening. Various artificial methods of fruit ripening have been observed mostly to meet consumers' demand and other economic factors. People consume chemically ripened (calcium carbide) fruits in Assam which is hazardous in nature. These pose great health risk to consumers (Rahim, 2012). Fruit sellers particularly of Assam usually ripen green fruits artificially to meet the high demand and make high profit of seasonal fruits. Transporting and distributing fruits from the farmers' orchards to consumers' baskets may take several days. During this time, the naturally ripened fruits may get damaged during harsh condition of transportation. It indeed increases great economic loss for the fruit sellers and therefore, to minimize the loss, fruit sellers sometimes prefer collecting immature fruits and artificially ripen the fruits before selling to the consumers (Mursalat *et al*., 2013).

Ripening is the final stage of development of a fruit which involves series of physiological and biochemical events leading to changes in colour, flavour, and texture that make the fruits both tasty and attractive. It imparts numerous quality and nutritional characteristics to fruits which are a significant component of human diet (Payasi and Sanwal, 2005). In general, a fruit becomes sweeter, less green and softer as it ripens naturally. Though the acidity as well as sweetness rises during ripening, the fruit still taste sweeter (Rahman *et al.*, 2008).

Banana fruit once harvested, is highly perishable, with short shelf life leading to high post-harvest losses of about 20-50 per cent due to poor handling and quality deterioration (Ajayi and Mbah, 2007; Zewter *et al*., 2012). In order to reduce the high post-harvest losses, banana is harvested at green, mature stage and artificially ripened when needed with the use of ripening agents. Ripening agents are the substances which hasten the ripening process and it is available in different forms. These include ethylene gas, ethephon, ethylene glycol, ethrel and calcium carbide (Singal *et al*., 2012); African bush mango fruit (*Irvingia gabonesis*) and *Jathropha curcas* leaves, palm nut, Cassia leaves, yellow papaya leaves, torch light battery, calcium carbide, potash ash and *newbouldia* leaves (Ajayi and Mbah, 2007; Adewole and Duruji, 2010). The adverse potential of calcium carbide as a ripening agent has been established (Singal *et al*., 2012) while other chemicals used as ripening agents like ethephon, ethrel and ethylene glycol are also considered hazardous to human health and they have to use within recommended safe limits. The use of artificial agents might give more acceptable colour than naturally ripened fruits (Hakim *et al*., 2012) but it might increase the risk of contamination of food materials. Calcium carbide has many health hazards and having carcinogenic properties due to traces of arsenic and phosphorous hydride (Rahman *et al.*, 2008). A generous consumption of ethylene glycol may cause kidney failure. Low cost chemicals such as calcium carbide, ethylene glycol, ethephon are commonly used to trigger the ripening process artificially (Goonatilake, 2008; Siddiqui and Dhua, 2010). Therefore, the present study is designed to find out the alternative option and to compare natural ripening agents with chemical (calcium carbide) on nutritional composition and ripening of banana with the following objective:

1) Effect of different ripening methods on quality of fruits
2) Effect of different ripening methods on the shelf life of banana fruits

CHAPTER II

REVIEW OF LITERATURE

Banana is a climacteric fruit but it is generally not allowed to ripe on the plant itself. Banana is harvested at fully mature and green stage and after harvesting, the ripening process starts. To advance the ripening process, different chemicals or indigenous methods are adopted and changes in colour, texture and flavour occur during ripening. A brief review of research works on the effect of different chemicals and indigenous methods of ripening on shelf life and quality of banana fruits carried out earlier in India and abroad is presented below.

2.1 Effect of different indigenous methods on ripening of fruit

Fully mature banana cv. Harichal fruits showed light green colour when exposed to smoke generated by burning leaves in a closed chamber for 24 hours (standard local practice). The treated fruits were then stored at 15-20˚C temperature and 70-72 per cent relative humidity. The result showed that smoking gave poorer result but caused quicker (3 days) ripening (Ram *et al.*, 1979).

Different indigenous ripening technologies were used for ripening of banana and plantain by Ajayi and Mbah, (2007). They used different types of containers for ripening of banana fruits and revealed that African bush mango fruit containers induced ripening within 2 days as compared to other indigenous ripening technologies. Banana covered with leaves of banana/plantain and cassia induced ripening within 4 days.

A study was conducted to describe the effect of traditional practice on ripening of dessert banana by application of smoke and to determine the effect of the practice on ripening period, shelf life etc. Results showed that smoking induced rapid ripening as compared to other treatments, which occurred within 2 days, but resulted in green ripe fruits, with relatively shorter shelf life (2-8 days). It was considered that the heat produced from the fire during smoking raised the temperature in the ripening pit causing the softening of fruit pulp or high respiration rate that hastened ripening and fruit deterioration (Maerere and Munubi, 2008).

Ram *et al.* (2009) reported that the banana fruits treated with *Adhatoda vasica* leaves (Asuro) and *Bauhinia variegata* (Koiralo) could soften the fruits in 4 to 5 days; with 2 to 3 days more shelf life than the ethephon treated fruits. They also reported that banana fruits could be ripen using ripe banana with excellent taste. However, shelf life was relatively shorter than other treatments. Banana fruits could also be ripened within a day by keeping the *Cassia fistula* leaves (Kanikonna) in between the bunches of banana (Swapna, 2003).

The result of the experiment conducted by Singal *et al.* (2012) showed that apple fruits can be used as a ripening agent as an alternative to the indiscriminately used calcium carbide, which is carcinogenic in nature. The study indicated that banana fruits ripened with apple fruit as a ripening agent, took merely 3 days to ripe as compared to 10 days without any ripening aid and thus it can be exploited as a natural and safer mode for fruit ripening. Pokhrel (2013) reported that ripe climacteric fruits produce ethylene gas in higher amount than the threshold level required to induce the ripening process of fruits. Hence ripe fruits can be taken as an alternative to ethylene to ripe the mature climacteric fruits.

According to Tadesse (2014), among the plant ethylene sources used (avocado, mango and tomato), avocado resulted in the shortest ripening period (6.4 days) and shelf life (9.8 days). Similarly, longest ripening period (7.10 days) and shelf life (10.5 days) was recorded in mango. However, avocado fruit in combination with wooden box could be used to get shortest ripening period without any undesirable effect on the quality of the fruit. On the other hand, Sogo-Temi *et al.* (2014) showed that the African mango and *Jathropha curcus* leaves treated fruits ripen earlier as compared to untreated fruits (6 days).

A study was conducted by Gama *et al.* (2015) to study the most effective indigenous method of ripening of bananas. Banana fruits were ripened with different ripening agents such as tomato, banana leaves and mixture of ashes with water and acacia leaves. The results showed that the fruits ripened using tomatoes recorded the least ripening period (4 days) as compared to other indigenous ripening methods and the shelf life was intermediate (6 days) while the untreated fruits (control) recorded the longest shelf life (9 days).

It was observed that smoking enhanced the ripening process considerably than ripening with no exogenous ethylene source. Smoke treatment resulted in the shortest ripening period of 6 days without affecting the measurable ripening qualities of banana with reduced shelf life of 8 days (Mebratie *et al.*, 2015).

The effect of natural ripening agents (apple, pear and tomato fruits) for ripening of banana and their ripening ability was studied by Gandhi *et al.* (2016). The results revealed that banana fruit placed in container with apple fruit required 4 days for ripening as compared to artificial ripening agents. Among the natural ripening agent's apple was found better. Similarly, Bhardwaj (2016) conducted an experiment with different indigenous treatments such as cassia leaves, old banana leaves, *Adhatoda vasica* leaves, wheat straw, paddy straw, smoke of cow dung. The results showed that maximum ripening (100 %) was recorded in fruits ripened on 9^{th} day of treatment in presence of ripe fruits (apple/banana) in an air tight container. The minimum ripening percentage (0 %) was observed in fruits without any treatment even after 12^{th}days of treatment.

2.2 Effect of different indigenous methods of ripening on fruit qualities

Narasimham *et al.* (1971) reported that banana fruit ripened with smoke changed its color from green to yellow color in 5 days compared to non-smoked fruits (7days). The fruits in the smoked group became edible, ripe and soft in 7 days while the fruit in the non-smoked group was yellow and hard even on the 8^{th}day. The pulp-peel ratio increased from 1.45 to 2.21 in the non-smoked samples. The non-reducing and total sugars showed higher values in the smoked samples and reducing sugar did not show any appreciable difference.

Maerere and Munubi (2008) studied the effect of traditional practice on ripening of dessert banana by application of smoke and reported that the fruits harvested at the "full three-quarters" stage of maturity and ripened by smoke were of a quality falling within the standard range with respect to pH (4.8-5.3), total soluble solid (14.9-23.0˚Brix) and reducing sugar content (20-20.3 mg/100ml) but there was no direct effect on the fruit organoleptic qualities.

Effect of different wrapping materials on fruit quality of mango was studied by Roy *et al.* (2011) who reported that among the treatments, the maximum 5.25 days was required for ripening of mango kept in white paper and minimum 3.57 days for mango fruits kept in room temperature. The highest total soluble solid (18.60˚Brix) and the longest shelf life of 11.5 days were recorded in mango fruits kept in brown paper bags while the highest weight loss (16.07 %) with shortest shelf life (7.83 days) were recorded in fruits without any treatment.

Adane *et al.* (2015) reported that the fruits treated with kerosene smoking system completed their maximum ripening stage within 7days of the ripening period. The study conducted by Mebratie *et al.* (2015) revealed that smoking enhanced the ripening process considerably than the ripening with no exogenous ethylene source. Banana treated with smoke reached a color score of 6 within 6 days with highest total soluble solid (17.9˚Brix) after 8 days of storage and titratable acidity attained 0.45 per cent on day 4.

Gama *et al.* (2015) conducted an experiment on ripening of banana using indigenous materials like acacia leaves, tomatoes and ashes mixed with water, banana leaves and banana firuits taken from the bunch left to ripen naturally (untreated control). Banana firuits from the untreated bunch had the highest TSS (11˚Brix) followed by banana treated with ashes mixed in water (10.16˚Brix). The banana ripens using tomatoes showed the best color.

The results of experiment conducted by Bhardwaj, (2016) revealed that the highest TSS (19.20ºBrix), reducing sugar (8.09 %) and total sugar content (13.33 %) in fruits treated with ripe fruits (apple/banana) in an air tight container. The minimum TSS (6.14ºBrix) were recorded in fruits treated with wheat straw kept in air tight container, while the lowest reducing sugars and total sugar contents were recorded in fruits ripened in the presence of old banana leaves in an air tight container and control fruits, respectively. The titratable acidity content (0.380 %) and ascorbic acid content (5.50 mg/100g) of fruits were higher in an air tight container treated with apple or banana fruits, respectively. However, the minimum titratable acidity content (0.250 %) and ascorbic acid content (3.38 mg/100g) were found in fruits ripened with wheat straw kept in air tight container.

The effects of ripening acceleration methods on the proximate, biochemical and mineral compositions of *Musa paradisiaca* (Plantain) was carried out by Izundu *et al.* (2016). They treated the fruits with several methods such as hot water treatment, dried plantain leaves treatment, smoked treatment and then polythene bag treatment. The plantain fruit under control was left in the open without any treatment. The results of the study showed that hot water treatment gave higher of moisture (64.77 %); the control gave higher dry matter (40.08 %), titratable acidity (0.085 %) while smoke treatment gave higher composition of ash (2.49 %), reducing sugar (10.31 %), vitamin C (8.61 mg/100g) and Magnesium (7.88 %).

2.3 Effect of Chemical methods on ripening

Calcium carbide is widely used as ripening agent for fruits like banana, mango, tomato etc. This chemical in contact with moisture produces acetylene gas which is an analogue of natural ripening hormone ethylene. The acetylene gas contains arsenic and phosphorous hydride. Consumption of fruit ripened with acetylene gas generated from calcium carbide is extremely hazardous for health, mainly for the nervous system and also reduces oxygen supply to the brain (Fatah and Ali, 2010).

In India, the use of calcium carbide for fruit ripening has been prohibited under rule 44AA of the prevention of Food Adulteration Rules 1955 (FSSA, 2006). Similarly, Food Safety and Standards Act, 2006 (Rules, 2011) totally banned the practice of ripening of fruits with carbide in India. The government of India has allowed the use of ethephon or ethrel for ripening of fruit as it has less harmful effect (Siddiqui and Dhua, 2010).

Though the calcium carbide is banned in many countries, including India, it is being freely used across the country to ripen fruits. Traders pick green fruits before maturation and ripen artificially just to scale up the sell in the market well ahead of the season for higher profit, this is because green fruits are more suitable for transportation with minimum damage and ripened later at the place of retail sell, thus work done to study the effect of calcium carbide on fruit quality has been reviewed here.

Calcium carbide is used methodically for ripening of fruits in many countries including India. In India, it is being used openly, commonly and in an inappropriate way for ripening fruits. A very strong reactive chemical, calcium carbide has carcinogenic properties. Acetylene gas generated from carbide is flammable and explosive even in a low concentration as compared to ethylene (Geesner, 1977).

Smith and Thompson (1987) observed that fruits developed good peel colour with calcium carbide and the intensity of colour developed commensurate with increase in the concentration of calcium carbide used; but fruits were less in flavour volatiles and had shorter shelf-life. Practically calcium carbide only changed the skin colour, whereas the fruit remained raw inside. More immature the fruit, higher calcium carbide is required to ripen it.

Chandramonti *et al.* (1991) reported that dipping fully mature banana fruits cv. Robusta in different concentrations of calcium chloride (0, 0.5, 1, 2, 3, 4, 5 and 6 %) at ambient pressure and subsequent storage at room temperature enhanced ripening by around 2 to 5 days of the time taken for control fruit to ripen. A study was conducted by Amarakoon *et al.* (1999) to determine the optimum dose of calcium carbide required to induce ripening of 'Velleicolomban' and ‘Willard' mangoes and revealed that the optimum dose of calcium carbide required to induce ripening was found to be 1g/kg fruit.

Ripening was very slow in untreated (control) fruits and in calcium carbide treated fruits ripening was very fast whereas ethephon treated fruits have a slow and uniform ripening. They also observed that fruits in contact with calcium carbide packages were unmarketable after 4 days (Joon *et al.*, 2001). Jayawickrama *et al.* (2001) observed that papaya fruit developed off flavor when ripened with calcium carbide.

The effect of calcium carbide as an artificial ripening agent on shelf life and physical properties of peach fruit were evaluated by Mahmood *et al.* (2013) and revealed that artificial ripened fruits have shorter shelf life as compared to naturally ripening fruits. The period of ripening is usually determined by the change in color of the banana peel. The fastest color change indicated by the peel color to fully yellow color was observed in banana ripened with calcium carbide as well as banana ripened with potash within 3 days as compared to untreated banana which ripened 6 days (Sogo-Temi *et al.*, 2014).

A study was carried out by Adeyemi *et al.* (2018) to examine the effect of calcium carbide as a ripening agent where calcium carbide was administered to 12 samples (mango, banana, and papaya) at three different concentrations (1g, 5g and 10g calcium carbide per kg of fruit) and control without calcium carbide. The results revealed that calcium carbide was a good ripening agent with a ripening period of 2 days (48 hours) among all the fruits (mango, banana, and papaya @ 10 g/kg). The control fruit had the longest ripening time of 7 days, 5 days, and 6 days for mangoes, banana and papaya fruits, respectively. However, the longest shelf life (12 days) was observed in control fruits over the treated fruits.

2.4 Effect of chemical methods of ripening on quality of fruit

In an experiment conducted by Joon *et al.* (2001) found that physiological loss in weight was maximum in calcium carbide treated mango fruits whereas physiological loss in weight was minimum in untreated fruits. Similarly, TSS increased from 8 per cent to 14 per cent on second day of storage in calcium carbide treated fruits but in untreated fruits, TSS increased very slowly which reached to 14 per cent on 6 days of storage. Decrease in acidity was very fast in all the treated fruits as compares to untreated fruits. Gunasekara *et al.*, (2015) revealed that artificially ripened banana had significantly low level of physico-chemical, nutritional and quantitative quality than naturally ripened banana fruit. Calcium carbide treated banana fruit had comparatively low level of nutritious factors (total sugar, vitamin C, moisture content and TSS) than ethephon treated fruit. The maximum level of total sugar (22.25 %), vitamin C (7.96 mg/100gm), TSS (18.67˚Brix) and moisture (69.4 %) were observed in untreated banana fruit on 6^{th} day of ripening period.

Damodar *et al.* (2015) reported that the mango fruit kept in controlled ripening chamber with straw resulted faster ripening rate (6 days) as compared to non-treated fruit in wooden box. The total soluble solid (19.05^0Brix), total sugar (16.31 %) and reducing sugar (6.79 %) were higher in ripening chamber mangoes without straw as compared to untreated (control) fruits while the titratable acidity was maximum 0.33 per cent in treatment of ethephon (39 %) with straw and control treatment.

Among all the treatments, banana fruits treated with ethephon and calcium carbide with different concentrations showed that the maximum TSS (14.93^0B), reducing sugar (5.96 %), total sugar (7.10 %) titratable acidity (0.400 %) and ascorbic acid (4.66 mg/100g) were recorded in fruits treated with 300 ppm of ethrel for 48 hours. While minimum values (7.09 %, 1.93 %, 2.70 %, 0.290 % and 3.28 mg/100g respectively) were recorded in control fruits (Bhardwaj, 2016). The study revealed that common nutrient contents were higher in naturally ripened banana as compared to artificially ripened banana. The results also indicated that fat (0.017 %), protein (1.65 %), ash (0.71 %), moisture (78.26 %), vitamin C (7.45 mg/100gm) and iron (1.65 mg/100g) contents were higher in naturally ripened banana. The sensory quality of naturally ripen banana had higher score in terms of taste and flavour than artificially ripened bananas (Rabaya *et al.,* 2017). Freshly harvested bunches of green mature banana were ripened by using different level (0, 5, 10, 15, 20 and 25 g) of calcium carbide per kilogram of banana (*Musa spp*) in two stages of ripening method and it was found that the vitamin C content (28.0 to 16.0 g/100g), titratable acidity content (0.13 to 0.09 %) and pH (7.35 to 6.93) were in decreasing order with increase in calcium carbide concentration. Whereas the moisture content (60.82 to 69.69 %) and ash content (1.14 to 2.85 %) were found to be increasing with increase in calcium carbide concentration (Nura *et al.,* 2018).

CHAPTER III
MATERIALS AND METHODS

The present investigation entitled “Effect of indigenous methods of ripening on shelf life and quality of banana fruits” was carried out in the laboratories of the Department of Horticulture, B. N. College of Agriculture, AAU, Biswanath Chariali. The materials and methods adopted during the course of investigation are presented in this chapter.

3.1 Details of the treatments

Banana fruits of two cultivars ‘Amritsagar’ (AAA) and ‘Chenichampa’ (AAB) were collected from commercial growers of Jamuguri of Sonitpur district. Fruits were harvested at mature green stage and immediately after arrival, the bunches were dehanded, washed with chlorinated water and air dried. Uniform size fruits were selected for the various postharvest treatments under the study. Treatments were arranged in factorial CRD with three replications.

The treatment notations are as below:

Notations	**Treatment**
T_1	Ripening in covered pit with smoke
T_2	Ripening with ripe tomato fruit
T_3	Ripening with paddy straw
T_4	Ripening in covered pit without smoke
T_5	Ripening with chemical (Calcium carbide)
T_6	Ripening naturally at room temperature

3.2 Cultivars of banana

V_1 : Amritsagar

V_2 : Chenichampa

Banana is one of the major fruits of Assam and among different cultivars, Amritsagar (AAA) and Chenichampa (AAB) are the most popular cultivars of North Bank Plain Zone of Assam. These two cultivars are cultivated in commercial scale in this zone. The height of ‘Amritsagar’ is medium tall and produces an average sized bunch with 11-12 hands. The fruits are long like Cavendish group and on an average 15-20 fruits are found in each hand depending upon management practices. The fruits develop bright yellow colour when ripe. On the hand, Chenichampa (AAB) is a hardy and tall cultivar and bunches bear average of 10-11 hands. Its fruits are short and stout with thin peel. The pulp is creamy in colour and its taste is sub-acid. The fruits turn golden yellow when ripe and shelf life is longer than other cultivars. The bunch contains 150-200 fruits with an average weight of 16 kg.

Both the cultivars may be grown under rainfed condition or with minimal irrigation. The climate of Assam is very much suitable for cultivation of both Amritsagar and Chenichampa and their production is also higher. Again from the social and economic point of view, these two cultivars play an important role and they are easily available in the market and due to which these two cultivars were selected for the present investigation.

3.3 Treatment details

3.3.1 Ripening in covered pit with smoke

A pit (60 cm x 60 cm x 45 cm) was dug out on the ground covered by shed and then a layer (8-10 cm thick) of paddy straw was placed at the bottom of the pit. Over the paddy straw, 5 hands of banana hands were laid down gently. Finally, banana hands were covered with a layer of paddy straw and then top of the pit is sealed by plastering with soil. Simultaneously, another small pit (15 cm x 15 cm x 15 cm) was dug out by the side of the bigger pit and both the pits were joined by making a small tunnel for passing the smoke. Dried paddy straw was burnt in the small pit and smoke was passed to the bigger pit through the tunnel. Smoking was done for 5-6 minutes and then the tunnel was sealed to keep the smoke inside the bigger pit. After 24 hours, the banana hands were taken out from the pit for allowing the fruits to ripe further at ambient condition.

3.3.2 Ripening with ripe tomato fruit

Uniform and mature banana fruits were selected. Each banana hand along with a ripe tomato fruit were kept inside a brown paper bag and sealed the bag. The data on ripening period was recorded in days from the day of packing to the day of ripening Fruits which showed 95 per cent ripening were considered as standard of ripening.

3.3.3 Ripening with paddy straw

Banana hands were covered with dry paddy straw of 8-10 cm thickness layer and packed in gunny bags so that they themselves evolved ethylene and ripe properly.

3.3.4 Ripening in covered pit without smoke

A pit (60 cm x 60 cm x 45 cm) was dug out on the ground covered by shed and dry banana leaf was placed and over this, paddy straw was spread at the bottom of the pit. The banana hands were placed over the paddy straw and again covered with paddy straw (thin layer) and then covered with soil and allowed to remain in the pit for 3 days for ripening.

3.3.5 Ripening with chemicals

Ten gram of calcium carbide was kept inside the CFB box (60 cm x 45 cm x 30 cm) with 5 hands of banana and the CFB box was sealed properly. After 24 hours, the hands were taken out of the CFB box and kept for ripening at ambient condition.

3.3.6 Ripening naturally at room temperature

Banana fruits (5 hands) were kept in a plastic tray in the room to ripen naturally at room temperature.

3.4 Observation recorded

Physico-chemical qualities of banana fruits including colour, physiological loss in weight were determined at alternate days and TSS, acidity, sugars and ascorbic acid at acceptable ripe stage. Ripening period and shelf life were determined considering the changes in the physico-chemical qualities.

3.4.1 Phenological character

3.4.1.1 Ripening period

Ripening period was determined based on the changes in colour, firmness and TSS value of banana (Dadzie and Orchard,1997). Ripening period for fruit in each treatment was recorded as the number of days until fruit attained full ripe stage (Colour stage 6).

3.4.1.2 Shelf life

Shelf life was assessed by visual inspection of fruits at alternate days; it was calculated as the period between commencement of ripening and end of saleable life or edible life (Dadzie and Orchard, 1997).

3.4.2 Physical characters of banana fruits

3.4.2.1 Colour of banana peel

Colour of banana peel was visually determined using a standard colour chart. A scale of 1- 8 was used to indicate the stages of colour of banana peel (Collin and Dalnic,1991).

Scale	**Stage of colour**
1	Hard Green
2	Green with a trace of yellow
3	More green than yellow
4	More yellow than green
5	Green tipped
6	Fully yellow
7	Yellow flecked with brown
8	Browning and Overripe

3.4.2.2 Pulp-peel ratio

The pulp to peel ratio of banana was determined by dividing pulp weight to the peel weight. Pulp and peel was separated, weighed and expressed as pulp to peel ratio (Dadzie and Orchard,1997).

3.4.2.3 Specific gravity of fruit

The specific gravity of banana fruit was determined by dividing the weight of each fruit by the volume of water displaced by it and expressed in g/cc

$$\text{Specific gravity} = \frac{\text{Weightof fruit (g)}}{\text{Volumeof waterdisplacedby thefruit (cc)}}$$

3.4.2.4 Physiological loss in weight

Physiological loss in weight (PLW) was determined according to the methods described by Mohammed *et al*. (1999). Weight loss was calculated by dividing the final weight with that of initial fruit weight and expressed as percentage

$$\text{WL}~(\%) = \frac{\text{Wi}-\text{Wf}}{\text{Wi}} x~100$$

Where, W_i= initial weight

W_f = final weight

3.4.3 Biochemical characters of banana fruits

3.4.3.1 Total soluble solids

Total soluble solid content was recorded with the help of an Erma hand refractometer. Crushed fruit pulp was placed on the prism of the refractometer and reading was observed through the eye piece. For accurate measurement, the readings taken were corrected for temperature variations to 20°C and results were expressed as °Brix (Ranganna, 1986).

3.4.3.2 Titratable acidity

Titratable acidity was estimated by using the standard method of AOAC (1980). Ten gram of pulp was macerated with little distilled water and taken in 100 ml volumetric flask and made the volume with distilled water. After filtration, 10 ml of the filtrate was taken in separate conical flask and titrated against 0.1 N NaOH using phenolphthalein as indicator. The end point was determined by the appearance of a faint pink colour. Titratable acidity as anhydrous citric acid was calculated and expressed in percentage with the following formula

$$\text{Titratable acidity}~(\%) = \frac{\text{Titre value x Normality of alkali x Equivalent weight of citric acid}\times 100}{\text{Weight of sample x Aliquot x 1000}}$$

3.4.3.3 Ascorbic acid

Ascorbic acid content was determined by the visual titration method using 2,6dichloro-phenol indophenol dye (Freed, 1966), and expressed in mg per 100 g.

Ten gram of sample was taken in 100 ml volumetric flask and volume made up with 4 percent oxalic acid and filtered. Ten ml of filtrate was taken and titrated against the standard dye. The pink colour indicates the end point. It was calculated by the following formula and expressed as mg/100g.

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{titre value x dye factor x volume made up}}{\text{wt.of sample taken x Aliquot of sample taken}}\text{ x 100}$$

*Dye factor = 0.5/titre value

3.4.3.4 Reducing sugar

Ten ml of saturated lead acetate and 5 g of sodium oxalate were added to 25 g pulp and the volume was made up to 250 ml with distilled water. The made up solution was titrated against 10 ml boiling Fehling's solution mixture (5 ml of Fehling's solution A + 5 ml of Fehling's solution B) using methylene blue as indicator. Deep brick red colour of the solution indicated the end point and the value was expressed as percentage (AOAC, 1980).

$$\text{Reducing sugar (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre value} \times \text{Weight of the sample}}$$

3.4.3.5 Total sugar

From the solution of 250 ml made up for reducing sugar estimation, 50 ml of the solution was taken and 5 ml of concentrated HCL was added to it and kept overnight. The solution was then neutralized with 1 N NaOH using phenolphthalein as indicator and volume was made up to 150 ml with distilled water and titrated against 10 ml boiling Fehling's solution mixtures (Fehling's solution A + Fehling's solution B). Total sugar was calculated with the following formula and expressed in percentage (AOAC, 1980).

Total sugar = (% Sucrose + % Reducing sugars)

Sucrose % = (% Total invert sugar - % Reducing sugar originally present) x 0.95

3.4.3.6 Moisture Content

Moisture was determined according to AOAC (1980) method. At first, the weight of crucible was taken and then 5-10 g sliced sample was put into it. The crucible was then placed in an oven at 105°C for overnight. Then the crucible containing sample was weighed in an electric balance and heated in an oven until constant weight was found each time. The crucible was cooled in desiccators before weighing. The moisture content was computed using the following formula and expressed in percentage.

$$\text{Moisture content (\%)} = 100 \times \frac{A-B}{A}$$

In which, A= Sample weight before oven drying,

B= Final weight of the sample

3.4.3.7 Ash content

Ash content of the dried integument was determined according to AOAC (1980) method by incinerating the samples in porcelain cup and kept in a muffle furnace at 550^0C for 12hours. The following equation was used to calculate the ash content and expressed as percentage.

$$\text{Ash content (\%) } 100 \times \frac{Wa}{Wb}$$

Where,

W_a=Weight of sample (g) after ashing

W_b= Weight of sample (g) before ashing.

3.4.4 Mineral compositions of the fruits

3.4.4.1 Calcium and Magnesium

For estimation of Ca and Mg, first 1 g sample was digested by following wet ashing method (Saini *et al.*, 2012). Then 5 ml aliquot was taken in china dish and pH of the aliquot was adjusted to 10 by adding 15 ml NH_4Cl + NH_3OH buffer solution. Ten drops of Erichrome Black-T indicator were added and titrated with 0.01 N EDTA solution till colour changes from red to bright blue. A blank was carried out exactly the same manner.

For Ca estimation, five ml of NaOH solution and 50mg of murexide indicator was added to 5 ml of aliquot and titrated with 0.01 N EDTA solutions till the colour changes from pink to purple. Similarly, a blank was also prepared. Both the minerals were calculated by the following formula and expressed as following,

For Ca + Mg

$$\text{Meq of (Ca+Mg)/100g of plant material} = (0.01 \times V_3) \times (V/V_1) \times (100/1)$$

$$\text{Meq of Ca/100g of plant material} = (0.01 \times V_2) \times (V/V_1) \times (100/1)$$

Where,

V = Volume of the plant digest made

V_1= Volume of the aliquot taken for analysis

V_2 = volume of EDTA solution in titration (titre value)

V_3 = Volume of EDTA solution in titration (titre value)

3.4.4.2 Potassium

Ten ml of aliquot was taken from the pre-digested sample and 25 ml of neutral NH_4OAc solution was added. The content was then shook on an electric shaker for 5 minutes and filtered. The filtrate was then fed to the atomizer of the flame photometer. The flame photometer reading was set zero for the blank (NH_4OAc solution) and at 100 for 40 ppm K solution. A standard curve was prepared by making different concentrations of K as 5 ppm, 10 pmm, 15 pmm, 20 ppm, 25 ppm, 30 ppm, 35 ppm and 40 ppm, respectively. The reading of the sample solution was then located on the standard curve which gave the concentration of K in the extract and calculated as per Ward and Johnson (1962).

$$\text{Potassium (mg/100g)} = \frac{\text{ppm found from std curve x Volume made up xDilution x 100}}{\text{Wt of sample x 1000}}$$

3.4.4.3 Phosphorus

Five ml of pre-digested sample aliquot was taken in a 50ml volumetric flask where 10 ml of nitric acid-molybdate-vanadate mixture was added and volume was made up. Yellow colour was developed in about 30 minutes and the colour intensity was read on a colorimeter at a wavelength of 450 µ filter. A standard curve was prepared using different concentrations *viz*. 0,0.1 ppm, 0.2 ppm, 0.4 ppm, 0.6 ppm,0.8 ppm and 1 ppm solutions of KH_2PO_4. The amount of phosphorus present in the sample was calculated by using the following formula given by Saini *et al*. (2012).

ppm of P in the given plant material = Y x (50/1) x (V/V_1)

Where,

V = volume of the plant digest made

V_1 = Volume of aliquot taken for analysis

Y = ppm of P (as read from the standard curve) against Transmitance

3.4.5 Sensory evaluation

Sensory evaluation of ripe banana fruit of different treatments was carried out by a panel of judges. The basis for scoring for colour, flavour and texture were done using a nine-point Hedonic scale rating (Amerine *et al*., 1965). A score of 5.5 and above was considered as acceptable.

Hedonic scale for sensory quality evaluation

Rating	**Score**
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

3.5 Statistical analysis

The data recorded were statistically analysed adapting the procedure of analysis of variance by Factorial Completely Randomized Design (CRD). Significance or non-significance of the variance due to treatments was determined by calculating the respective 'F' values by following the method described by Panse and Sukhatme (1985). The significance of difference between mean values of the character of treatment was tested by computing Least Significance Difference (LSD) estimates.

CHAPTER IV

EXPERIMENTAL FINDINGS

The results of the present investigation entitled "Effect of Indigenous methods of ripening on shelf life and quality of Banana fruits" obtained during the experimentation were analysed statistically and are presented in this chapter with tables and figures.

4.1 Phenological character

4.1.1 Ripening period

The variation among indigenous ripening methods on days to fully ripe stage (colour score 6) of banana is presented in **Table 4.1**. Banana fruits treated with calcium carbide (T_5) attained fully ripe stage within 2.5 days and smoke treated fruits (T_1) which attained within 5 days of storage, respectively, signifying that they reached the acceptable ripening level during the period. Banana fruits ripened in T_4 (without smoke) attained full yellow colour (8.5 days) which was at par with T_3 (9.50 days). Longest period to attain fully ripe stage was observed in control (13 days**).**

Table 4.1: Effect of different indigenous ripening methods on ripening period (days) of banana fruit

Treatment	**Ripening period (Days)**		
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	**Mean**
T_1:Smoke	4.00	6.00	**5.00**
T_2:Ripe tomato	5.00	7.00	**6.00**
T_3:Paddy straw	9.00	10.00	**9.50**
T_4:Without smoke	8.00	9.00	**8.50**
T_5:Calcium carbide	2.00	3.00	**2.50**
T_6:Control	12.00	14.00	**13.00**
Mean	**6.67**	**8.16**	**---**
LSD (P=0.05)	**T=1.29**	**V=0.74**	**T×V=NS**

4.1.2 Shelf life of ripened banana fruits

The shelf life of banana fruit was found to have significant difference among the ripening methods **(Table 4.2)** and maximum shelf life (12.50 days) was obtained in control fruits (T_6), which was followed by T_2 and T_4. Among the treatments, fruit ripened with calcium carbide (T_5) had the shortest shelf life of 5.33 days.

Shelf life of banana fruits differed significantly between the varieties. Chenichampa fruits exhibited longer shelf life (11.61 days) than the Amritsagar fruits (8.48 days). However, interaction between treatments and variety was found to be non-significant. The longest shelf life (14.33 days) was observed in control fruit (T_6V_2) while lowest was found in T_5V_1 (4.33 days).

Table 4.2: Effect of different indigenous ripening methods on shelf life (days) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	7.00	11.00	**9.00**
T_2:Ripe tomato	9.33	14.00	**11.66**
T_3:Paddy straw	9.33	11.33	**10.33**
T_4:Without smoke	10.25	12.66	**11.45**
T_5:Calcium carbide	4.33	6.33	**5.33**
T_6:Control	10.67	14.33	**12.50**
Mean	**8.48**	**11.61**	---
LSD (P=0.05)	**T=1.34**	**V=0.77**	**T × V =NS**

4.2 Physical characters of banana fruits

4.2.1 Colour of banana peel

Variation in banana peel colour development is presented in **Table 4.3**. Among the treatment fast colour development was noticed in T_5 (ripened with calcium carbide).

Table 4.3: Effect of different indigenous ripening methods on peel colour (days) of banana fruit

Treatment	Colour initiation (days)		
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	**Mean**
T_1:Smoke	3.00	4.00	**3.50**
T_2:Ripe tomato	3.00	5.00	**4.00**
T_3:Paddy straw	7.00	8.00	**7.50**
T_4:Without smoke	5.00	7.00	**6.00**
T_5:Calcium carbide	2.00	2.00	**2.00**
T_6:Control	10.00	12.00	**11.00**
Mean	**5.00**	**6.33**	---
LSD (P=0.05)	**T=0.77**	**V=0.44**	**T×V=NS**

In calcium carbide and smoke treated banana, colour initiation occurred within 2 and 3.5 days respectively. Chemically ripened banana fruit showed a bright yellow colour which was followed by T_2 (ripened with tomato) as compared to rest of the treatment. On the other hand, slow ripening was observed in untreated control fruits (T_6) which took 11 days for colour initiation.

4.2.2 Pulp-peel ratio

The pulp-peel ratio of bananas differed significantly among the ripening methods (**Table 4.4**). The result indicated higher pulp peel ratio (2.20) in T_2 (ripened with tomato) followed by T_1 (smoke) which was 2.02. The lowest ratio (1.83) being found in T_4(without smoke).

Similarly, significant difference was found between the varieties in terms of pulp-peel ratio. Higher pulp-peel ratio (2.16) was found in Chenichampa (V_2) than Amritsagar (1.76).

Due to interaction effect, the highest pulp-peel ratio (2.23) was observed in banana treated with paddy straw (T_3V_2) and lowest value (1.53) was found in T_4V_1. The value for pulp-peel ratio was in the range of 1.53 to 2.23.

Table 4.4: Effect of different indigenous ripening methods on pulp-peel ratio of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	1.82	2.21	**2.02**
T_2:Ripe tomato	2.21	2.19	**2.20**
T_3:Paddy straw	1.54	2.23	**1.88**
T_4:Without smoke	1.53	2.13	**1.83**
T_5:Calcium carbide	1.70	2.08	**1.89**
T_6:Control	1.76	2.13	**1.95**
Mean	**1.76**	**2.16**	---
LSD (P=0.05)	**T=0.21**	**V=0.12**	**T × V =0.30**

4.2.3 Specific gravity

There were no significant differences among the treatments and between the varieties of banana in terms of specific gravity **(Table 4.5).** However, among the treatments, specific gravity of the fruit was maximum in T_4 (1.21 g/cc). Interaction between treatments and variety was found to be non-significant.

Table 4.5: Effect of different indigenous ripening methods on specific gravity (g/cc) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	1.23	0.97	1.10
T_2:Ripe tomato	1.15	1.07	1.11
T_3:Paddy straw	0.97	0.98	0.97
T_4:Without smoke	1.29	1.14	1.21
T_5:Calcium carbide	1.20	1.19	1.19
T_6:Control	1.29	1.02	1.16
Mean	1.19	1.06	---
LSD (P=0.05)	**T=NS**	**V=NS**	**T × V =NS**

4.2.4 Physiological loss in weight

Data on the effect of various ripening methods on physiological loss in weight is presented in **Table 4.6**. The result revealed that there was a progressive increase in physiological loss in weight of banana with an increase in ripening period. The fruits of Amritsagar (V_1) showed higher physiological loss in weight as compared to Chenichampa (V_2) during ripening period. A relatively higher weight loss (14.30 %) was observed in the calcium carbide (T_5) treated fruits on 6th day in V_1 (Amritsagar) and 11.02 per cent in V_2 (Chenichampa) on 8th day. However, naturally ripened and other indigenously ripened fruits lost more than 12 per cent of their weight on day 14th day after treatment.

Table 4.6: Effect of different indigenous ripening methods on physiological loss in weight (%) of banana fruit

Treatment	Variety	Days after treatment						
		2	**4**	**6**	**8**	**10**	**12**	**14**
T_1	V_1	3.02	6.84	9.43	-	-	-	-
	V_2	3.47	5.14	7.23	9.07	-	-	-
T_2	V_1	2.43	5.32	7.94	10.26	12.30	-	-
	V_2	2.88	4.41	6.24	8.22	9.71	11.08	-
T_3	V_1	3.65	4.67	6.84	8.61	10.67	-	-
	V_2	3.38	5.04	6.56	8.91	9.94	11.06	-
T_4	V_1	3.23	4.15	6.19	8.81	9.61	-	-
	V_2	2.08	2.93	4.83	7.92	8.23	10.62	12.33
T_5	V_1	5.68	8.25	14.30	-	-	-	-
	V_2	3.95	6.47	9.76	11.02	-	-	-
T_6	V_1	2.55	4.02	6.33	9.13	11.74	-	-
	V_2	2.12	3.85	6.19	8.10	10.13	11.67	12.16

V_1 = Amritsagar V_2 = Chenichampa

4.3. Biochemical characters of banana fruits

4.3.1 Total soluble solids

Data on TSS content of banana pulp is presented in **Table 4.7.** It was evident from the data that there was significant difference among the treatments. Banana ripened with ripe tomato (T_2) attained maximum TSS (21.75˚Brix) and it was followed by T_3. On the other hand, the minimum TSS content (19.25ºBrix) was recorded in carbide treated fruit (T_5).

Significant variation in TSS content was observed between the varieties. Higher TSS (21.29˚Brix) was recorded in V_1 than that of V_2 (19.27ºBrix). The interaction between treatment and variety significantly affected the TSS content of the pulp and maximum TSS (23.13˚Brix) was observed in T_3V_1 (paddy straw), whereas lowest (17.33˚Brix) was found in T_4V_2.

Table 4.7: Effect of different indigenous ripening methods on TSS content (˚Brix) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	20.33	18.33	**19.33**
T_2:Ripe tomato	22.00	21.50	**21.75**
T_3:Paddy straw	23.13	20.16	**21.64**
T_4:Without smoke	22.50	17.33	**19.92**
T_5:Calcium carbide	20.83	17.67	**19.25**
T_6:Control	19.00	20.67	**19.83**
Mean	**21.29**	**19.27**	---
LSD (P=0.05)	**T=1.620**	**V=0.935**	**T × V =2.291**

4.3.2 Titratable acidity

The different ripening methods significantly influenced the titratable acidity of banana pulp **(Table 4.8).** Among the treatments, highest titratable acidity (0.347 %) was observed in T_5 (calcium carbide) followed by smoke treated banana (T_1). The lowest titratable acidity content (0.245 %) was observed in fruits ripened in control (T_6).

Significant difference in titratable acidity content of banana pulp was observed due to treatment. The higher acidity was found in V_2 (0.323 %) than that of V_1 (0.274 %).

Due to interaction effect the maximum titratable acidity content was observed in T_4V_2 (0.368 %) and minimum 0.179 per cent in T_6V_1.

Table 4.8: Effect of different indigenous ripening methods on Titratable acidity content (%) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	0.313	0.332	**0.322**
T_2:Ripe tomato	0.313	0.234	**0.274**
T_3:Paddy straw	0.223	0.344	**0.284**
T_4:Without smoke	0.268	0.368	**0.318**
T_5:Calcium carbide	0.346	0.348	**0.347**
T_6:Control	0.179	0.310	**0.245**
Mean	**0.274**	**0.323**	---
LSD (P=0.05)	**T=0.063**	**V=0.036**	**T × V =0.089**

4.3.3 Ascorbic acid

Data presented in **Table 4.9** revealed the effect of various indigenous ripening methods on the ascorbic acid content. The ascorbic acid content was recorded maximum (5.19 mg/100g) in T_3 (ripened with paddy straw). The fruit treated with calcium carbide (T_5) recorded minimum ascorbic acid content (3.05 mg/100g).

There was no significant difference between the varieties on ascorbic acid content of banana. Similarly, interaction effect due to treatment and variety was found non-significant. However, highest ascorbic acid (5.46 mg/100g) content was observed in T_3V_2 and lowest in T_5V_2 (calcium carbide).

Table 4.9: Effect of different indigenous ripening methods on Ascorbic acid content (mg/100g) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	4.43	4.35	**4.39**
T_2:Ripe tomato	3.06	4.20	**3.63**
T_3:Paddy straw	4.93	5.46	**5.19**
T_4:Without smoke	4.50	4.08	**4.29**
T_5:Calcium carbide	3.10	3.00	**3.05**
T_6:Control	3.83	4.50	**4.17**
Mean	**3.91**	**4.27**	---
LSD (P=0.05)	**T=0.88**	**V=NS**	**T × V =NS**

4.3.4 Reducing sugar

The data pertaining in **Table 4.10** indicated that the reducing sugar differed significantly among the treatments. The highest (5.12 %) reducing sugar was observed in T_2 (fruit ripened with ripe tomato) which was followed by T_1 (4.54 %) and

T_3 (4.50 %). The lowest reducing sugar (3.40 %) was recorded in calcium carbide treated (T_5) fruits.

It was found that Amritsagar (V_1) had more reducing sugar (4.55 %) as compared to Chenichampa (V_1) (3.97 %). Due to interaction effects, the highest reducing sugar content of 5.66 per cent was recorded in T_3V_1 (paddy straw), whereas lowest was found in T_5V_2 (3.09 %).

Table 4.10: Effect of different indigenous ripening methods on reducing sugar content (%) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	4.93	4.15	**4.54**
T_2:Ripe tomato	4.81	5.43	**5.12**
T_3:Paddy straw	5.66	3.35	**4.50**
T_4:Without smoke	4.36	4.19	**4.27**
T_5:Calcium carbide	3.71	3.09	**3.40**
T_6:Control	3.84	3.63	**3.74**
Mean	**4.55**	**3.97**	---
LSD (P=0.05)	**T=0.56**	**V=0.32**	**T × V =0.79**

4.3.5 Total sugar

The results revealed significant differences with respect to total sugar content of banana due to different ripening treatments (**Table 4.11).** The total sugar was recorded to be maximum (6.15 %) in T_2 (ripened with ripe tomato) followed by T_1 (5.97 %). The lowest total sugar content (3.71 %) was observed in fruits treated with calcium carbide (T_5).

Table 4.11: Effect of different indigenous ripening methods on total sugar content (%) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	6.32	5.63	**5.97**
T_2:Ripe tomato	7.55	4.76	**6.15**
T_3:Paddy straw	5.65	4.96	**5.30**
T_4:Without smoke	4.97	4.72	**4.84**
T_5:Calcium carbide	3.28	4.14	**3.71**
T_6:Control	3.57	4.76	**4.16**
Mean	**5.22**	**4.83**	---
LSD (P=0.05)	**T=0.72**	**V=NS**	**T × V =1.02**

There were no significant differences in total sugar content between the varieties. However, on an average, higher total sugar was found in V_1 (5.22 %). Due to interaction effects, the higher total sugar content of 7.55 per cent was observed in T_2V_1 (fruit ripened with ripe tomato) and minimum (3.28 %) in T_5V_1 *i.e.* calcium carbide treated Amritsagar fruits.

4.3.6 Moisture content

Moisture content of banana fruit as observed in the present investigation is displayed in **Table 4.12.** It was evident from the table that there was a significant difference between the treatments and the varieties. It was noted that moisture content in banana fruit was significantly higher (73.85 %) in the fruits ripened by using ripe tomato fruit (T_2). The moisture content in smoke treated (T_1) fruit was 71.71 per cent. The lowest moisture (68.92 %) content was found in banana fruits that were ripened with calcium carbide (T_5).

There were significant differences between the varieties in relation to moisture content where Amritsagar (V_1) retained 71.65 per cent and Chenichampa (V_2) retained 70.16 percent.

The moisture content was found to be significantly highest (74.64 %) in T_2V_1 (ripe tomato) and due to interaction effect lowest being found in T_4V_2 (66.97 %) which were ripened without smoke.

Table 4.12: Effect of different indigenous ripening methods on moisture content (%) of banana fruit.

Treatment	**Variety**		**Mean**
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	70.73	72.68	**71.71**
T_2:Ripe tomato	74.64	73.06	**73.85**
T_3:Paddy straw	69.50	71.23	**70.36**
T_4:Without smoke	71.95	66.97	**69.46**
T_5:Calcium carbide	70.04	67.81	**68.92**
T_6:Control	73.03	69.18	**71.11**
Mean	**71.65**	**70.16**	---
LSD (P=0.05)	**T=2.40**	**V=1.39**	**T × V =3.40**

4.3.7 Ash content

Ripening by different indigenous methods significantly influenced the ash content of banana fruits (**Table 4.13)**. The higher ash content (1.84 %) was observed in T_4 followed by T_2 (1.83 %). Ash content (1.52 %) of smoke treated banana fruits (T_1) was at par with control fruit (T_6). The minimum ash content (1.39 %) was recorded in fruits ripened with paddy straw (T_3).

No significant difference was observed between the varieties of banana with respect to ash content.

Table 4.13: Effect of different indigenous ripening methods on ash content (%) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2** (Chenichampa)	
T_1:Smoke	1.65	1.39	**1.52**
T_2:Ripe tomato	1.89	1.76	**1.83**
T_3:Paddy straw	1.66	1.12	**1.39**
T_4:Without smoke	1.91	1.76	**1.84**
T_5:Calcium carbide	1.17	1.64	**1.40**
T_6:Control	1.44	1.60	**1.52**
Mean	**1.66**	**1.54**	---
LSD (P=0.05)	**T=0.23**	**V=NS**	**T × V =0.33**

The interaction between treatments and varieties had significant effect on ash content of banana fruit. Banana fruit ripened without smoke (T_4) had maximum ash content (1.91 %) in Amritsagar (V_1) and lowest ash content was found in T_3V_2 (1.12 %) which were ripened with paddy straw.

4.4 Mineral compositions of the fruits

4.4.1 Calcium content

The effect of different ripening method on calcium content of banana revealed that fruit ripened with tomato (T_2) gave higher calcium content (17.38 mg/100g) while carbide treated fruit (T_5) exhibited lowest calcium content (9.90 mg/100g) as in **Table 4.14.** The treatment T_4 (14.68 mg/100g) was at par with T_1 (14.16 mg/100g).

Significant variation in calcium content between the varieties of banana was observed. Chenichampa (V_2) retained more calcium (14.19 mg/100g) than Amritsagar (V_1) *i.e.* 11.95 mg/100g. The interaction effect between varieties and treatments was found to be significant. Due to interaction effect, calcium content was maximum 17.71 mg/100g in fruits with ripe tomato (T_2V_2) and lowest (8.38 mg/100g) recorded in T_5V_1 (calcium carbide treated Amritsagar fruits).

Table 4.14: Effect of different indigenous ripening methods on calcium content (mg/100g) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	11.07	17.24	**14.16**
T_2:Ripe tomato	17.05	17.71	**17.38**
T_3:Paddy straw	12.90	11.09	**11.99**
T_4:Without smoke	13.74	15.62	**14.68**
T_5:Calcium carbide	8.38	11.43	**9.90**
T_6:Control	8.53	12.04	**10.28**
Mean	**11.95**	**14.19**	---
LSD (P=0.05)	**T=1.85**	**V=1.07**	**T × V =2.62**

4.4.2 Magnesium content

The amount of magnesium present in banana fruit varied significantly among the treatments **(Table 4.15)**. Banana fruits ripened with ripe tomato contained the highest magnesium (58.47 mg/100g) followed by T_1 *i.e.* fruits ripened with smoke treatment (57.06 mg/100g). The minimum magnesium content (52.90 mg/100g) was recorded in T_5 (calcium carbide).

A significant difference was noticed between the varieties in respect to magnesium content where Chenichampa (V_2) recorded higher magnesium (70.88 mg/100g) as compared to 39.72 mg/100g in Amritsagar (V_1).

It was observed that interaction effect between treatments and varieties on magnesium content was significant in the present study. Due to interaction, magnesium content was higher in T_1V_2 (74.89 mg/100g) followed by T_3V_2 (73.28 mg/100g) and the lowest (33.19 mg/100g) was recorded in T_3V_1.

Table 4.15: Effect of different indigenous ripening methods on magnesium content (mg/100g) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	39.24	74.89	**57.06**
T_2:Ripe tomato	46.55	70.39	**58.47**
T_3:Paddy straw	33.19	73.28	**53.23**
T_4:Without smoke	42.31	71.11	**56.71**
T_5:Calcium carbide	38.61	67.18	**52.90**
T_6:Control	38.42	68.44	**53.43**
Mean	**39.72**	**70.88**	---
LSD (P=0.05)	**T=2.31**	**V=1.33**	**T × V =3.27**

4.4.3 Potassium content

A perusal of data (**Table 4.16)** revealed that there was significant effect of different ripening methods on potassium content of banana fruits. The highest potassium content (427.28 mg/100g) was observed in fruits ripened with ripe tomato (T_2) while the lowest (396.30 mg/100g) was observed in T_5 (calcium carbide treated fruit). T_1 (413.45 mg/100g) and T_3 (410.37 mg/100g) were at par with each other.

The banana fruit showed significant difference in potassium content between the varieties. It showed that the V_2 contain higher (412.05mg/100g) potassium than V_1 (405.73 mg/100g).

Potassium content due to interaction effect between treatment and variety was significant. The maximum potassium (434.67 mg/100g) was observed in T_2V_2 (Amritsagar fruits ripened with tomato) and minimum in 393.98 mg/100g in T_5V_2.

Table 4.16: Effect of different indigenous ripening methods on Potassium content (mg/100g) of banana fruit

Treatment	**Variety**		**Mean**
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	410.03	416.88	**413.45**
T_2:Ripe tomato	419.88	434.67	**427.28**
T_3:Paddy straw	401.13	419.60	**410.37**
T_4:Without smoke	397.91	401.04	**399.48**
T_5:Calcium carbide	398.62	393.98	**396.30**
T_6:Control	406.78	406.15	**406.47**
Mean	**405.73**	**412.05**	---
LSD (P=0.05)	**T=5.52**	**V=3.19**	**T × V =7.81**

4.4.4 Phosphorous

Data representing phosphorous content of banana is presented in **Table 4.17.** The phosphorous content was significantly influenced by the different ripening methods. The highest phosphorous content (74.81 mg/100g) was recorded in T_5 (calcium carbide) and it was followed by T_3 *i.e.* fruits ripened with paddy straw (69.02 mg/100g). On the other hand, T_4 (without smoke) exhibited the lowest phosphorous (63.77 mg/100g) content.

There was significant difference between the varieties in respect to phosphorous content. The results indicated higher phosphorous content in V_1 (74.56 mg/100g) as compared to V_2 (60.16 mg/100g).

The interaction effect due to treatment and variety was significant. Due to interaction effect the higher Phosphorous content of 81.96 mg/100g was observed in

T_5V_1 (calcium carbide treated) and it was followed by 76.82 mg/100g inT_3V_1 (paddy straw). The minimum phosphorous content was 53.94 mg/100g in which banana ripened in without smoke.

Table 4.17: Effect of different indigenous ripening methods on Phosphorous content (mg/100g) of banana fruit

Treatment	Variety		Mean
	V_1 (Amritsagar)	**V_2 (**Chenichampa)	
T_1:Smoke	70.86	59.08	**64.97**
T_2:Ripe tomato	73.46	60.35	**66.90**
T_3:Paddy straw	76.82	61.22	**69.02**
T_4:Without smoke	73.60	53.94	**63.77**
T_5:Calcium carbide	81.96	67.66	**74.81**
T_6:Control	70.65	58.69	**64.67**
Mean	**74.56**	**60.16**	---
LSD (P=0.05)	**T=2.49**	**V=1.44**	**T × V =3.53**

4.5 Sensory evaluation

Consumer's acceptability of banana depends on colour, flavour and taste. The result of the preferential score of the panel members were summarized **(Table 4.18)**. It was observed that banana fruit ripened with calcium carbide (T_5) had the highest score for colour in both V_1 and V_2 (8.89 and 8.35) followed by fruit ripened with tomato (T_2). Similarly, in terms of flavour and taste of banana fruit ripened with ripe tomato was able to score highest (8.01 and 7.88) in V_1 and (7.89 and 7.78) in V_2 as compared to rest of the ripening methods. The overall score (23.93) was highest in T_2 (fruit ripened with tomato) while lowest score found in T_5 (21.35) for Chenichampa.

Table 4.18: Effect of different indigenous ripening methods on sensory evaluation of banana fruit

Treatment	Variety	Colour	Flavour	Taste	Overall score
T_1 :Smoke	V_1	7.5	7	7.7	**22.20**
	V_2	7.3	7.11	7.54	**21.95**
T_2 :Ripe tomato	V_1	8.04	8.01	7.88	**23.93**
	V_2	8.00	7.89	7.78	**23.67**
T_3 :Paddy straw	V_1	7.00	7.78	7.66	**22.41**
	V_2	7.30	7.22	7.18	**21.73**
T_4 :Without smoke	V_1	7.33	7.33	7.22	**21.88**
	V_2	7.78	7.56	7.56	**22.90**
T_5 :Calcium carbide	V_1	8.89	7.06	6.42	**22.37**
	V_2	8.35	6.78	6.22	**21.35**
T_6 :Control	V_1	6.88	7.72	7.29	**21.89**
	V_2	7.12	7.30	7.39	**21.81**

V_1 = Amritsagar V_2 = Chenichampa

CHAPTER V

DISCUSSION

Banana is a fruit which is generally used after ripening. Ripening of fruit is a natural process and it makes the fruit sweeter and soft. Ethylene activates the enzymes which ultimately change the internal composition of the fruits. Natural ripening depends upon certain factors like management practices, stage of harvesting, environmental factors, temperature etc. Some chemicals or ripening agents are used for artificial ripening of the fruits by the traders and growers to advance the ripening process. But the use of chemicals particularly ethephon and calcium carbide in artificial ripening has already been proved as health hazards chemicals. Continuous consumption of artificially ripened fruits by such chemicals causes number of disorders in human body. The present investigation was aimed to evaluate the effect of different indigenous methods of ripening on quality and shelf life of banana fruits. The results have already been presented in the preceding chapter and in this chapter, an attempt has been made to discuss the findings with a view to bring about a clear understanding of the reasons.

5.1 Phenological characters

The findings of the study showed that banana fruits treated with calcium carbide attained fully ripe stage within 2.5 days with shortest shelf life of 5.33 days. The faster ripening in calcium carbide treated fruits might be due to acceleration of the ripening process as acetylene initiates ethylene. The results were in conformity with Sogo-Temi *et al.* (2014); Smith and Thompson (1987) in papaya and Ajayi and Mbah (2007). Similar observation was also reported by Chandramonti *et al.* (1991) and Joon *et al.* (2001) in mango fruits. As the ripening period was very short in calcium carbide treated fruits this might have contributed to reduce the shelf life of banana. The application of calcium carbide also increases the rate of respiration, release more heat which caused rapid ripening and eventually leads to faster deterioration or shorter shelf life of the banana fruits.

Ripening period was 5-6 days in ripe tomato treated and smoke treated banana fruits. The shortening of ripening period in ripe treated fruits might be due to the release of ethylene by the ripe tomato fruits while ripening period was shortened in ripening of fruits in covered pits with smoke due to the generation of heat and ethylene. On the other hand, the longest ripening period with longest shelf life was observed in fruits that were ripened naturally (control). This might be due to the fact that the fruits were kept in open condition without effect of any climatic factor advanced the ripening process slowly. These results, generally, are matched with those reported by Adeyemi *et al,* (2018) and Thompson and Seymour (1982).

Among the varieties, Amritsagar fruits ripened faster than chenichampa. with shorter shelf life. The results might be due to increase in respiration, producing large amount of heat and ethylene production in Amritsagar (V_1). Since banana is also a climacteric fruit, it exhibits a respiratory peak during ripening advancing its ripening period. Similar results were also reported by Gane (1936) and Masimbe (1997) in banana. This finding was also in agreement with the results presented by Adewole and Duruji (2010). Since Chenichampa fruits (V_2) ripened slowly as compared to Amritsagar therefore, the slower ripening rate might have increased the shelf life of Chenichampa variety in the present study. The result is supported by the findings of Godambe (2012).

5.2 Physical characters of banana fruits

The results of the experiment showed that among the treatments fast colour initiation was observed in banana fruits ripened with calcium carbide and the colour initiation was very slow in fruits without any treatment (T_6). This might be due to loss of green colour in the peel due to the continuing degradation of the chlorophyll structure during ripening (Tourky *et al.*, 2014 in banana and Salvador *et al.* (2007) in persimmon). Ripening agents accelerated ripening process faster than the fruits ripened naturally. Similar findings were also recorded by Adewole and Duruji (2010) in plantain; Hakim *et al.* (2012) and Singal *et al.* (2012) in banana.

The pulp-peel ratio of banana was highest in fruits ripened with ripe tomato. The increase was related to accumulation of moisture in the pulp derived from carbohydrate breakdown and osmotic transfer from peel to pulp. Increasing the sugar content in the pulp could allow the water to move from the peel to pulp, hence pulp-peel ratio increased with increase in TSS and moisture content. The results were in line with Narasimham *et al.* (1971).

The values of the specific gravity of ripe banana fruits were in the range of 0.97 per cent to 1.21 per cent. The increase in the specific gravity during ripening revealed that, the depletion of fruit weight was more than corresponding decrease in its volume. Accelerated biochemical activities and respiration might have contributed to increase in specific gravity. The high correlation between pulp, peel-ratio and specific gravity revealed that migration of bio-chemical compound from peel to pulp might cause the increase in specific gravity. Similar observations had been reported in karonda by Joshi *et al.* (1986) and in sapota by Pawar *et al.* (2011).

The physiological loss in weight of banana, irrespective of different ripening methods, increased as the time advanced. The maximum physiological loss in weight was recorded in fruits treated with calcium carbide. This increase in physiological loss in weight in calcium carbide treated fruits during ripening could be due to upsurge in respiration rate leading to faster and uniform ripening compared to other treatments. Similar results were reported by Singh *et al.* (1977) in banana and Mahajan *et al.* (2008) in guava fruits. In all the treatments, the percentage of weight loss increased with the progress of storage time and ripening, which possibly resulted from transpiration and respiration process of the fruits. Dharmasena and Kumari (2005) remaked that energy produced from the respiration process in the form of heat was released from the fruits by evaporation of water which caused weight loss. Mahajan *et al.* (2010), Venktasubbaiah *et al.* (2013) and Kumar (2006) also reported the similar findings in banana fruits.

Among the varieties, the colour initiation was faster in Amritsagar than Chenichampa but Chenichampa variety exhibited higher pulp-peel ratio (2.16). The faster colour initiation in Amritsagar might be due to the faster degradation of chlorophyll and genetic factor. The peel of Chenichampa banana lost water by transpiration to the atmosphere and also to the pulp by osmosis, thereby contributing to an increase in the fresh weight of the pulp as the fruit ripened. The increases in sugar concentration in the pulp increased the pulp weight (Stover and Simmonds, 1987; Dadzie and Orchard, 1997 in banana).

5.3 Biochemical characters of banana fruits

In the present study, the biochemical characters were studied and observed that TSS (21.75˚Brix), reducing sugar (5.12 %), total sugar (6.15 %), and moisture (73.85 %) were highest in fruits ripened with ripe tomato while the lowest values of these parameters were found in calcium carbide treated fruits. The increase in TSS, reducing sugar and total sugar during ripening might be resulted from an increase in concentration of organic solutes as consequences of water loss and hydrolysis of starch into soluble sugars as sucrose, glucose and fructose. Islam (1998) revealed that the conversion of starch into reducing sugar through the process of glucogenesis caused increase in reducing sugar. Similar results were also revealed by Gama *et al.* (2015) and Mebratie *et al.* (2015) in banana fruits.

The titratable acidity (0.347 %) was highest in calcium carbide treated fruits in which TSS, reducing sugar and total sugar were lowest. The highest acidity level in calcium carbide treated fruits might be due to faster ripening leading to incomplete hydrolysis of starch during the ripening of fruits. This result was in conformity with the work of Das and Balamohan (2013) in mango fruit.

Among the different indigenous ripening methods, the ascorbic acid content was recorded to be maximum (5.19 mg/100g) in banana fruits ripened with paddy straw. As per ripening chemistry, ascorbic acid decreases with increase in temperature. The fruits treated with calcium carbide (T_5) recorded minimum ascorbic acid content which could be due to the effect of increase in temperature and the storage duration. Gunasekara *et al*. (2015) reported that the least ascorbic acid was detected from the fruits treated with calcium carbide which confirms the findings of the present investigation. Izundu *et al*. (2016) also found that calcium carbide treated banana contained lesser ascorbic acid as compared to untreated naturally ripened banana. The various ripening methods significantly influenced the ash content of banana fruits.

The higher ash content (1.84 %) was observed in banana fruits kept in pits without smoke (T_4) and the lower ash content was recorded in fruits ripened with paddy straw (1.39 %) and with calcium carbide (1.40 %). Lower ash contents in fruits might be due to loss of fruit weight through respiration where significant carbon was lost. According to Kulkarni *et al.* (2004), calcium carbide increased the metabolism of the fruits resulting reduced ash content.

It was noted that moisture content in banana fruits was significantly higher (73.85 %) in the fruits which were ripened by using ripe tomato fruits. This increase in moisture in fruits might be due to the carbohydrate breakdown and osmotic transfer from peel to pulp (John and Marchal, 1995). The least moisture content was found in the banana fruits ripened by calcium carbide. Liu (2003) opined that reduction in moisture content might be mainly due to water loss through transpiration process, while some weight loss was due to loss of carbon in respiration process. Similar results were also reported earlier by Gunasekara *et al.* (2015) in banana. Joon *et al.* (2001) also revealed the affects of calcium carbide on moisture content in fruits.

Among the varieties, Amritsagar fruits had higher TSS (21.29˚Brix), reducing sugar (4.55 %), total sugar (5.22 %) and moisture (71.65) than in Chenichampa fruits. The results obtained might be due to the reduced titratable acidity (0.274 %) in Amritsagar. Marriot (1980) and Seymour *et al*. (1993) reported that during the climacteric stage, the accumulated polysaccharide is rapidly degraded and most of it is converted into soluble sugars which form a large proportion of TSS in the banana. The increase in TSS of banana is previously reported by Bravelled (1993) and Abu *et al*. (1995). On the other hand, the higher titratable acidity (0.323 %) was recorded in Chenichampa banana. Desai and Deshpande (1975) reported that the increased acidity in banana fruits during ripening might be resulting from an obstruction in Proton transfer as the fruits ripen; while decrease in acidity later during ripening might be due to utilization of organic acid in respiratory process The present findings were also in line with the findings of Pendharkar *et al.* (2011) in banana.

The moisture content was significantly higher in Amritsagar which could be due to increase in sugar content in the pulp as a result of starch hydrolysis to sugar (Mohapatra *et al.*, 2010).

There was no significant difference between the variety on ascorbic acid and ash content of banana that were ripened by various method. However, Ascorbic acid was higher in Chenichampa and the lowest was recorded in Amritsagar. The decrease in ascorbic acid during storage could be due to the conversion of dehydro ascorbic to diketogulonic acid by oxidation (Ishaq *et al.*, 2009). Though there was no significant difference between the varieties, ash content in Amritsagar (V_1) was higher than Chenichampa (V_1). Higher ash contents in Amritsagar fruits might be due to the genetic constituents of cultivars with more *acuminata* than that of Chenichampa. Similar result was also reported by Wadud and Absar (1996) in banana.

5.4 Mineral composition of banana fruits

Results of mineral compositions (calcium, magnesium, phosphorous and potassium) of ripe banana pulp showed that they were significantly influenced by different ripening methods. The maximum calcium content, magnesium content and potassium content were recorded in fruits ripened with ripe tomato while the highest phosphorous content (74.81 mg/100g) was exhibited by calcium carbide treated fruits.

Among the different ripening methods, the most abundant mineral composition of banana fruits was potassium followed by phosphorous. The variation in the mineral compositions might be due to the application of different ripening treatments. The lowest magnesium content was observed in T_5 (calcium carbide) which could be due to rapid color development of the fruit. Hearer (1986) and Fonad (1996) reported that the level of magnesium in ripe banana depends on the conversion of chlorophyll, the green pigment in unripe banana to carotenoids in ripe banana. Similar variation in calcium content was also reported by Smitha *et al.* (2015) in banana.

The present study revealed that potassium content was found to be highest in fruits ripened with ripe tomato and lowest in T_5 (calcium carbide). The results are in close agreement with the findings of Jyothirmayi and Rao (2015) and Sampath *et al.* (2012).

The phosphorous content of ripe banana was found to be the highest in the fruits ripened by using calcium carbide. It could be due to the increased rate of production of energy rich phosphate compounds during ripening (Khan *et al.*, 1972). This result was supported by Wadud and Absar (1996).

5.5 Sensory evaluation

Consumer's acceptability of banana fruits depends on colour, aroma and Taste. The results of the preferential score of the panel members were summarized. It was observed that banana fruits ripened with calcium carbide had the highest score for colour in both the varieties. Fruits ripened with calcium carbide had good peel colour development with poor flavor (Singal *et al.*, 2012). Similarly, in terms of flavour and taste, banana fruits ripened with ripe tomato was able to score highest in fruits treated with ripe tomato (T_2) than rests of the ripening methods. This increase and decrease in taste score might be due to conversion of starch, organic acid into sugars as occurred in ripening stage. It was supported by Anthey and Philip (2005). On the other hand, the increase in flavour during ripening might be due to the formation of organic acids, alcohols, soluble sugars and other volatile compounds.

The lowest score of colour was observed in fruits without any treatment (T_6) while flavour and taste score were lowest in fruits ripen using calcium carbide. The result was in conformity with the work of Das *et al.* (2011) in mango cv Alphonso.

CHAPTER VI

SUMMARY AND CONCLUSION

An experiment on, "Effect of indigenous methods of ripening on shelf life and quality of banana fruits" was carried out in the Laboratories, Department of Horticulture and Plant Pathology, Biswanath College of Agriculture, Assam Agricultural University, Biswanath Chariali, during 2017-2019. The experiment was designed in factorial complete randomized design to study the effect of different ripening methods on shelf life and quality of banana fruits. There were six treatments namely: ripening in covered pit with smoke (T_1), ripening with ripe tomato (T_2), ripening with paddy straw (T_3), ripening in covered pit without smoke (T_4), ripening with calcium carbide (T_5) and ripening naturally at room temperature (T_6).

The salient findings of the present investigation were summarized below:

1. The phenological characters *i.e.* ripening period and shelf life of banana fruits were significantly influenced by the different ripening methods. The shortest ripening period (2.5 days) with shortest shelf life (5.33 days) and longest ripening period (13 days**)** with longest shelf life (12.50 days) was observed in calcium carbide (T_5) and control fruits (T_6). Among the varieties, Amritsagar had shortest ripening period (6.67 days) and shelf life (8.48 days) than Chenichampa.
2. Faster peel colour initiation was observed in T_5 (ripened with calcium carbide). In T_5 (carbide) and T_1 (smoke) colour initiation was attained within 2 days 3.5 days, respectively. On the other hand, slow ripening was observed in fruits kept in room temperature which required 11 days for colour initiation.
3. The pulp-peel ratio (2.20) was found to be highest in T_2 (ripened with tomato). While higher specific gravity (1.21%) and lowest pulp-peel ratio (1.83) was observed in T_4 (without smoke). Chenichampa fruits showed higher pulp-peel ratio (2.16) than Amritsagar fruits (1.76). The values for pulp-peel ratio were in the range of 1.53 to 2.23.

4. There was a progressive increase in PLW of banana fruits with an increase in ripening period. The Amritsagar fruits showed higher PLW as compared to the Chenichampa fruits during ripening period. A relatively higher weight loss (14.30 %) was observed in the fruits treated with calcium carbide (T_5) on 6^{th} day.
5. Bi-ochemical characters particularly total soluble solids (TSS), titratable acidity, ascorbic acid, reducing sugar and total sugar of the fruits determined in the present study were significantly different among the treatments. The higher TSS (21.75˚Brix), reducing sugar (5.12 %), total sugar (6.15 %), and moisture content (73.85 %) were recorded in T_2 (ripened with ripe tomato) and the lowest TSS (0.347 %), reducing sugar (3.40 %), total sugar (3.71 %), ascorbic acid (3.05 mg/100g), moisture content (68.92 %) and the maximum titratable acidity (0.347 %) were found in T_5 (calcium carbide). The values of TSS (21.29^0Brix), reducing sugar (4.55 %), total sugar (5.22 %), moisture (71.65 %) and ash content (1.66 %) and lowest titratable acidity (0.274 %) was recorded in Amritsagar fruits.
6. Among the treatments, it was observed that the average ascorbic acid (5.19 mg/100g) and ash content (1.84 %) was found to be highest in T_3 (ripened with paddy straw) and T_4 (without smoke) while the lowest titratable acidity (0.245 %) and ash content (1.39 %) were recorded in T_6 (control) and T_3 (ripened with paddy straw). Higher ascorbic acid content (3.05 mg/100g) was observed in Amritsagar (V_1).
7. The analysis of mineral compositions of banana fruits revealed that calcium, magnesium, potassium and phosphorous were differed significantly due to treatment effect. The highest calcium (17.38 mg/100g), magnesium (58.47 mg/100g) and potassium (427.28 mg/100g) was found in fruits ripened with ripe tomato. Calcium carbide treated fruits exhibited the highest phosphorous (74.81 mg/100g) content but it showed the lowest values for calcium, magnesium and potassium contents. Among the varieties, it was observed that the mineral composition was found to be higher in Chenichampa variety except phosphorous which was higher in Amritsagar variety.
8. The result of the preferential score displayed that fruit ripened with calcium carbide had the highest score for colour in Amritsagar (8.89) and Chenichampa (8.35). However, in terms of flavour and taste, fruit ripened with ripe tomato

was able to score highest score irrespective of variety. The overall score (23.93) was observed to be the highest in fruits ripened with ripe tomato (T_2) and lowest in fruits treated with calcium carbide (T_5). Among the varieties, the preferential scores for flavour and taste were highest in Amritsagar (8.01 & 7.88) and lowest in chenichampa (6.78 and 6.22).

CONCLUSION:

From the findings, it could be concluded that banana fruits could be ripened effectively either by chemical or indigenous methods. In case of calcium carbide ripened fruits, colour change was faster with bright yellow colour but with short shelf life and inferior taste. The use of carbide is known to be carcinogenic as reported earlier; thus an alternative method to induce ripening of banana fruits by ripe tomato or ripening of banana in covered pits with smoke might be used for ripening of bananas with desirable quality in terms of colour, shortening the ripening period, bio-chemical characters and shelf life. Ripening of banana using ripe tomato or ripening in covered pits with smoke might be considered as effective methods especially for small traders. Naturally ripened fruits developed poor colour, which might reduce the market price but they exhibited the longest shelf life. Further study on volume of ethylene released in different ripening agents would give an idea about the improvement of indigenous ripening methods. The measurement of release of ethylene by different ripening agents would help in quantifying the ripening agents required for artificial ripening.

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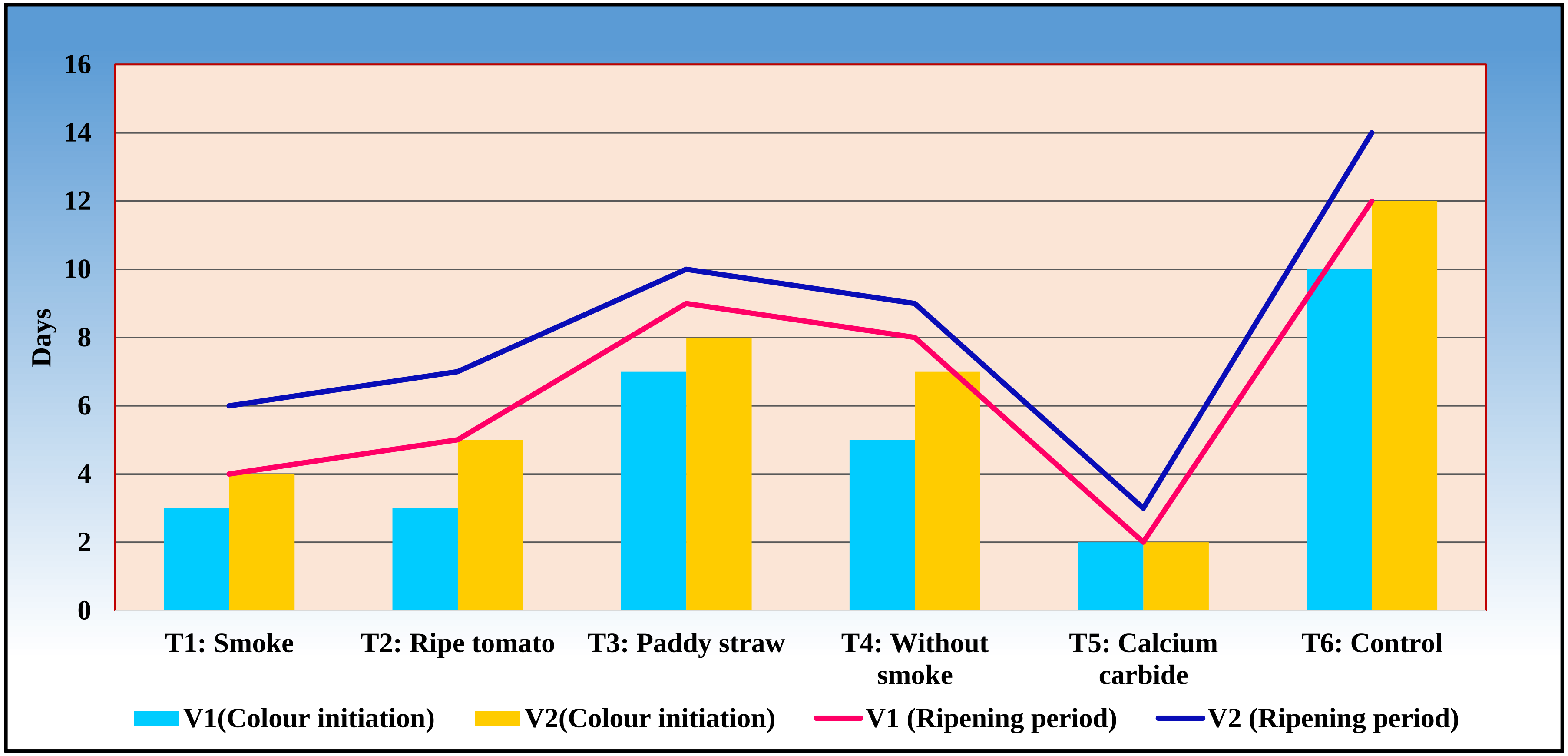


Bar graph=Colour initiation   Line graph=Ripening period

Fig 4.1: Colour initiation and Ripening period in Amritsagar (V_1) and Chenichampa (V_2)

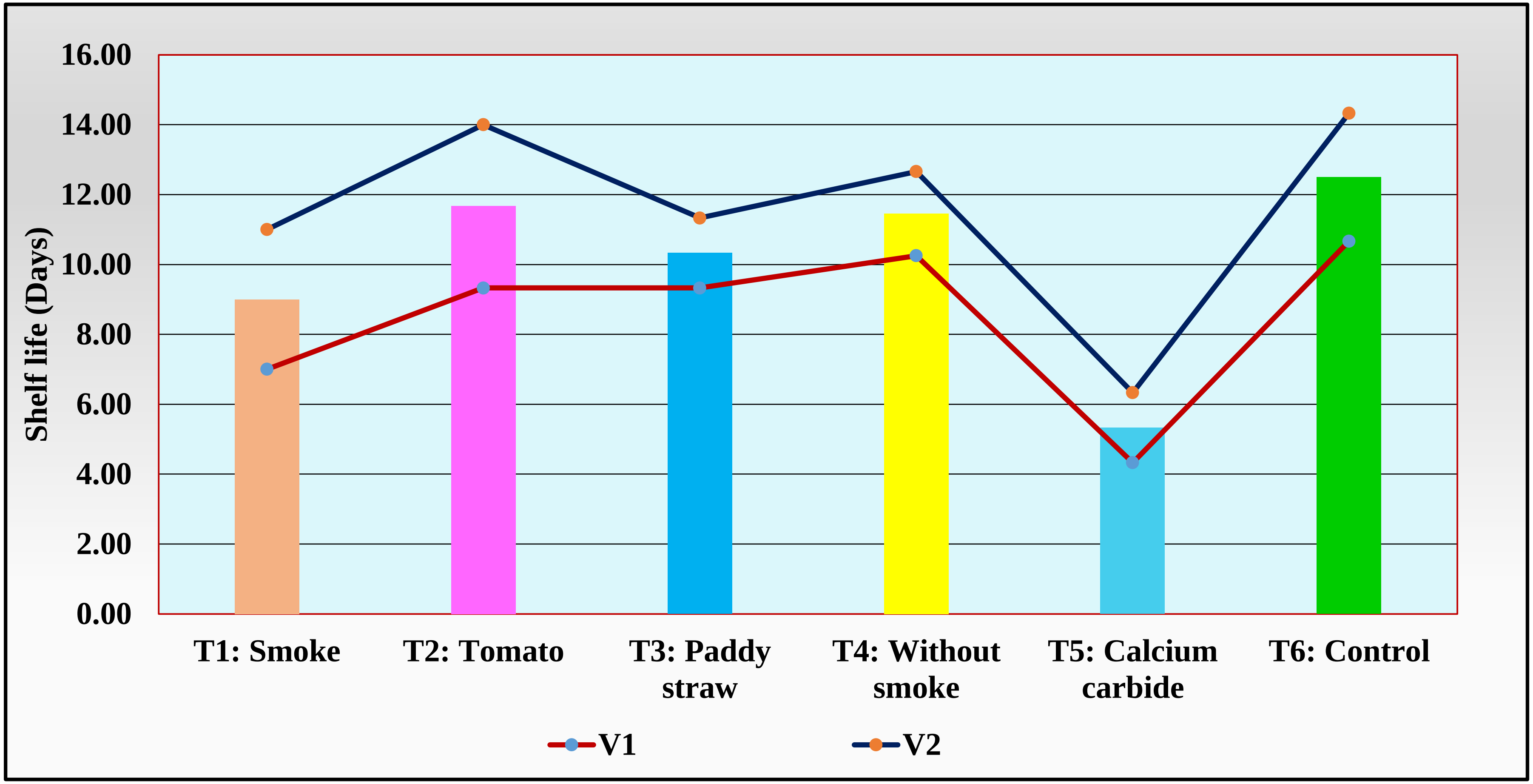


Fig 4.2: Shelf life (Days) of Amritsagar (V_1) and Chenichampa (V_2)

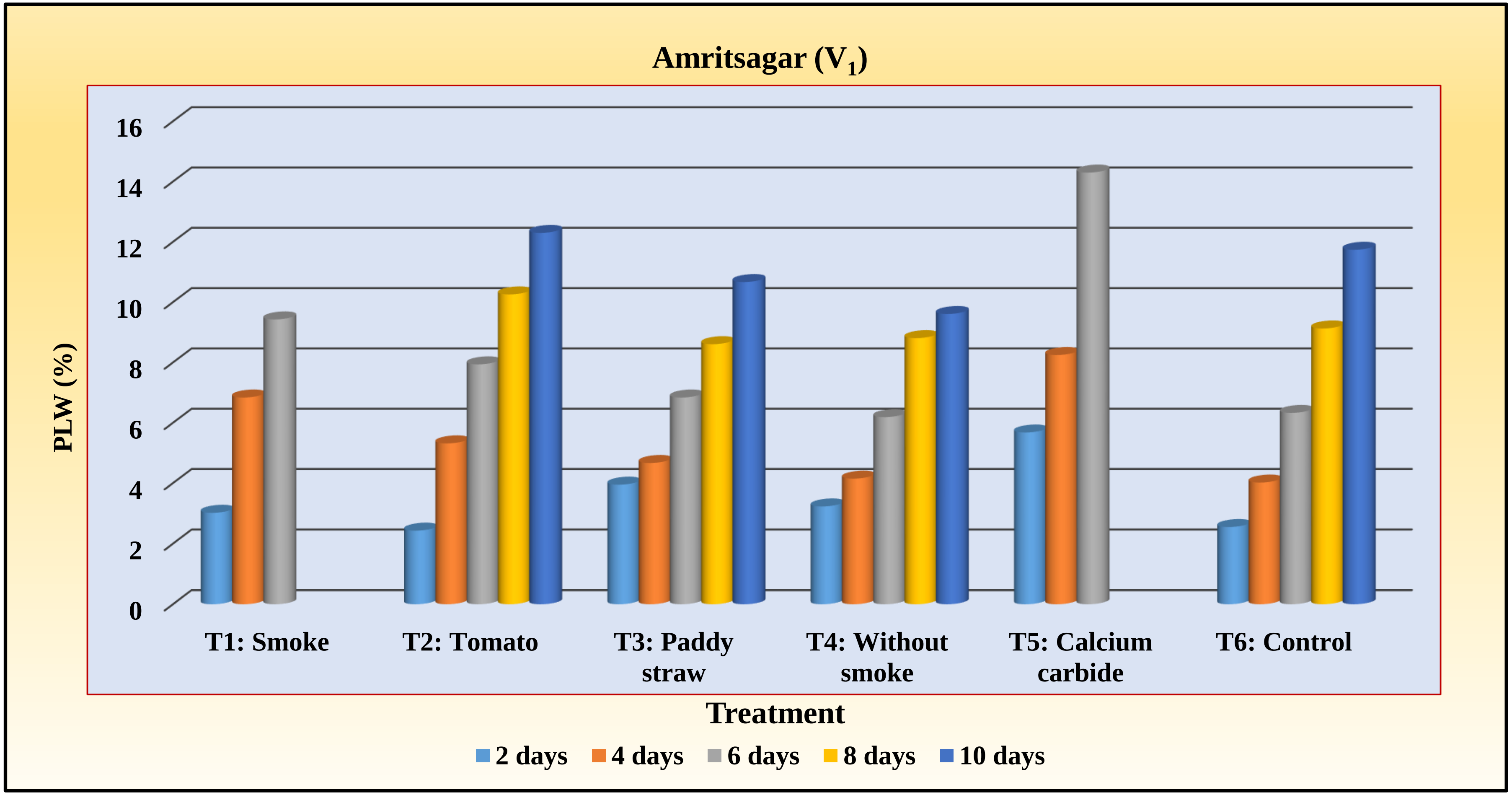


Fig. 4.3: Physiological Loss in weight (%) in Amritsagar (V_1)

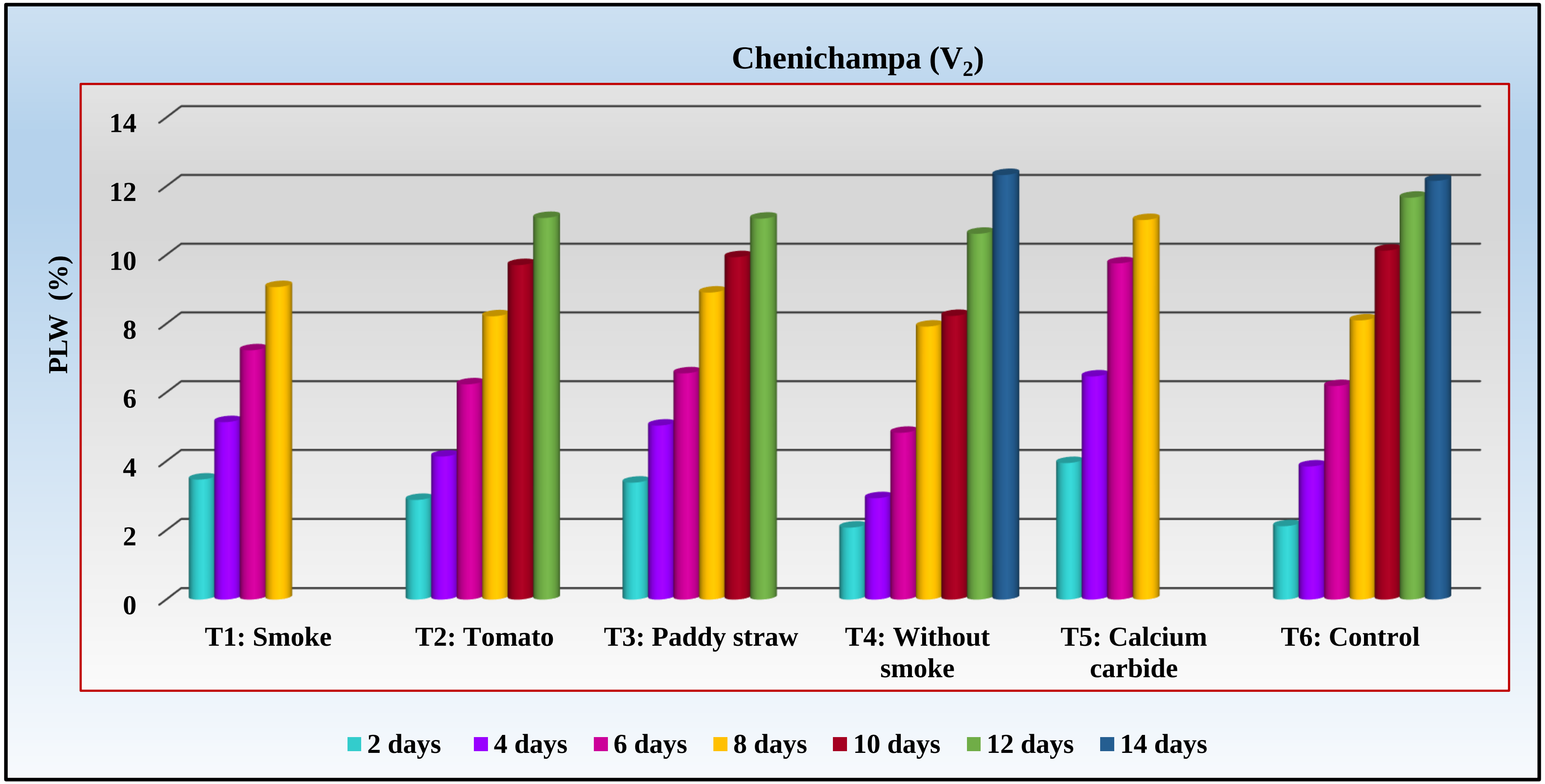
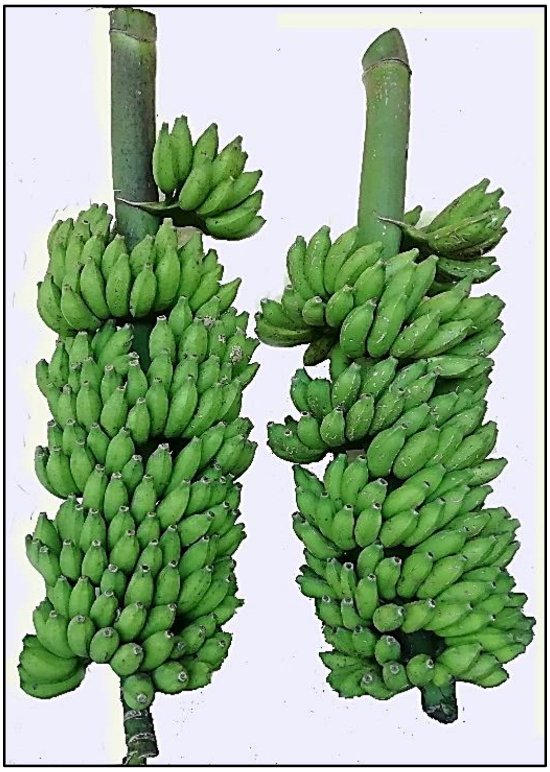


Fig 4.4: Physiological Loss in weight (%) in Chenichampa (V_2)

Amritsagar



Chenichampa

Plate 3.2: Banana fruit (Amritsagar and Chenichampa)

Amritsagar

Chenichampa

Plate 3.3: Banana hand washed with chlorinated water

T_1: Smoke

T_2: Tomato

T_3: Paddy straw

T_4: Without smoke

T_5: Calcium carbide

T_6: Control

Plate 3.4: Different ripening treatment in Amritsagar (V_1)

T_2: Tomato

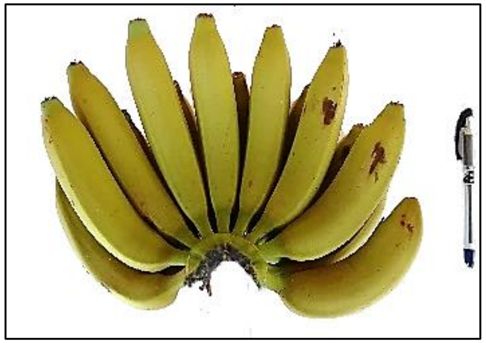
T_3: Paddy straw

T_4: Without smoke

T_5: Calcium carbide

T_6: Control

Plate 3.5: Different ripening treatment in Chenichampa (V_2)



Smoke (T_1)

Tomato (T_2)

Paddy straw (T_3)

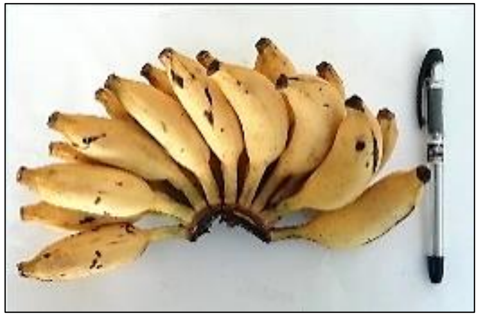
Without smoke (T_4)

Calcium Carbide (T_5)

Control (T_6)

Plate 4.5: Colour of fully ripened banana (Amritsagar)

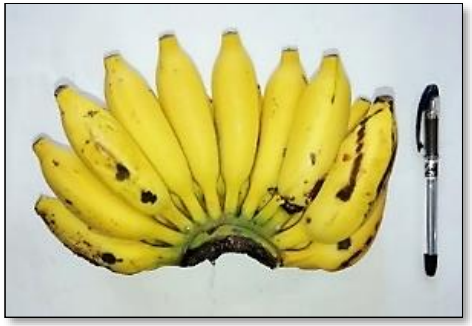
Smoke (T_1)



Tomato (T_2)

Paddy straw (T_3)

Without smoke (T_4)



Calcium Carbide (T_5)

Control (T_6)

Plate 4.6: Colour of fully ripened banana (Chenichampa)

	1st day	3rd day	5th day	7th day
T_1				
T_2				
T_3				

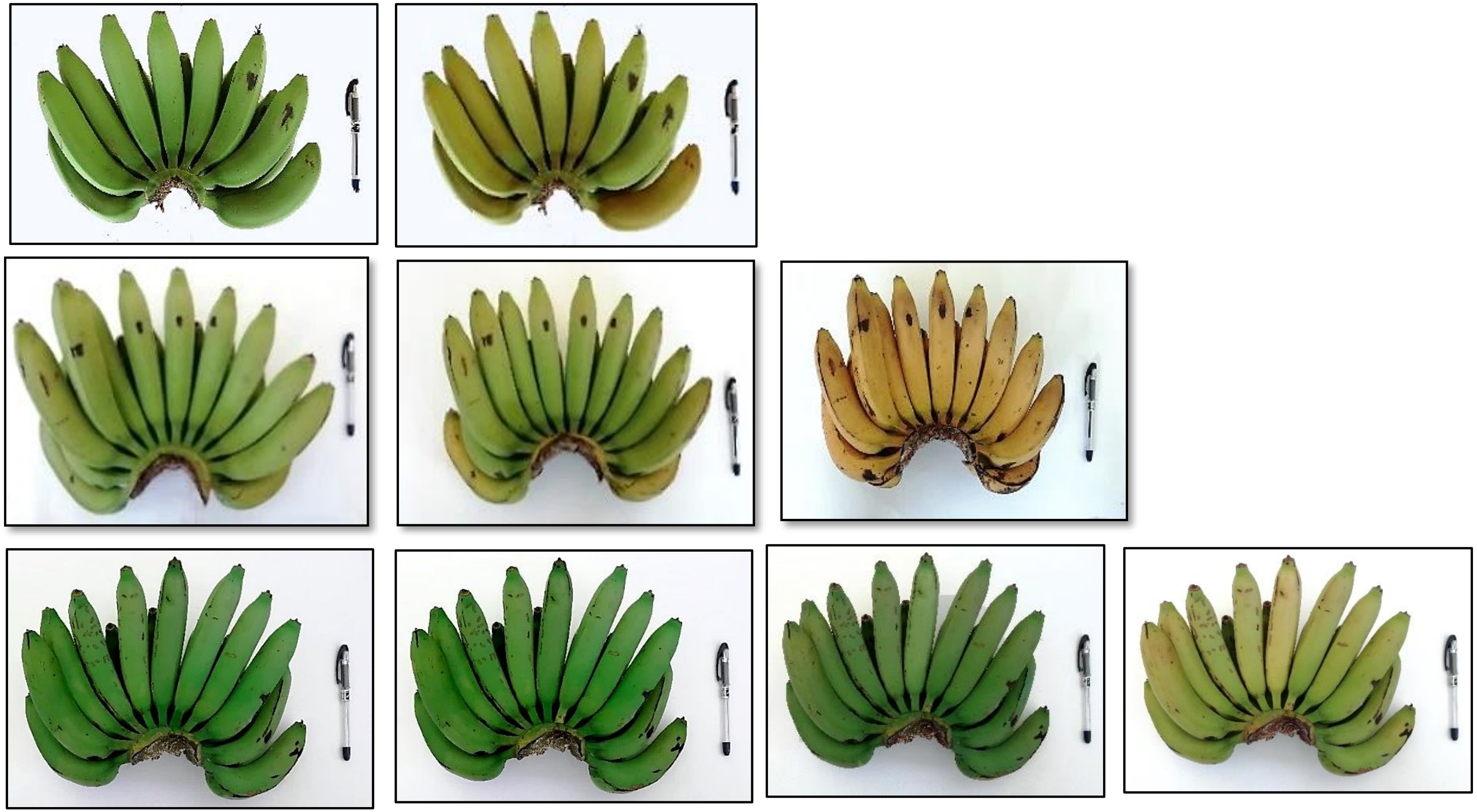


Plate 4.1: Colour changes in Amritsagar (V_1) up to 7th days of storage

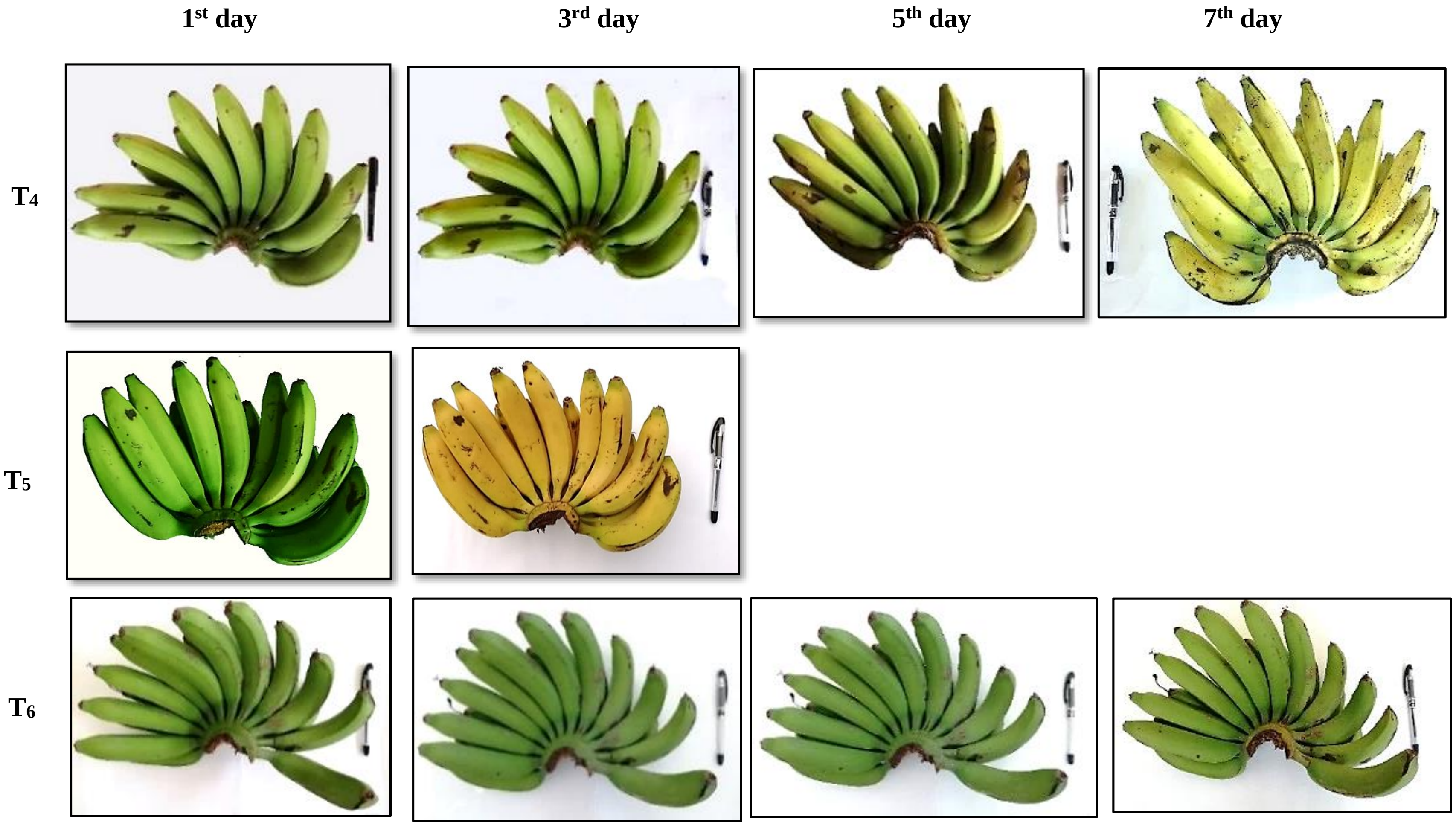


Plate 4.2: Colour changes in Amritsagar (V_1) up to 7th days of storage

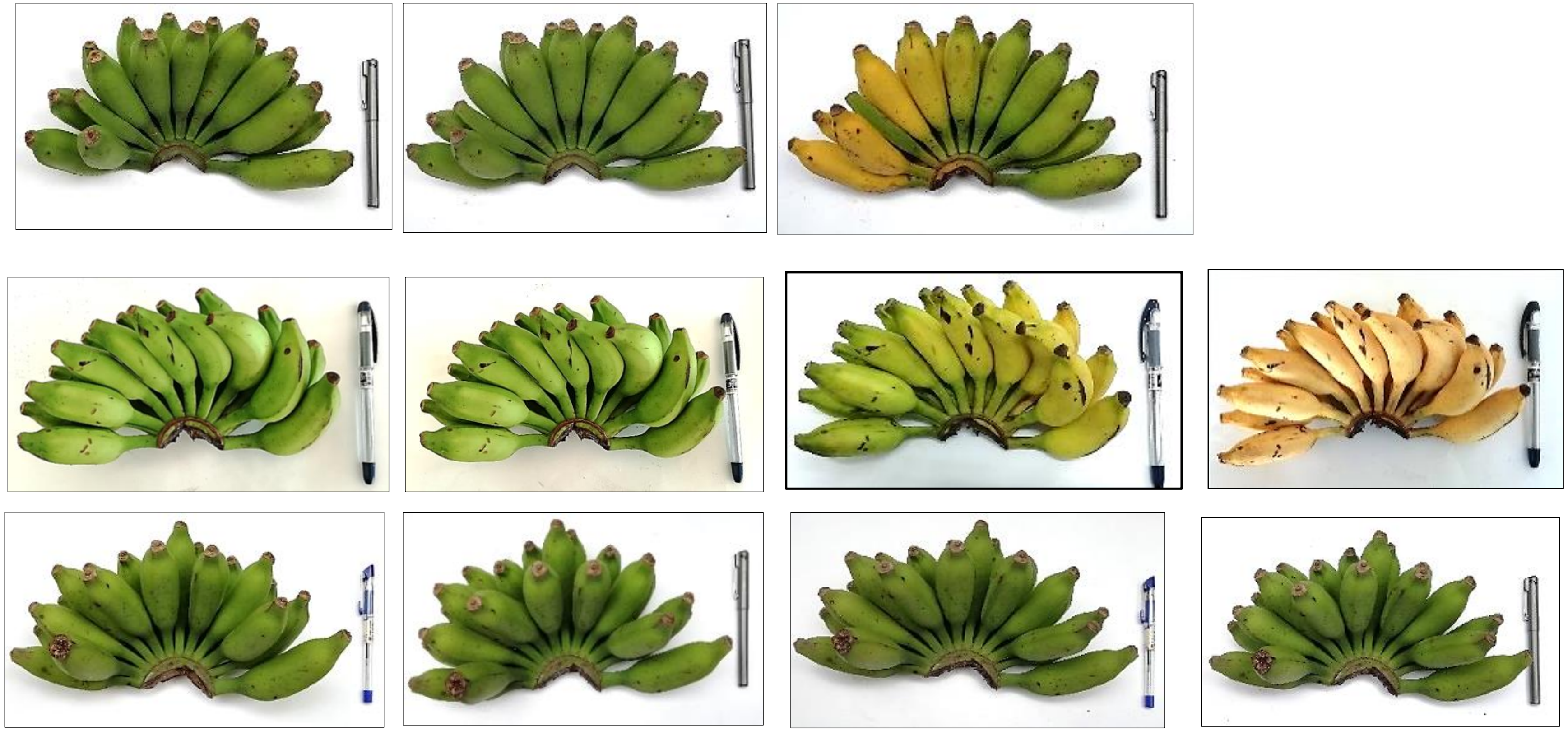


Plate 4.3: Colour changes in chenichampa (V_2) up to 7th days of storage

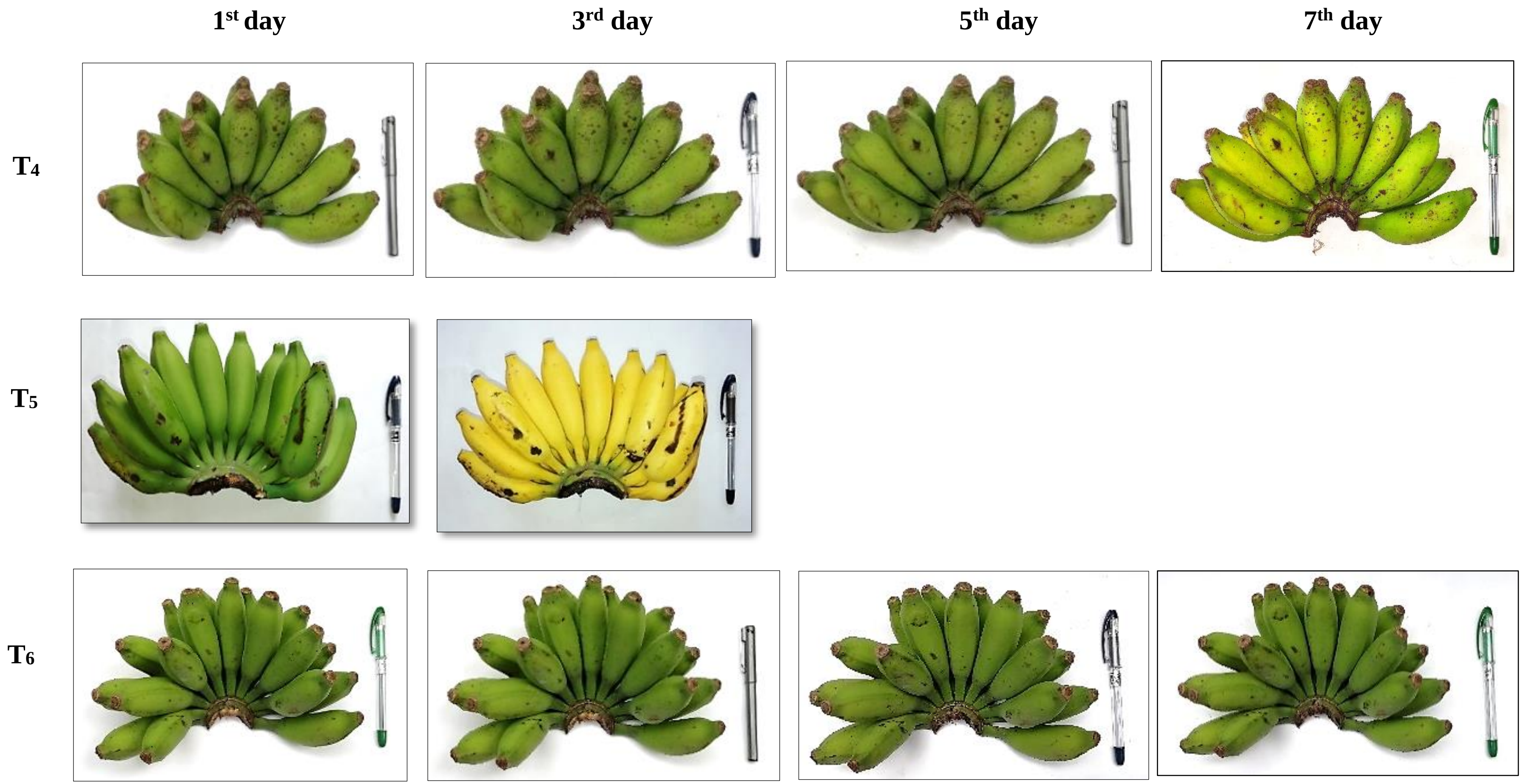


Plate 4.4: Colour changes in Chenichampa (V_2) up to 7th days of storage

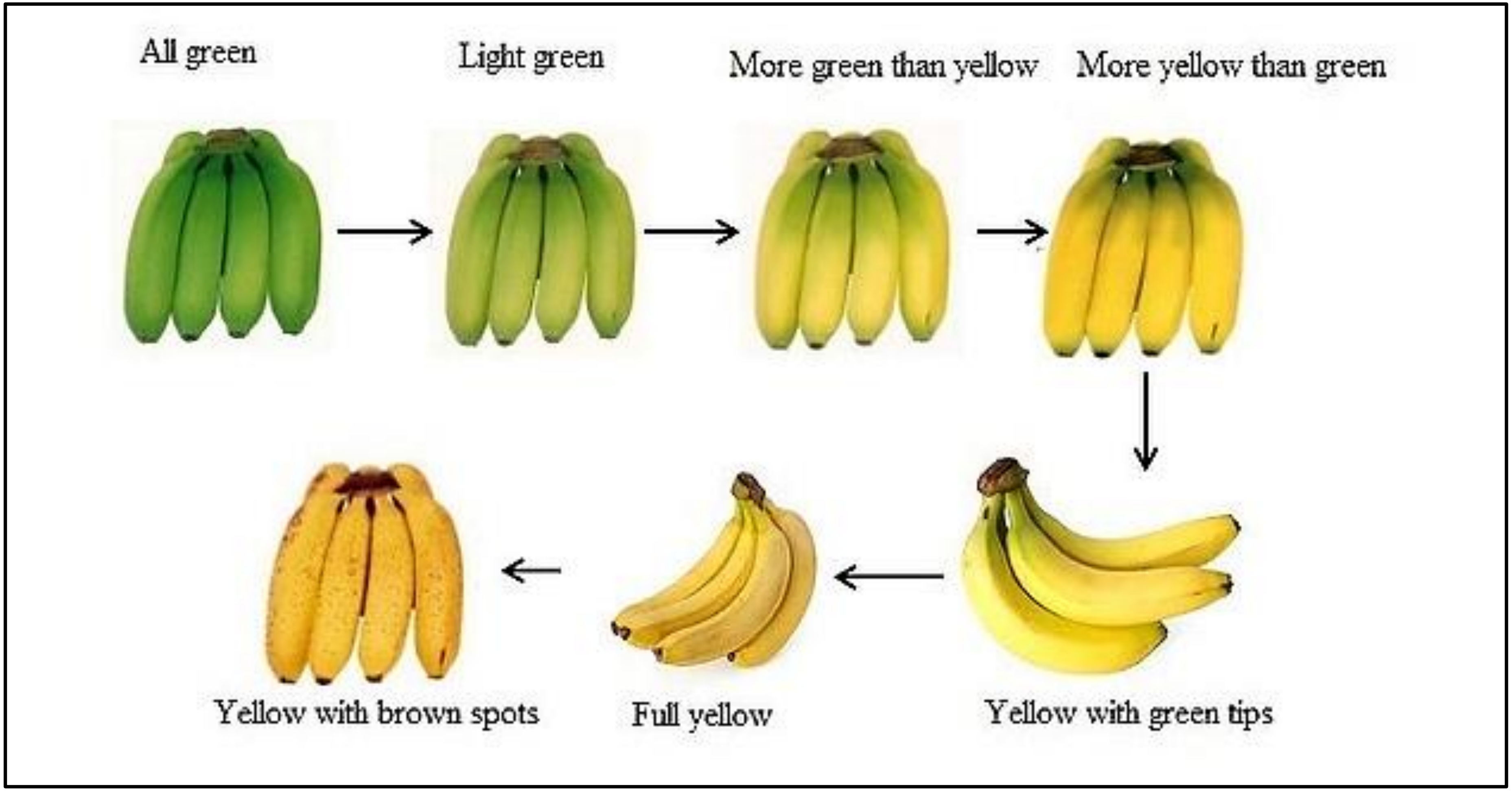


Plate 3.1: Standard Colour chart for ripening of banana fruit