CHARACTERIZATION AND VALUE ADDITION OF MALE BUDS OF BANANA CULTIVARS

By

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(2017-12-014)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"CHARACTERIZATION AND VALUE ADDITION OF MALE BUDS OF BANANA CULTIVARS"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"CHARACTERIZATION AND VALUE ADDITION OF MALE BUDS OF BANANA CULTIVARS"** is a bonafide record of research work done independently by **Ms. Thanzeela Hoorlin K. A. (2017-12-014)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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Thanzeela Hoorlin K. A.

Dedicated to

My Baby Doll

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

1. INTRODUCTION

Banana (Musa spp.) is one of the most popular and widely cultivated fruits belonging to family Musaceae. It is the world's fourth most important fruit crop and the second important crop in India, after mango. The fruit which is nutritionally rich in carbohydrates, fibre, vitamins and minerals is considered as one of the most widely consumed fruits in the world, and also the staple food of some countries. India is the largest producer of banana in the world with 14.2 million tons of production annually (National Horticulture Board). The state of Kerala is rich with wide array of banana varieties with specific regional preferences and commercial importance. It is popular among all classes of people due to its year round availability, low price and high nutritive value. The fruit, both ripe and raw, is consumed as dessert and also used for culinary preparations.

Banana is also called as 'Kalpatharu' or plant of virtues owing to its multifarious uses. Banana plant in whole is useful as food, fuel and pharmaceutical with many industrial applications (Mahapatra *et al.*, 2010). Banana peel, fibre, corm, male bud and pseudo stem are also used as food (Joy *et al.*, 2016). Male buds seen on the bunch after fruit set also called banana blossom, banana heart are removed, after the completion of female phase, for quality assurance of fruits and the practice called denavelling is commonly done in commercial banana cultivation. These male buds loaded with lots of nutrients like fibre, protein, potassium, calcium, copper, phosphorus, iron, magnesium, vitamin E, A and C along with various antioxidants are considered as a good functional food and it has good therapeutic value also (Singh, 2017). It has also found to cure diabetes, heart diseases, inflammation, itches and promote wound healing. Hence in places where large scale cultivation of banana is done, the male buds are used for culinary purpose.

After harvest when banana male buds are stored colour change, shriveling, weight loss and microbial infections are noticed under ambient conditions. Storage temperature influences the post harvest physiology and thereby the nutrient content and shelf life of the produce. Low temperature storage slows

down the metabolism in fruits and also makes the environment non congenial for growth and proliferation of microorganisms (Varghese, 2006).

Post harvest management practices like, subjecting the produce to various pretreatments, minimal processing, improved packaging and storage techniques can reduce the post harvest losses, increase shelf life and retain the produce quality which enhances its economic value. Effective pretreatments reduce browning and improve the sensory attributes like appearance, colour, flavor and overall acceptability of the produce.

Proper packaging reduces the moisture loss and retains the freshness of the produce by retarding physiological processes during metabolism. It also gives protection against microbial contamination and physical damage thus extending the storage life of the produce. Modified Atmosphere Packaging (MAP) and storage under low temperature can enhance the shelf life by restricted gas exchange across the package during respiration of produce (Singh *et al*., 2014).

Minimal processing operations of fresh cut fruits and vegetables include washing, peeling, chopping and packing in suitable containers which help to maintain the original appearance of the produce without any loss of quality. It is convenient for the consumer as they require little or no secondary processing before cooking.

Being nutritious with negligible cost, utilization of banana male bud can be considered as one of the means to attain food security. The awareness regarding the presence of nutritive factors in the bud has made it a high demanded commodity in the market during recent years. However, research on post harvest techniques including minimal processing, pre-storage treatments and packaging with suitable storage methods for extending the shelf life of banana male buds are scarce.

Hence the present study entitled "Characterization and value addition of male buds of banana cultivars" was undertaken with the following objectives.

1. To characterize the male buds of banana cultivars and standardize their harvesting stage
2. To standardize the packaging and storage methods
3. To standardize the minimal processing techniques for banana male bud

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Banana, belonging to the family *Musaceae,* is the world's fourth most important fruit crop for its nutritive value with high carbohydrates, fibre, protein and less fat. Fruits which are the main produce are a source of starch for people. In addition, banana peel, fibre, corm, male bud and pseudo stem are also used as food (Joy *et al.*, 2016).

Most of the edible bananas are triploids derived from natural crosses of *Musa acuminata* and *Musa balbisiana*. Based on their genomic status, they are further classified into AA, AB, AAA, AAB, ABB, AAAA and ABBB. Palayankodan (syn. Mysore Poovan) is a banana variety belonging to AAB genotype cultivated for both fruit and vegetable purpose. It has a good keeping quality and most widely cultivated single clone because of its drought tolerance and suitability for ratooning (Rajeevan and Geetha, 1982). Grand naine is a cultivar of Cavendish bananas belonging to AAA genotype and triploid variant of the species *M. acuminata* producing seedless fruits through parthenocarpy. Its characteristic medium height and large fruit yields make it ideal for commercial agriculture. Njalipoovan variety of banana belonging to AB group is one of the important varieties cultivated in the homesteads of Kerala grown for fruit purpose with high export potential due to its significant edible and keeping quality (Indira and Nair, 2008). Nendran banana is a popular variety grown in Kerala belonging to AAB group used as a table fruit as well as for processing for domestic and export markets (Mulagund *et al.*, 2015).

In commercial banana cultivation, banana male buds also called banana blossom or banana heart are removed for quality assurance of fruits. Male buds thus removed are usually discarded in most of the varieties due to the high astringency and bitterness. Studies conducted on the nutrient status of the banana bud have shown the presence of fibre, protein, potassium, calcium, copper, phosphorus, iron, magnesium, vitamin E, A and C along with various antioxidants (Singh, 2017). The awareness regarding the presence of nutritive factors in the

bud has made it a high demanded commodity in the market during recent years. At present Palayankodan is the most popular variety used for utilization of male bud as vegetable. The state of Kerala is rich with wide array of banana varieties with specific regional preferences and commercial importance, and there are ample opportunities in the utilization of varieties for the purpose.

The stages of harvest after bunch emergence influence the quality of the produce. Changes occurring within one or two days of harvest adversely affect the quality and it is one of the crucial problems in marketing. Hence there is scope for minimal processing coupled with pretreatments using surface decontaminants, antioxidants and preservatives, which can meet the demand in the current societal situation. Suitable packaging methods coupled with modified and low temperature storage will also be effective in enhancing the storage life. Hence the present study was undertaken in this context and the related works carried out at different locations are cited here under the titles.

2.1. Banana male bud

Banana plants generally produce the flower buds within 10 to 15 months of emergence as a new sucker, which may vary according to variety and weather. Banana flower development is initiated from the true stem portion of the plant 9-12 months after planting. The inflorescence grows up through the center of the pseudo stem. After bunching the unopened male flowers along with the bract is seen at the bottom of the bunch as a bell.

Midhila and Nirmala (2014) opined that the year round and easy availability, high nutritive value and low market price have made the banana blossom a unique commodity in the market. Being nutritious and a low cost vegetable, banana male bud can be utilized to attain food security.

Several ready to eat products are made using banana inflorescence, notable ones are lentil- banana flower mixed vada, fried vegetable, pakoda and pickle or relish. In China, banana flower is traditionally used for certain illness such as

heart pain, diarrhea, asthma and stomach cramps (Sumathy *et al.*, 2011).A number of studies have proved that consumption of banana flowers have various health benefits like anti-diabetic and anti-AGEs (advanced glycation end-products) properties (Bhaskar *et al.*, 2011) and helps in prevention of oxidative stress (China *et al.*, 2011).

Based on the studies conducted by Liu and Lai (2012), banana blossom is a rich source of minerals, amino acids, dietary fibres, proteins, unsaturated fatty acids *etc*. and it has got edible value.

Banana inflorescence is used as a vegetable in all the southern and eastern states of India. Bud and bracts of the inflorescence showed a wide spectrum of inhibition against food borne pathogenic bacteria. Inflorescence of Cavendish banana varieties are not suitable for consumption due to its bitter taste whereas the inflorescence of plantains and cooking types are most suitable for making value added products (Narayana, 2015).

2.1.1 Harvesting stage of male bud

Denavelling is the process of removal of male buds after completion of female phase. It helps to improve fruit development and increases bunch weight. Male buds are removed from the last 1-2 small hands with a clean cut, keeping a single finger in the last hand.

Denavelling for nutrient diversion and post-shooting feeding of nutrients through the distal stalk-end of rachis to achieve high yields is practiced (Ancy *et al*, 1998). The studies by Ancy and Kurien (2000) have also revealed that bunch stalk feeding at 14 and 28 days after full bunch emergence is more beneficial to increase the yield. Denavelling serves dual purposes of saving mobilization of food into unwanted sink of banana plant as well as earning additional income when excised male bud is used as a vegetable (Singh *et al.*, 2001). Removal of male bud caused an increase in the nutrient composition of fruits and bunch weight. It aids in conservation and utilization of nutrient energy for finger

development which would be otherwise lost for opening of the remainder of the flower (Kurien *et al*, 2000). Also it helps in removal of a strong and active competing sink for photosynthates and mineral nutrients despite its smaller size relative to the bunch (Singh *et al*., 2001). According to Kotur and Murthy (2008), denavelling caused 13.8% (20.143 g) higher bunch yield.

2.1.2. Use of male bud as vegetable

Vegetables include a vast variety of plant organs such as roots, tubers, stem, leaves, flowers, fruits, seeds, sprouts and bulbs.

Tin *et al*. (2015) reported that banana inflorescence is eaten as vegetable by some ethnic groups in Malaysia. In Malaysia, banana flower is cooked to serve in preparing different types of cuisines. According to Marikkar *et al*. (2016), banana flower usually red or purple red in color and attached to the end of the banana fruit bunch is a popular vegetable among the people living in countries such as Malaysia, Philippines, Indonesia and Sri Lanka.

2.2. Physical and biochemical characterization of edible banana parts

The physico chemical properties of a produce influence its quality and edibility. Primarily, appearance which is due to the shape, size and colour will be the criteria for any consumer. Nutritional composition is also of prime importance in choosing the produce for culinary purpose. Since studies pertaining to banana male bud are meager, work done elsewhere on edible parts of banana is reviewed.

2.2.1 Physical parameters

Horticulture commodities show diversity in physical attributes such as color, shape, size, form, taste, aroma, texture, *etc*., as the result of great diversity in anatomical, morphological, physiological and biochemical origins, characteristics, and requirements and hence their post harvest handling needs also differ (Yahia, 2019).

2.2.1.1 Weight

Tripathi *et al.* (1981) studied four banana varieties and reported that physical characters of the fruits varied widely among varieties, weight of the fruits ranged from 81.6 g to 222.5 g. Studies conducted by Thajuddeen (2000) revealed that the weight of the fruits ranged from 35 g for Njalipoovan to 153.3 g for Monthan

2.2.1.2 Length

As per the descriptors by Simmonds and Shepherd (1955), banana male bud can be divided into three types based on its length like small, less than or equal to 20 cm, intermediate 21 to 30 cm and large when more than or equal to 31 cm. Male bud length in Grand naine variety was reported to be 31.18 cm during the flowering period of banana plant (Tak, 2012).

2.2.1.3 Diameter

Maximum diameter of male bud should be less than or equal to 20 cm in small type, intermediate 21 to 30 cm and more than or equal to 31 cm as per the banana descriptors (Simmonds and Shepherd, 1955). Male bud diameter was reported to be 30.70 cm during the flowering period of banana plant in Grand naine variety (Tak, 2012).

2.2.1.4 Shape

Male bud shape of banana should be like a top, lanceolate, intermediate, ovoid or rounded (Simmonds and Shepherd, 1955).

2.2.1.5 Colour

Colour of bract external face could be yellow, green, red, red-purple, purple-brown, purple, blue, pink-purple, orange-red or others and the inner bract colour could be whitish, yellow or green, orange red, red, purple, purple brown, pink purple or others (Simmonds and Shepherd, 1955).

2.2.1.6 Recovery

Kleinhenz and Wszelaki (2003) obtained the recovery in cabbage by measuring the head dimensions after removing the five outer leaves from the head, and this was considered as marketable yield.

2.2.1.7 Firmness

According to Thajuddeen (2000), the firmness of the banana fruits ranged from 1.43 kg cm^{-2} in Palayankodan to 4.06 kg cm^{-2} in Nendran. Firmness in banana cultivars differed significantly from 1.1 kg cm^{-2} to 1.9 kg cm^{-2} (Ngalani *et al.*, 1998). Amin *et al.* (2015) reported a decreasing trend in fruit firmness with the advancement of maturity.

2.2.1.8 Shelf life

Shelf life was found to decrease exponentially with increasing temperature (Peacock, 1980). Shaun and Ferris (1997) stated that at ambient tropical temperatures, bananas have an average market life of 1 to 10 days depending on genotype, maturity stage at harvest and storage and handling conditions. Narayana (2015) opined that storage temperature influences the post harvest physiology of banana and its interaction with the microbes in the storage environment. Lowering of temperature slows down the catabolic process in the fruit and also makes the environment non- congenial for the growth and proliferation of spoilage microorganisms.

Shelf life of bananas is coupled with several physico-chemical changes (Guo *et al.*, 2014) including weight loss, softening, starch hydrolysis, chlorophyll degradation and browning development that increase susceptibility to several physiological and pathological disorders (Al-Qurashi *et al.*, 2017).

2.2.1.9 Physiological Loss in Weight (PLW)

Weight loss occurs as a result of moisture loss due to transpiration, which further leads to the shrinkage of commodity. The cumulative loss of reserve food due to respiration and the respiratory water loss lead to weight losses in the product (Peiris *et al.*, 1997).

Bosland and Votava (2000) observed that fruits stored at ambient condition were highly susceptible to water loss, wrinkle and colour change within a few days after harvest. Yehoshua and Rodov (2003) reported about 3-10 % weight loss in fresh produce. Hameed *et al.* (2013) observed that during storage minimum weight loss occurred at 10 °C and maximum at 15 °C. The weight loss at 15 °C (30.57 %) was significantly lower compared to ambient conditions (39.61 %).

Brar *et al.* (2000) reported lowest PLW (5.5 %) in fruits packaged in 100 gauge polyethylene after 25 days of storage. Based on the studies of Koraddi and Devendrappa (2012), minimum PLW was observed in polyethylene bags. Grewal *et al.* (2017) reported an increase in weight loss with increase in temperature which was also higher (15.6 %) in perforated packages.

2.2.1.10 Respiration rate

The respiration rate is a good indicator of the physiological stage of the fruit and its storage potential. It can be expressed in terms of amount of oxygen consumed or carbon dioxide evolved per unit weight of produce per unit time. It is an index of metabolic turnover in the produce which is proportional to the rate of deterioration. Since post harvest metabolic changes are tightly coupled to the rate of respiratory metabolism, its measurement gives a good indication of the rate of these subsequent metabolic reactions, and its control has traditionally been used to prolong commodity shelf-life and maintain its quality (Saltveit, 2019).

A rapid rise in rate of respiration concurrent with enhanced ethylene production is commonly seen in many climacteric fruits including banana (Jayanty *et al.*, 2002). Respiration rate is affected by the development stage and respiration pattern of the fruit, whether it is climacteric or non- climacteric (Sen *et al.*, 2012).

Jobling (2012) reported that the respiration rate was slowed under low temperature and got faster as temperature increased. Manolopoulou *et al.* (2012) observed an increase in respiration of unpackaged cut produce by 24 % than intact produce under same storage temperature. The rate of deterioration of harvested commodities is generally, proportional to the respiration rate (Hailu *et al.*, 2013).

2.2.2 Nutritional and biochemical constituents

According to Aranvindakshan (1981) biochemical constituents in banana during the post harvest period varied constituently with respect to variety, specific situation, time of harvest, method of ripening and storage conditions.

2.2.2.1 Acidity

Titrable acidity is the measurement of total acid concentration contained within the food. It is an important physico chemical parameter which affects the product quality and protects against the development of microorganism to a large extent.

Azlin *et al.* (2014) observed a gradual increase in total titrable acidity of fruits up to 3 weeks of storage and thereafter fluctuated until the end of storage. Tapre and Jain (2012) also opined that titrable acidity showed an increasing trend from mature green to full ripe stage. The increase in acidity in ripe fruits is mainly due to increase in malic acid and citric acid contents (Wayman and Palmer, 1963).

The acidity in Palayankodan fruits was reported as 0.502 percent by Sheela (1982). Rajeevan and Mohanakumaran (1983) reported 0.3 to 0.48 percent acidity in four plantain cultivars cultivated in Kerala. In Nendran variety,

Thajuddeen (2000) reported 0.15 percent acidity. Agrawal *et al.* (1997) reported an acidity of 0.48 percent in Robusta.

2.2.2.2 Ascorbic acid

Ascorbic acid is a water soluble vitamin found in fruits and vegetables and is the most abundant antioxidant in plants. Investigations by Wall (2006) revealed that ascorbic acid content of bananas ranged from 4.5 to 12.7 mg 100^{-1} g.

Arvanitoyannins *et al.* (2005) reported that vitamin C content gets retained in storage atmosphere with low levels of oxygen. The decrease in ascorbic acid during storage may be due to inversion of ascorbic acid into dehydro ascorbic acid (Mahajan *et al.*, 2005).

Azlin *et al.* (2014) observed an increase in concentration of ascorbic acid up to 4 weeks of storage of fruits. A reduction in quality was observed with respect to the reduction in ascorbic acid that was associated with surface browning and degradation in fruit quality. Grewal *et al.* (2017) observed a better retention of ascorbic acid at 5°C which decreased significantly with increase in temperature (15 °C). The loss was more in samples packaged in perforated containers.

2.2.2.3 Protein

Banana male buds contain high quality protein because of its well balanced essential amino acid content (Sheng *et al.*, 2010). The total protein content in male buds varied from 8.89 percent in AAB to 10.35 percent in AAA genotype (Florenta *et al.*, 2015).

2.2.2.4 Carbohydrate

Carbohydrates are very important in horticultural commodities because of their contribution to texture, flavor, color and nutritional value (Yahia *et al.*, 2019).

According to Gopalan *et al.* (2009), 34 kcal of energy is present per 100 g of fresh plantain flower. Sheng *et al.* (2010) reported that energy value of fresh banana blossom was observed to be 51 kcal/ 100 g. Banana fruit is one of the high calorie tropical fruit which provides 90 calories of energy per 100 g of fruit (Narayana, 2015).

Florenta *et al.* (2015) reported that the total carbohydrate content in banana blossom was in the range of 22.36 percent in AAA to 62.19 percent in AAB genotype.

2.2.2.5 Total Phenols

Phenolic compounds are the plant secondary metabolites having antioxidant, anti-carcinogenic and anti-inflammatory properties. Phenolic content in fruits and vegetables vary according to their maturity. The increase in phenol content of juice tissue is influenced by increased synthesis of anthocyanin and carotenoids which are of polyphenol in nature (Ram and Singh, 2004).

According to China *et al.* (2011), the variation in total phenolic content was quite general among different cultivars of banana grown in India. The highest phenolic content of Indian banana flower was noted for cultivar Kacha (11.94 ± 0.03 mg of GAE / g of extract).The processed flower in Kunnan shows higher phenols and tannins which make it a promising variety for application in nutraceuticals and medicinal preparations (Joy *et al.,* 2016).

As per the findings of Yang *et al.* (2011), phenolic compounds are synthesized during storage. However, during prolonged storage, phenolic compounds get decreased due to oxidation.

2.2.2.6 Minerals

Based on the studies conducted by Ngamsaeng *et al.* (2006), banana flower is most abundant in minerals like potassium and phosphorus followed by calcium, magnesium and sulphur. Gopalan *et al.* (2009) reported that fresh banana

blossom has a sodium content of 20.1 mg/ 100g. Kanchana *et al.* (2010) reported that the calcium content of dehydrated banana blossom ranged between 262.00 mg/ 100g and 282.19 mg/ 100g. Sheng *et al.* (2010) reported that banana blossom contain 553 mg/ 100g potassium content. According to Florenta *et al.* (2015), banana and plantain male buds are rich in macro minerals such as potassium and calcium. According to Krishnan and Sinija (2016), banana blossom contain 2.42-3.21 percent minerals.

Banana male bud can be considered as a good functional food because it provides therapeutic value and is also loaded with lots of nutrients like fibre, protein, potassium, calcium, copper, phosphorus, iron, magnesium, vitamin E, A and C along with various antioxidants (Singh, 2017).

2.2.2.7 Dietary fibre

Narayana (2015) reported that bananas contain good amount of soluble dietary fibre which helps in easy bowel movement and reduction of constipation. According to Florenta *et al.* (2015), banana blossoms of AAA genotype is rich in total dietary fibres (50.09 %) and these blossoms could be considered as a source of dietary fibres for the control of obesity and diabetes.

2.2.2.8 Anthocyanin

Haytowitz *et al.* (2013) pointed out that the cultivar and growing conditions accounted for about 25 to 33 % of the variability in the flavonoid content of foods.

Flavonoids are the most commonly distributed phenolic constituents of the plant kingdom. They are a group of low molecular weight phenolic compounds that are responsible for the aroma and antioxidant properties of food (Marikkar *et al.*, 2016).

Naresh (2016) standardised method of extracting anthocyanin pigments from jamun. The highest content of anthocyanin (61.07mg/ 100 g) was obtained in

acidified solvent extraction method with 20 per cent ethanol and 0.5 per cent citric acid.

Anthocyanin is one of the major flavanoids widespread among the group of phytochemicals. They are phenolic substances, seen distributed in vegetables, giving rise to blue, purple, red and orange colour in flowers and fruits (Karishma, 2017).

2.2.2.9 Antioxidants

Recent research on antioxidant determination showed that plant foods with rich colours had high scores of Oxygen Radical Absorbance Capacity (ORAC) whereas those that were white had low ORAC (Wu *et al.*, 2004). Assessing the flavonoid contents of various food varieties is a common practice because of their radical scavenging abilities (Anwar *et al.*, 2013).

Liu and Lai (2012) claim that banana buds have antioxidant properties and are found to cure diabetes, heart diseases, inflammation and itches and promote wound healing. Schmidt *et al.* (2015) have remarked that banana male flower extracts contain high amount of phenolics and flavonoids and these compounds are mainly responsible for the antioxidant potential of banana inflorescence.

Banana contains health promoting flavanoids, polyphenolic antioxidants such as lutein, zeaxanthin, β and α carotenes in small amounts. These compounds act as protective scavengers against oxygen derived free radicals and reactive oxygen species (ROS) that play a major role in ageing and various disease development processes (Narayana, 2015).

2.2.2.10 Moisture content

Ketiku (1973) reported that the moisture content of Cavendish banana is 75 percent while that of plantain is only 60 percent. Chadha (1992) reported a moisture content of 70 percent in ripe bananas. The moisture content in

the banana varieties ranged from 61 percent in Njalipoovan to 77.23 percent in Red Banana (Thajuddeen, 2000).

According to Brar *et al.* (2000), fruits packaged in polyethylene had higher moisture content under all storage conditions. Rux *et al.* (2016) remarked that lower water vapour transmission in polymer material resulted in high relative humidity and condensation of vapour inside the package.

The moisture content in banana blossoms ranged from 92.29 percent in AAA genotype to 93.73 percent in AAB genotype (Florenta *et al.*, 2015). Dash (2013) reported that only minor variation in moisture content was observed in minimal processed broccoli over the period of storage in micro perforated films.

2.2.2.11 Microbial load

Increased bacterial and fungal load might be due to weakening of the defense system against microbial attack (Jawandha *et al.*, 2009).

Chandra *et al.* (2013) reported a significant reduction in aerobic plate count in all washing treatments such as 100 ppm chlorine solution, 0.5% calcium solution and 1% citric acid than untreated samples. Yeast and mould count was less in chlorine and citric acid treated samples.

Xavier (2017) reported a higher bacterial population in unwrapped fruits stored under ambient condition compared to other packages under both refrigeration and cold storage.

2.2.2.12 Sensory evaluation

According to Herrington (1991), sensory evaluation technology is a method using skilled management and trained panelists to provide confirmation on the acceptability of the product in terms of product profile, consumer acceptability and consistency.

Almedia and Nogueria (1995) reported that in organoleptic method, visual observation is the main factor that determines the acceptance or rejection of a food by the consumer. Sensory analysis is the identification, scientific measurement, analysis and interpretation of the properties or attributes of a product as they are perceived through the five senses of sight, smell, taste, touch and hearing (Carpenter, 2002).

Bini (2003) reported that for judging the consumer acceptability of a product, organoleptic evaluation is the best method. Kavitha (2011) remarked that low temperature was rated excellent for organoleptic quality. The loss of flavour and conversion of vitamin C and polyphenols into di and polycarbonyl compounds may be responsible for decreasing trend in organoleptic scores.

2.3 Methods of Packaging

Packaging is the enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, bottle or other containers to perform the functions such as containment, protection, preservation, communication and it establishes an identity for the product in the market (Robertson, 1992). Permeability of the film used in packaging is important as it modifies the surrounding atmospheric composition and in turn determines the quality and shelf life of the produce. Packaging in plastic films can modify the atmosphere surrounding the produce, called as Modified Atmosphere Packaging (MAP). Gunes and Lee (1997) observed that modified atmospheric packaging followed by storage reduces the metabolic rate such as respiration, transpiration and protection from microbial contamination. John (2011) opined that packaging maintains freshness and protects the nutritive value of the produce. It is known to extend the shelf life of fresh produce by retarding the physiological metabolism leading to senescence, by increased CO_2 and decreased O_2 concentration in 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 (Reni, 2005).

According to Gorny (1997), MAP extended the shelf life of most of the horticultural produces both in whole and fresh cut form. Porat *et al.* (2004) suggested that MAP reduces the development of rind disorders in citrus fruits by maintaining the fruit in high humidity and maintaining elevated CO_2 and lowered O_2 levels. According to Techavises and Hikida (2008) macro perforations on the film provide additional gaseous diffusion across the film packages.

In broccoli the modified atmosphere reduced the chilling injury symptoms. The pulp softness, sweetness and flavour of MA- packed fruits are better than in control fruits (Rai *et al.*, 2009). MAP is reported to be very efficient in increasing storage life of fresh as well as minimally processed commodities like tomato, shredded cabbage, potato *etc.* (Dhall *et al.*, 2010).

2.3.1 Packaging materials

While selecting a packaging material for a produce, systems of production, storage, handling, transport and consumer attitude should be considered. Packaging materials can act as vapour barriers and can help maintain higher relative humidity within the package, and thereby reduce the water loss and retains the freshness and marketability of the produce. According to Narayana (2015), different type of products, pack size, strength requirements and quantities dispatched by different types of transport need to be carefully assessed before deciding on the type of packaging.

Permeable polymeric films are used to extend the shelf life of minimally processed vegetables through modification of atmospheric conditions of packaging like MAP (Singh and Goswami, 2006).

2.3.1.1 Shrink wrapping

Shrink wrapping of mandarins has been very promising with respect to controlling water loss and spread decay, retention of fruit shape without adverse effect on flavour and colour development (Ladaniya *et al.*, 1997).

Thompson (1981) found that arracacha roots deteriorated quickly after harvest but could be stored for 7 days if packed in shrink film. Samsoondar *et al.* (1998) observed that breadfruits that had been shrink-wrapped with PE film (60-gauge thickness) had an extended storage life. Lemons stored in PVC 100 20 % shrink-wrap retained their quality, with reduced loss of weight and rotting compared with those stored non-wrapped or waxed (Mari *et al.*, 2007).

Individual shrink film wrapping is a form of MAP used to enhance the storage life and maintain the post harvest freshness of fruits and vegetables (Nanda *et al.*, 2001). Shrink film wrapped papayas showed minimum weight loss (2.085%). Shrink film delayed the ripening process most promisingly. Aishwarya (2016) reported that shrink wrapping enhances the shelf life, reduces the physiological weight loss and retains biochemical constituents like TSS, titrable acidity, vitamin C, sugars etc. in passion fruit. According to Ranganna *et al.* (2014), sweet corn cobs showed maximum shelf life in shrink wrapping during package studies.

According to Venkatesh *et al.* (2016), polyolefin shrink wrapped fruits had significantly lower weight loss compared with other treatments and recorded lowest value for reducing sugar content under refrigerated condition .Under ambient condition, maximum acidity retention after 49 days of storage was observed in fruits packed with polyolefin shrink wrapping (0.59 %). The acidity of fruits declined throughout the storage period. Decline of acidity may be due to higher utilization of organic acids in metabolic activities, which reduced the level of acidity with the progress in storage period.

2.3.1.2 Cling film wrapping

The cling films are usually the plastic films used for packing of food materials to keep them fresh for longer period of time (Sharma *et al.*, 2019).

For minimal processed vegetables, packaging in polystyrene tray overwrapped with cling film enhanced visual appearance and keeping quality with

low microbial count both under ambient and refrigerated storage (Varghese, 2006).

Chandran *et al.* (2016) reported that, in beetroot, polystyrene tray overwrapped with cling film reduced the physiological loss in weight, while micro ventilated polyethylene and polypropylene was effective in shredded vegetables like beans and cabbage respectively.

2.3.1.3. Polyethylene cover

Fruits stored in PE film bags at 21 °C had almost twice the storage life of fruits stored without wraps (Thompson, 1971).According to Shorter *et al.* (1987), the storage life was increased fivefold when bananas were stored in plastic film (where the equilibrium gas content was about 2 % O2 + 5 % CO2) with an ethylene scrubber compared with fruit stored without wraps. Tiangco *et al.* (1987) also observed that the variety Saba (Musa BBB) remained unripe held in MA at ambient temperature and had a considerable extension of storage life compared with fruit stored without wraps, especially if combined with refrigeration.

In Thailand, Tongdee (1988) found that the green life of KluaiKhai (Musa AA) could be maintained for more than 45 days in PE bags at 13 °C. Black sapota fruits wrapped in plastic film had 40–50 % longer storage life at 20 °C than fruits not wrapped (Nerd and Mizrahi, 1993). Naik *et al.* (1993) reported an extended shelf life of 42 days in tomato packaged with 300 gauge polyethylene.

Loss in weight, yellowing and stem hardening in broccoli were delayed in MA packaging, especially in microperforated PP film and non-perforated PP film, with total antioxidant activity, ascorbic acid and total phenolic compounds remaining almost unchanged during the whole storage period of 28 days (Serrano *et al.*, 2006). Babarinde and Fabunmi (2009) reported highest ascorbic acid content, lowest weight loss and an extended shelf life up to 9 days in okra packed in polyethylene and stored under refrigerated temperature. Individual bagging of banana clusters in polythene bags is recommended. Koraddi and Devendrappa

(2011) suggested that polythene package formed high relative humidity around the vegetables, which reduced the moisture loss due to transpiration and thereby physiological loss in weight

2.3.1.4. Polystyrene trays overwrapped with cling film

For minimal processed vegetables, packaging in polystyrene trays overwrapped with cling film enhanced visual appearance and keeping quality with low microbial count both under ambient and refrigerated storage (Varghese, 2006).

Chandran *et al.* (2016) reported that in beetroot, polystyrene tray overwrapped with cling film reduced the physiological loss of weight, while micro ventilated polythene and polypropylene was effective in shredded vegetables like beans and cabbage respectively. Polystyrene tray retained the vitamin C in shredded beans and carrot, while unventilated polyethylene and micro ventilated polypropylene retained that in beetroot and beans respectively. For maintaining highest TSS in beetroot, unventilated polyethylene and polystyrene were effective and for cabbage, polyethylene, polystyrene and polypropylene also could be used effectively (Chandran *et al*, 2016).

2.3.1.5. Polypropylene punnets

Gomez and Artes (2005) observed that celery packaged in polypropylene and stored at 4 °C has better quality with more than 15 days shelf life. Roshita (2005) reported that minimally processed shredded cabbage could be stored up to 3 weeks with minimum colour change, reduction in weight loss and deterioration in sensory properties by packaging in polypropylene. Chilli packaged in polypropylene films showed significantly higher TSS at 10 °C (Edusei and Ofosu-Anim, 2013).

2.4 Minimal processing

Minimal processing includes operations like washing, peeling, chopping and packaging in suitable containers which help to maintain the original fresh like appearance without any loss of quality. It is convenient for the consumer as they require little or no secondary processing and cooking before consumption.

Minimal processed products possess higher rate of respiration, which generally leads the ageing of the products by using the energy reserve during oxidative- reduction process (Watada *et al.*, 1996). Minimal processing increases the perishability rather than the stability of fruits and vegetables (Rolle and Chism, 1987).

Minimal processing is defined as procedure, short of traditional complete preservation procedures, that adds value to the fruits or vegetables (Price and Floros, 1993). The microbiological, sensory and nutritional shelf life of minimally processed fruits and vegetables should be atleast 4-7 days but preferably even longer (Ahvenainen, 1996).

According to Narayana (2015), the minimal processing operations of fresh cut fruits and vegetables mainly consist of simple unit operations including cooling, washing, trimming or shredding, peeling, grating, slicing, drying etc., with mild preservation techniques before packaging which make the produce ready to use. Minimal processing has two purposes; to keep the product fresh but convenient without losing its nutritional quality and to have a shelf life sufficient enough to facilitate distribution within the region of consumption.

The shelf life of minimally processed vegetables is usually extended by means of a combination of Modified Atmosphere Packaging and low temperature storage. However, it is important to control the factors affecting the physiological response of vegetables to minimal processing in order to enhance the shelf life of the produce (Olarte *et al.*, 2009).

2.4.1 Ascorbic acid

Ascorbic acid as a reducing compound can temporarily inhibit browning caused by pH, temperature, enzymes, oxygen, iron and substrate concentration (Gardner *et al.*, 1991). Dipping of fresh cut fruits and vegetables in solutions of ascorbic acid, citric acid and calcium chloride at various concentrations of 0.1-1.55 % is recommended as a practice (Zhu *et al.*, 2007).

2.4.2 Citric acid

Immersion of the banana blossom slices in 0.2 % citric acid solution for 30 minutes followed by drying reduced browning, and the product was ready-to-cook and acceptable with respect to appearance, flavour and overall quality (Wickramarachchi and Ranamukhaarachchi, 2005). Citric acid act as a preservative and enhance flavor and control enzymatic browning if used at concentrations less than 2 percent (Klein and Kurilich, 2000).

2.4.3 Turmeric and salt

Dried tomato slices pretreated with 1 percent turmeric and 2.5 percent salt resulted in a product with good taste and appearance (Pushpa *et al.*, 2010).

2.5 Storage conditions

Controlled Atmospheric Storage (CAS) and Modified Atmospheric Storage (MAS) are the effective methods for prolonging the shelf life of many crops (Ali *et al.*, 2004). Storage temperature influences the post harvest physiology of banana and its interaction with microbes in the storage environment (Narayana, 2015).

2.5.1 Ambient condition

Fruits stored in ambient conditions are more prone to colour change, shriveling and microbial infections. Shelf life was found to decrease exponentially with increase in temperature (Peacock, 1980).

Shaun and Ferris (1997) stated that at ambient tropical temperatures, bananas have an average market life of 1-10 days depending on genotype, maturity stage at harvest and storage and handling conditions.

Acedo *et al.* (2009) reported that in tomato during storage, firmness decreased along with softening due to ripening which was slow at 10 °C and was rapid at ambient storage and there was no significant change in acidity during storage.

Hameed *et al.* (2013) observed that weight loss was higher at ambient conditions (22 °C) compared to low temperatures 0 °C, 5 °C, 10 °C and 15 °C. titrable acidity and ascorbic acid content were observed higher in ambient conditions than low temperature storage at 0 °C, 5 °C, 10 °C and 15 °C.

2.5.2 Refrigeration

Varghese (2006) opined that the shelf life of cut vegetables can be extended and undesirable physical and microbial spoilage can be reduced under refrigerated storage. Lowering of temperature slows down the catabolic process in fruits and also makes the environment non congenial for the growth and proliferation of spoilage microorganisms. The produce for overseas markets are carried in refrigerated ships, which maintain a circulating cool temperature (Narayana, 2015).

2.5.3 Cold storage

Cold storage is a common method adopted to enhance the shelf life of fresh fruits and vegetables. Though it has high energy demand, it is a highly efficient method. Since different varieties of fruits and vegetables have different optimal storage temperature, cold storage may cause cold damage under same storage condition.

Senesi *et al.* (2000) reported that low temperature storage at 2 °C caused pitting due to chilling injury, while storage at 8 °C retained the initial quality of the produce.

Storage of banana at 13 °C considerably suppressed the respiration rate, ethylene production and ripening (Narayana, 2015).

This brief review of literature reveals that there is still scope to carry out investigation on banana male bud to enhance the shelf life. Hence in the present study, an attempt had been made to standardize the harvesting stage of male buds of different cultivars and suitable packaging and storage methods for the minimally processed buds.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation on "Characterization and value addition of male buds of banana cultivars" was conducted at the Department of Post harvest Technology, College of Horticulture, Vellanikkara, Thrissur, Kerala, during the period of 2017-2019.

The study was formulated with an objective of characterizing the male buds of banana cultivars and standardizing the correct harvesting stage, along with developing a suitable packaging and storage method to enhance the shelf life of whole and minimally processed male bud. The study was conducted under three experiments as given below:

I. Characterizing male buds of banana cultivars and standardizing their harvesting stage
II. Standardization of packaging and storage methods
III. Standardization of minimal processing techniques for banana male bud

The fresh male buds required for the experiment were collected from Banana Research Station, Kannara, Thrissur and were brought to the laboratory immediately after harvest. The experiments were conducted in the laboratories of Department of Post harvest Technology.

3.1 Characterizing male buds of banana cultivars and standardizing their harvesting stage

The banana male buds of commercial banana varieties of Kerala used for the study were harvested at different stages of maturity. The varieties used and the stages of harvest are given below.

3.1.1 Treatments

Varieties:

V1: Palayankodan (AAB)

V2: Grandnaine (AAA)

V3: Njalipoovan (AB)

V4: Nendran (AAB)

Stages of harvest:

S1: 15 days after full bunch emergence

S2: 20 days after full bunch emergence

S3: 25 days after full bunch emergence

3.1.2 Design and replication

The experiment was laid out in a Completely Randomized Design (CRD) with three replications for each treatment.

3.1.3 Observations

Observations on physical and biochemical parameters were taken to fix the most appropriate stage of harvest.

3.1.3.1 Physical parameters

3.1.3.1.1 Bud weight

Individual bud weight was recorded and expressed in gram as the average of three buds.

3.1.3.1.2 Bud length

The length of the bud was measured using a measuring scale and expressed in centimeter (cm) as an average of three male buds.

3.1.3.1.3 Bud diameter

The diameter of the bud at the widest part was measured using a vernier caliper and expressed in centimeter (cm) as an average of three male buds.

3.1.3.1.4 Shape

The shape of the male bud was determined using the descriptor by Simmonds and Shepherd.

3.1.3.1.5 Colour

Colour of the outer and inner portion of the bracts were examined.

3.1.3.1.6 Recovery

After removal of outer loose bracts the weight of material recovered was observed and expressed in percentage.

3.1.3.1.7 Firmness

Firmness of the male buds was measured using a penetrometer and was expressed in kg cm^{-2}.

3.1.3.2 Biochemical parameters

Biochemical parameters of male buds which include both male flowers and bracts were estimated.

3.1.3.2.1 Acidity

The titrable acidity was estimated by titrating with 0.1N sodium hydroxide (0.1N NaOH) solution using phenolphthalein indicator and expressed as per cent of malic acid. Five gram of male bud was ground using distilled water and made upto 100 ml in a standard flask. From this, 10 ml aliquot was titrated against 0.1N NaOH (Ranganna, 1997).

$$\text{Acidity (\%)} = \frac{\text{Normality x Titre Value x Equivalent weight x volume made up x 100}}{\text{Weight of sample x vol. of aliquot x 1000}}$$

3.1.3.2.2 Ascorbic acid

One gram of bud was taken and extracted using 4 per cent oxalic acid. Ascorbic acid was estimated using standard indicator 2, 6- dichlorophenol indophenols dye and expressed as mg $100g^{-1}$ of sample (Sadasivam and Manickam, 1996).

3.1.3.2.3 Protein

The protein content of banana male bud was determined by Lowry's method (Lowry *et al.*, 1951).

The sample (0.5 g) was ground well in a mortar and pestle with 5 to 10 ml of phosphate buffer. It was centrifuged and the supernatant needed for protein estimation was pipetted out into a series of test tubes. Sample extract (0.2 ml) was pipetted out in other test tubes. Tube with one ml water served as blank.

To each test tube including blank, alkaline copper solution (5ml) was added. It was mixed well and allowed to stand for 10 minutes. To all test tubes, 0.5 ml Folin-ciocalteau reagent was added, mixed well and incubated at room temperature in the dark for 30 minutes till blue colour was developed. Optical density values were recorded in a spectrophotometer at 660 nm. A standard graph was drawn and the amount of protein in the sample was calculated.

3.1.3.2.4 Carbohydrate

Total carbohydrate content in the male bud was determined using Anthrone reagent (Sadasivam and Manickam, 1996). Carbohydrates were first hydrolyzed in to simple sugars using dilute HCl and the glucose is dehydrated to hydroxymethyl furfural in hot acid medium. This compound reacts with anthrone reagent to produce a green coloured complex which has an absorbtion maximum at 630 nm.

100 mg of sample was taken in a boiling tube and hydrolyzed for three hours in boiling water bath by adding 5 ml of 2.5 N HCl and then cooled to room temperature. It was neutralized with solid sodium carbonate and the volume was made upto 100 ml and centrifuged. To 1 ml of the aliquot, 4 ml anthrone reagent was added and heated for 8 minutes in a boiling water bath. After cooling the absorbance was read at 650 nm against a reagent blank. A standard curve was prepared using different concentrations of glucose.

The concentration of carbohydrate in test sample was found out using standard curve and expressed as mg 100 g^{-1}.

3.1.3.2.5 Total phenol

Phenol content of banana male bud was determined using Folin-Ciocalteau reagent in which phenols react with phosphomolybdic acid in Folin-Ciocalteau reagent in an alkaline medium and produce blue coloured complex (molybdenum blue). The intensity of colour indicates phenol content in sample (Sadasivam and Manickam, 1996).

One gram of banana male bud was weighed and ground using 10 times volume of 80 per cent ethanol. The homogenate obtained was centrifuged at 10,000 rpm for 20 minutes. Supernatant was saved. The residue was re-extracted using 5 times volume of 80 per cent ethanol by centrifuging for another 20 minutes. The supernatant was pooled and evaporated to dryness. The residue was dissolved in 5ml distilled water. From this, 0.5 ml aliquot was transferred to a test tube and made up to 3 ml using distilled water. To this, 0.5 ml Folin-Ciocalteau reagent was added and after 3 minutes 2 ml of 20 per cent sodium carbonate was also added. Then the test tubes were placed in boiling water bath for exactly one minute. After cooling the absorbance was read at 650 nm against a reagent blank. A standard curve was prepared using different concentrations of catechol.

The concentration of phenol in test sample was found out using standard curve and expressed as mg 100 g^{-1}.

3.1.3.2.6 Minerals

10 g of each sample was taken in silica dishes after noting its tare weight and ignited on a Bunsen burner at 525 °C for 6 hours. The dishes were cooled and weighed again. The difference in weights gave the total ash content which was expressed in percentage.

3.1.3.2.6.1 Potassium

Potassium content in the sample was estimated by flame photometric method (Ranganna, 1997). An aliquot of ash solution was diluted so that it contained less than 150 ppm of potassium. HCl was added and atomized in a flame photometer with a wavelength of 768 nm. Concentration was calculated from the standard curve using the formula;

$$\text{Potassium (mg 100 g}^{-1}) = \frac{\text{ppm (std curve) x vol. made up x dilution x 100}}{\text{Weight of sample x 1000}}$$

3.1.3.2.6.2 Calcium

The calcium content of sample was estimated by precipitating calcium as calcium oxalate and dissolving precipitate in to dilute H_2SO_4 and titrating against standard potassium permanganate (Ranganna, 1997).

Saturated ammonium oxalate solution (10 ml) and two drops of methyl red indicator were added to 20 ml of aliquot of ash solution obtained by dry ashing. The solution was made alkaline by the addition of dilute ammonia and the made acidic with few drops of acetic acid until the colour was faint pink. The solution was then heated to the boiling point and allowed to stand at room temperature for four hours

followed by filtering and washing with water till the filtrate was free from oxalate. The point of filter paper was broken with glass rod and the precipitate was washed using hot dilute H_2SO_4 and titrated against 0.01 N $KMnO_4$ to the first permanent pink colour. Then filter paper was added to the solution and titration was completed.

$$\text{Calcium (mg 100 g}^{-1}) = \frac{\text{Titre Value x 0.2 x total volume of ash solution x 100}}{\text{Volume taken for estimation x weight of sample taken for ashing}}$$

3.1.3.2.6.3 Sodium

Sodium content in the sample was estimated by flame photometric method (Ranganna, 1997). An aliquot of plant extract was diluted so that it contained less than 10 ppm of sodium. HCl was added and atomized in a flame photometer with a wavelength of 589 nm. Concentration was calculated from the standard curve using the formula;

$$\text{Sodium (mg 100 g}^{-1}) = \frac{\text{ppm (std curve) x vol. made up x dilution x 100}}{\text{Weight of sample x 1000}}$$

3.1.3.2.6.4 Iron

The iron content of sample was determined by converting iron to ferric form using potassium persulphate and titrating thereafter with potassium thiocyanate to form the red ferric thiocyanate measured colorimetrically at 480 nm (Ranganna, 1997).

$$\text{Iron (mg 100 g}^{-1}) = \frac{\text{OD of sample x 0.1 x Total volume of ash solution x 100}}{\text{OD of standard x 5 x weight of sample taken for ashing}}$$

3.1.3.2.7 Dietary fibre

The dietary fibre in the sample was measured by removing the protein and starch from the alcohol insoluble residue. One gram sample was weighed and made in

to a clean thimble using filter paper and extracted in a soxhlet apparatus for 16 hours using 90 per cent ethanol as solvent. The alcohol insoluble residue is then dried, weighed and finely powdered and analyzed for protein and starch. The percentage of total dietary fibre (TDF) in the sample can be calculated using the formula (Englyst *et al.*, 1978).

$$TDF\ (\%) = \frac{W_1 - (W_2 + W_3)}{W} \times 100$$

Where, W – weight of sample taken (g)

W_1 – dry weight of alcohol insoluble residue (g)

W_2 – amount of starch present in the sample (g)

W_3 – amount of protein present in the sample (g)

3.1.3.2.8 Anthocyanin

Hot water extraction of the sample was done by placing 50 g of the homogenate in a beaker containing water equal to thrice the quantity of homogenate and then it was boiled for about five to six hours at 60-70 °C for complete extraction of the pigment. After extraction, the pigment was filtered with Whatman filter paper and stored in glass bottles at refrigerated condition by covering with aluminium foil for protection from light (Harbone, 1978).

Anthocyanin content estimation was done based on the method given by Iland *et al.* (1996). Malvidin-3-glucoside was used as the standard. 0.2 ml of the extract was transferred to a test tube. 3.8 ml of 1.0 M HCl was added to it and incubated for 22 hours at room temperature by covering with parafilm. This step is critical in allowing full expression of the colour. The absorbance of the acidified diluted extract was measured at 520 nm using a 1.0 M HCl blank in a UV spectrophotometer.

Anthocyanin content =

$$\frac{\text{Absorbance at 520 nm x D.F x Final Volume (ml) x Sample weight (g) x 1000}}{\text{D x 100 x homogenate weight (g)}}$$

Where,

DF = Dilution Factor

D = absorbance of one per cent w/v solution of malvidin-3-glucoside

3.1.3.2.9 Antioxidant activity

The antioxidant activity of banana male bud was estimated by the method suggested by Blois (1958) using DPPH (1, 1-diphenyl-1-picryl hydrazine). To various concentrations of the sample, methanolic solutions containing DPPH radicals (0.1 mM) was added and shaken vigorously. The reaction mixture was then left to stand for thirty minutes in dark. After the incubation period, the absorbance was measured at 517 nm against the corresponding test blanks. The percentage inhibition of DPPH free radical was calculated using the formula

$$\text{Percent inhibition} = \frac{\text{Control} - \text{Sample}}{\text{Control}} \times 100$$

The sample concentration providing 50 percent inhibition (Inhibitory Concentration – IC_{50}) was calculated from the graph of RSA (Radical Scavenging Activity) percentage against sample concentration. Gallic acid was used as standard.

3.1.3.3 Sensory evaluation

The male buds were chopped in to pieces and were evaluated using a nine point hedonic scale to assess the colour, appearance, texture, odour and overall acceptability of the produce by a panel of 15 semi trained judges. For organoleptic

test, Kendalls co-efficient of concordance was performed and the mean rank scores were taken to differentiate the best produce.

3.2 Standardization of suitable packaging and storage methods for enhancing the shelf life of whole male bud of banana

The male buds of the popular variety Palayankodan was harvested and after removing the loose outer bracts, it was cleaned, packed and stored at different conditions to find out the best method of packaging and condition of storage and also was evaluated for organoleptic quality.

3.2.1 Treatments

Four packaging treatments were given for the whole male bud of banana and stored in three different conditions.

Packaging treatments:

P0: Control
P1: Shrink wrapping
P2: Cling film wrapping
P3: Packaging in polyethylene cover (150 gauge)

Storage conditions:

S0: Ambient
S1: Cold storage (12±2°C)
S2: Refrigerated condition (5±2°C)

3.2.2 Design

The experiment was laid out in a Completely Randomized Design (CRD) with three replications for each treatment.

3.2.3 Observations

Observations on physical and biochemical parameters were taken to fix the most appropriate packaging material and storage conditions.

3.2.3.1 Physical parameters

3.2.3.1.1 Physiological Loss in Weight (PLW)

PLW was calculated on the initial weight basis as suggested by Srivastava and Tandon (1968) at weekly interval and expressed as percentage.

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

3.2.3.1.2 Shelf life

The shelf life was calculated as number of days from harvest till the buds remained marketable. The buds were rated not marketable when more than 25 per cent of the bud showed spoilage, browning and microbial growth.

3.2.3.2 Biochemical analysis

3.2.3.2.1 *Acidity*

Same as mentioned in 3.1.3.2.1

3.2.3.2.2 *Ascorbic acid*

Same as mentioned in 3.1.3.2.2

3.2.3.2.3 *Total phenol*

Same as mentioned in 3.1.3.2.3

3.2.3.3 Sensory evaluation

Same as mentioned in 3.1.3.3

3.3 Standardization of minimal processing techniques for banana male bud

Deveined male bud was sanitized and cut into thin pieces and after pretreatment, different methods of packaging was done and kept under cold storage condition. It was evaluated for the best method of pretreatment and packaging material and also for the organoleptic quality.

3.3.1 Treatments

The minimally processed male buds were given four pretreatments and packed in three different packaging materials.

Pretreatments:

M0: Control
M1: Ascorbic acid
M2: Citric acid
M3: Turmeric and salt

Packaging materials:

C1: Paper plate overwrapped with cling film
C2: Polystyrene trays overwrapped with cling film
C3: Polyethylene punnets

3.3.2 Design

The experiment was laid out in a Completely Randomised Design (CRD) with three replications for each treatment.

3.3.3 Observations

Observations on physical and biochemical parameters were taken to fix the most appropriate pretreatment and packaging material for the minimally processed male bud.

3.3.3.1 Physical parameters

3.3.3.1.1 Shelf life

Same as mentioned in 3.2.3.1.2

3.3.3.1.2 Physiological Loss in Weight (PLW)

Same as mentioned in 3.2.3.1.1

3.3.3.1.3 Respiration rate

Respiration rate was measured directly using a gas analyser. The hypodermic needle in the gas analyses helps to draw in air samples for 15 seconds through a septum pasted on the package. The rate of respiration was expressed as CO_2 per cent.

3.3.3.1.4 Moisture content

Moisture content in the male bud was estimated by oven dry method. An empty dish was weighed and placed in hot air oven at 105°C for 30 minutes and then in a desiccator for 15 minutes. 5 g of sample was weighed and placed in the dish and kept in hot air oven at 105°C for 2 hours, then cooled in a desiccator for 30 minutes. The procedure was repeated until a constant weight was obtained. The percentage moisture content can be calculated using the formula

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

Where, A = weight of fresh sample + dish

B = weight of dried sample + dish

C = weight of empty dish

3.3.3.2 Biochemical parameters

3.3.3.2.1 Acidity

Same as mentioned in 3.1.3.2.1

3.3.3.2.2 Ascorbic acid

Same as mentioned in 3.1.3.2.2

3.3.3.2.3 Total phenol

Same as mentioned in 3.1.3.2.3

3.3.3.3 Sensory evaluation

The minimally processed and pretreated male buds were evaluated,both fresh and after cooking, using a nine point hedonic scale to assess the appearance, colour, texture, flavor, taste, after taste, odour and overall acceptability by a panel of 15 semi trained judges. For organoleptic test, Kendalls co-efficient of concordance was performed and the mean rank scores were taken to differentiate the best produce.

3.3.3.4 Microbial load

Microbial population of the pretreated minimally processed banana male buds was assessed initially and two days after storage. The quantitative assay of the microflora was carried out by serial dilution pour plate technique (Johnson and Curl, 1972). Nutrient agar medium, Rose Bengal agar medium and Sabourd Dextrose agar

medium were used for the enumeration of bacterial, fungal and yeast population respectively.

Ten gram of sample was crushed and dissolved in 100 ml of sterile distilled water and shaken thoroughly to obtain 10^{-1} dilution. From this 1 ml of the supernatant was accurately pipetted out using a micropipette in to a test tube containing 9 ml sterile distilled water to get 10^{-2} dilution. This procedure was repeated until 10^{-6} dilution was obtained. One ml each of 10^{-3},10^{-4} and 10^{-6} was used for the enumeration of fungal, yeast and bacterial population respectively. The bacterial count was recorded after two days whereas the fungal and yeast count was recorded four days after inoculation.

The number of microorganisms per gram of the sample was calculated using the formula

$$\text{No. of colony forming units (cfu) per gram of the sample} = \frac{\text{Mean number of CFU}}{\text{weight of the sample}} \times 100$$

RESULTS

4. RESULTS

The results of the present study entitled "Characterization and value addition of male buds of banana cultivars" are presented in this chapter under the following titles.

4.1 Characterization of male buds of banana cultivars and standardizing their harvesting stage

4.2 Standardization of packaging and storage methods

4.3 Standardization of minimal processing techniques for banana male bud

4.1 CHARACTERIZATION OF MALE BUDS OF BANANA CULTIVARS AND STANDARDIZING THEIR HARVESTING STAGE

The experiment was done with the objective of characterizing the male buds of four commercial varieties of Kerala, Palayankodan, Grand naine, Njalipoovan and Nendran and to standardize the harvesting stage of buds by comparing the characters of buds harvested at 15, 20 and 25 days after full bunch emergence. The characterization was done by observing the physical and biochemical parameters.

4.1.1 Physical parameters

Weight, length and diameter of the bud, at different maturity stage were noted along with the size, shape, colour, recovery and firmness to determine the quality.

4.1.1.1 Bud weight (g)

The bud weight showed significant difference with regard to the variety and days of harvest (Table 1). The highest bud weight was expressed by Grand naine when at 20 days after full bunch emergence (1215 g). In Palayankodan (550g) also,

buds harvested at 20 days after full bunch emergence showed higher bud weight. Whereas, buds harvested 15 and 25 days after full bunch emergence showed higher bud weight in case of Njalipoovan (275g) and Nendran (845g) varieties respectively. Minimum bud weight was observed in Njalipoovan (185g) harvested at 25 days after full bunch emergence.

4.1.1.2 Bud length (cm)

The length of the buds was highest when harvested at 20 days after full bunch emergence for Grand naine (32 cm)and lowest for Njalipoovan (16.9cm) harvested at 25 days after full bunch emergence (Table 1).

4.1.1.3 Bud Diameter (cm)

Average bud diameter was found to be lowest for Njalipoovan (6.11 cm) harvested at 25 days after full bunch emergence (Table 1). The highest bud diameter was observed in Nendran (11.62 cm) variety at 25 days after full bunch emergence followed by Grand naine (10.73 cm) and Palayankodan (9.07 cm) at 20 days after full bunch emergence.

4.1.1.4 Shape

The male buds of Palayankodan and Nendran variety were broadly ovate and not tapering sharply whereas Grand naine and Njalipoovan were lanceolate or narrowly ovate and tapering sharply from the shoulder.

4.1.1.5 Colour

Colour of the outer and inner portion of the bracts were examined. Palayankodan and Nendran variety had a distinctive brownish purple outside and bright crimson inside. Grand naine and Njalipoovan had red, dull purple or yellow outside and pink, dull purple or yellow inside.

4.1.1.6 Recovery (%)

There was significant difference in bud recovery with respect to variety and stages of harvest (Table 1). Grand naine had a highest recovery percentage (99.3 %) when harvested 15 days after full bunch emergence and Nendran had a lowest recovery percentage (69.2 %) when harvested 25 days after full bunch emergence. Whereas bud recovery was maximum at 25 days after full bunch emergence for Palayankodan (97.8 %) and at 15 days after full bunch emergence for Njalipoovan (87.2%) and Nendran (77.9 %).

4.1.1.7 Firmness (kg cm^{-2})

No significant difference was observed in firmness among varieties (Table 1). Bud firmness was recorded to be highest for Palayankodan (1.304 kg cm^{-2}) at 25 days after full bunch emergence followed by Grand naine (1.232 kg cm^{-2}) Njalipoovan (1.201 kg cm^{-2}) and Nendran (1.115 kg cm^{-2}) at 15 days after full bunch emergence. Lowet bud firmness was observed in Njalipoovan (0.790 kg cm^{-2}) harvested at 25 days after full bunch emergence.

Table 1: Effect of harvesting stage on physical characters of male bud in banana cultivars

Parameters	Weight (g)			Length (cm)			Diameter (cm)			Recovery (%)			Firmness (kg cm^{-2})		
Treatments	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB
Palayankodan	305	550	465	18.0	22.5	21.0	7.00	9.07	8.37	90.1	91.8	97.8	1.087	1.000	1.304
Grand naine	740	1215	945	26.5	32.0	27.4	8.85	10.73	9.55	99.3	89.3	98.9	1.232	0.988	1.019
Njalipoovan	275	240	185	19.8	18.6	16.9	6.49	6.46	6.11	87.2	85.4	83.7	1.201	0.889	0.790
Nendran	680	710	845	24.3	24.6	25.0	9.68	10.7	11.62	77.9	76.7	69.2	1.115	0.953	0.793
CD for factor A	2.425			0.326			0.285			0.025			NS		
CD for factor B	2.100			0.282			0.247			0.022			NS		
CD for interaction	4.200			0.564			0.493			0.043			NS		

DAB – Days after full bunch emergence

Factor A - Variety

Factor B – Stage of harvest

Palayankodan

Grand naine

Njalipoovan

Nendran

15 DAB 20 DAB 25 DAB

Plate 1: Male buds of banana cultivars at different stages of harvest

62

4.1.2 Biochemical parameters

4.1.2.1 Acidity (%)

The titrable acidity did not show any significant difference among the four banana varieties at different stages of harvest. All the varieties had 0.67 percent acidity (Table 2).

4.1.2.2 Ascorbic Acid (mg 100 g^{-1})

Banana male bud is a rich source of ascorbic acid, an essential antioxidant in human nutrition. There was significant difference in the ascorbic acid content among the varieties and stages of harvest (Table 2). Ascorbic acid content of banana male bud ranged from 12.764 to 21.304 mg 100 g^{-1}. Ascorbic acid content was recorded to be highest at 25 days after full bunch emergence for Palayankodan (21.266 mg 100g^{-1}) and Nendran (21.270 mg 100 g^{-1}), at 20 days after full bunch emergence for Grand naine (21.304 mg 100 g^{-1}) and at 15 days after full bunch emergence for Njalipoovan (21.273 mg 100 g^{-1}). Whereas, the lowest ascorbic acid content was observed in Grand naine (12.764 mg 100 g^{-1}) at 15 days after full bunch emergence.

4.1.2.3 Protein (g 100 g^{-1})

Significant variation in protein content was observed among the varieties harvested at three different stages (Table 2). Protein content in male buds ranged from 7.437 to 13.577 g 100 g^{-1}. Protein content was maximum at 25 days after full bunch emergence for Palayankodan (7.855 g 100 g^{-1}) and Grand naine (13.577 g 100 g^{-1}), at 20 days after full bunch emergence for Njalipoovan (13.454 g 100 g^{-1}) and at 15 days after full bunch emergence for Nendran (10.763 g 100 g^{-1}) variety. Lowest protein content was recorded in Palayankodan (7.437 g 100 g^{-1}) at 15 days after full bunch emergence.

Table 2: Effect of harvesting stage on biochemical characters (acidity, ascorbic acid, protein, carbohydrate) of male bud in banana cultivars

Parameters	Acidity (%)			Ascorbic acid (mg 100^{-1})			Protein (g 100^{-1})			Carbohydrate (g 100^{-1})		
Treatments	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB
Palayankodan	0.67	0.67	0.67	17.026	17.024	21.266	7.437	7.571	7.855	21.694	9.027	1.554
Grand naine	0.67	0.67	0.67	12.764	21.304	17.030	13.447	13.184	13.577	7.502	7.044	3.905
Njalipoovan	0.67	0.67	0.67	21.273	17.031	21.269	10.692	13.454	10.406	10.254	14.434	15.381
Nendran	0.67	0.67	0.67	12.772	17.034	21.270	10.763	7.687	7.936	10.345	8.834	8.663
CD for factor A	NS			0.003			0.006			0.034		
CD for factor B	NS			0.004			0.005			0.030		
CD for interaction	NS			0.007			0.011			0.059		

DAB – days after full bunch emergence

Factor A - Variety

Factor B – Stage of harvest

4.1.2.4 Carbohydrate (g 100 g^{-1})

Carbohydrate content in buds harvested from different varieties at different stages exhibited significant variation (Table 2). The values ranged from 1.554 to 21.694 g 100 g^{-1}. Highest carbohydrate content was recorded at 15 days after full bunch emergence for Palayankodan (21.694 g 100 g^{-1}), Grand naine (7.502 g 100 g^{-1}) and Nendran (10.345 g 100 g^{-1}) whereas at 25 days after full bunch emergence for Njalipoovan (15.381 g 100 g^{-1}). Lowest carbohydrate content was observed in Palayankodan (1.554 g 100 g^{-1}) at 25 days after full bunch emergence.

4.1.2.5 Total Phenol (mg 100 g^{-1})

Total phenol content in male buds ranged from 1.902 to 6.363 mg 100 g^{-1} with significant variation (Table 4). Total phenol content was found to be maximum at 15 days after full bunch emergence for all the four varieties. The highest value was observed for Grand naine (6.363 mg 100 g^{-1}) at 15 days after full bunch emergence and lowest for Nendran (1.902 mg 100 g^{-1}) at 25 days after full bunch emergence.

4.1.2.6 Minerals (%)

Banana male buds are rich in minerals such as potassium, sodium, calcium and iron which add to its nutritional value. The total mineral content had significant variation among varieties which ranged from 0.85 percent in Palayankodan at 25 days after full bunch emergence to 1.45 percent in Njalipoovan at 25 days after full bunch emergence (Table 3). Mineral content was maximum at 15 days after full bunch emergence for Palayankodan (1.23 %) and at 25 days after full bunch emergence for Grand naine (1.01 %), Njalipoovan (1.45 %) and Nendran (1.32 %) variety.

4.1.2.7 Potassium (mg 100 g^{-1})

Potassium content varied significantly among different varieties ranging from 265.23 to 411.21 mg 100 g^{-1} (Table 3). Highest potassium content was observed at 15 days after full bunch emergence in Palayankodan (397.41 mg 100 g^{-1}), Grand naine (375.21 mg 100 g^{-1}) and Njalipoovan (411.21 mg 100 g^{-1}) whereas at 25 days after full bunch emergence in Nendran (368.76 mg 100 g^{-1}) variety. Potassium content was found to be lowest in Grand naine harvested 20 days after full bunch emergence.

4.1.2.8 Sodium (mg 100 g^{-1})

Sodium content had significant variation among different varieties and harvesting stages, ranging from 7.5 to 39.63 mg 100 g^{-1} (Table 3). Sodium content was recorded highest at 15 days after full bunch emergence in Njalipoovan (8.09 mg 100 g^{-1}) and at 20 days after full bunch emergence in Palayankodan (24.34 mg 100 g^{-1}), Grandnaine (39.63 mg 100 g^{-1}) and Nendran (19.25 mg 100 g^{-1}). Njalipoovan (7.5 mg 100 g^{-1}) harvested at 20days after full bunch emergence had the lowest sodium content.

4.1.2.9 Calcium (mg 100 g^{-1})

Calcium content in the buds ranged from 17.38 to 28.08 mg 100 g^{-1} with significant variation among varieties and harvesting stages (Table 3). Calcium content was recorded to be maximum at 20 days after full bunch emergence for Palayankodan (25.59 mg 100 g^{-1}), Grandnaine (28.08 mg 100 g^{-1}) and Nendran (22.53 mg 100 g^{-1}) whereas at 25 days after full bunch emergence for Njalipoovan (19.01 mg 100 g^{-1}). Lowest calcium content was recorded in Nendran variety (17.38 mg 100 g^{-1}) harvested 15 days after full bunch emergence.

Table 3: Effect of harvesting stage on mineral content of male bud in banana cultivars

Parameters	Total mineral content (%)			Potassium (mg 100^{-1})			Calcium (mg 100^{-1})			Sodium (mg 100^{-1})			Iron (mg 100^{-1})		
Treatments	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB
Palayankodan	1.23	1.12	0.85	397.41	364.88	326.51	21.89	25.59	18.48	13.73	24.34	11.92	2.10	2.01	0.35
Grand naine	0.95	0.92	1.01	375.21	265.23	334.66	19.15	28.08	22.48	11.74	39.63	18.30	1.12	0.45	1.40
Njalipoovan	1.42	1.44	1.45	411.21	375.30	389.70	18.61	18.25	19.01	8.09	7.5	8.79	0.53	2.10	0.79
Nendran	1.19	1.14	1.32	358.13	355.80	368.76	17.38	22.53	19.33	7.62	19.25	10.45	2.67	0.85	0.73
CD for factor A	0.033			0.209			0.033			0.047			0.026		
CD for factor B	0.028			0.181			0.029			0.041			0.022		
CD for interaction	0.057			0.362			0.058			0.081			0.045		

DAB – days after full bunch emergence

Factor A - Variety
Factor B – Stage of harvest

4.1.2.10 Iron (mg 100 g^{-1})

Iron content varied significantly among male buds of different varieties. The values ranged from 0.35 to 2.67 mg 100 g^{-1} (Table 3). Iron content was highest at 15days after full bunch emergence for Palayankodan (2.1 mg 100 g^{-1}) and Nendran (2.67 mg 100 g^{-1}), at 20 days after full bunch emergence for Njalipoovan (2.10 mg 100 g^{-1}) and at 25 days after full bunch emergence for Grand naine (1.40 mg 100 g^{-1}). Lowest iron content was recorded in Palayankodan (0.35 mg 100 g^{-1}) at 25 days after full bunch emergence.

4.1.2.11 Total dietary fibre (%)

Banana male buds are one of the richest sources of dietary fibre. The total dietary fibre content had shown significant variation among different varieties and stages of harvest (Table 4). The values ranged from 33.637 to 59.370 percent. The highest dietary fibre content was recorded at 15days after full bunch emergence in Palayankodan (50.753 %), Grandnaine (59.370 %) and Nendran (55.287 %) whereas at 25days after full bunch emergence for Njalipoovan (54.100 %). The lowest dietaryfibre content was observed in Palayankodan (33.637 %) at 25 days after full bunch emergence.

4.1.2.12 Anthocyanin (mg 100 g^{-1})

Anthocyanin is the colouring pigment in banana male buds. Significant difference in anthocyanin content was observed in Palayankodan and Njalipoovan at 15 days after full bunch emergence, only in Palayankodan at 20 days after full bunch emergence and in Palayankodan and Nendran at 25 days after full bunch emergence. Anthocyanin content in the buds ranged from 0.123 to 5.460 mg 100 g^{-1} (Table 4). Maximum anthocyanin content was recorded at 15 days after full bunch emergence in Njalipoovan (3.700 mg 100 g^{-1}), at 20 days after full bunch emergence in

Table 4: Effect of harvesting stage on biochemical characters (total phenol, dietary fibre, anthocyanin, antioxidant content) of male bud in banana cultivars

Parameters	Total phenol (mg 100^{-1})			Dietary fibre (%)			Anthocyanin (mg 100^{-1})			Antioxidant content (µg ml^{-1})		
Treatments	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB	15 DAB	20 DAB	25 DAB
Palayankodan	2.154	2.125	2.122	50.753	47.700	33.637	1.440	5.460	4.360	0.317	0.113	0.388
Grand naine	6.363	6.324	2.716	59.370	52.697	51.987	0.420	1.007	1.090	0.446	0.127	0.307
Njalipoovan	4.526	4.344	3.084	41.673	50.213	54.100	3.700	0.410	0.500	0.501	0.370	0.427
Nendran	2.903	2.636	1.902	55.287	44.367	50.580	0.123	1.250	2.640	0.163	0.213	0.243
CD for factor A	0.003			0.169			0.490			0.012		
CD for factor B	0.003			0.147			0.425			0.010		
CD for interaction	0.005			0.293			0.849			0.020		

DAB – days after full bunch emergence

Factor A - Variety

Factor B – Stage of harvest

Palayankodan (5.460 mg 100 g^{-1}) and at 25 days after full bunch emergence in grandnaine (1.090 mg 100 g^{-1}) and Nendran (2.640 mg 100 g^{-1}) variety. The lowest anthocyanin content was found in Nendran (0.123 mg 100 g^{-1}) harvested at 15 days after full bunch emergence.

4.1.2.13 Antioxidant (µg ml^{-1})

Antioxidant content in the buds ranged from 0.113 to 0.501 µg ml^{-1} (Table 4). Only Njalipoovan and Nendran varieties harvested at 20 days after full bunch emergence showed significant variation. Antioxidant content was recorded highest at 15 days after full bunch emergence in Grandnaine (0.446 µg ml^{-1}) and Njalipoovan (0.501 µg ml^{-1}), whereas at 25 days after full bunch emergence in Palayankodan (0.388 µg ml^{-1}) and Nendran (0.243 µg ml^{-1}). Palayankodan harvested 20 days after full bunch emergence exhibited the lowest antioxidant content (0.113 µg ml^{-1}).

4.1.3 Sensory evaluation

The mean rank scores for appearance, colour, texture, odour and overall acceptability of male buds of four different varieties harvested at 15, 20 and 25 days after full bunch emergence were recorded separately and is given in Table 5.

On comparing the buds harvested at 15days after full bunch emergence, highest mean rank score for appearance (8.13) was for Grandnaine, whereas mean rank scores for colour (8.26), texture (7.60), odour (7.53) and overall acceptability (8.13) was higher for Palayankodan with a total score of 39.25.

When buds harvested at 20days after full bunch emergence were compared, mean rank score for appearance (7.26) was highest for Grandnaine but colour (7.20), texture (7.13), odour (8.26) and overall acceptability (7.53) scores were maximum for Palayankodan with a total score of 36.52.

When the buds were harvested at 25 days after full bunch emergence, higher mean rank scores were exhibited by Grandnaine for appearance (6.73) and odour (7.13), whereas for colour (7.20), texture (7.20 and overall acceptability (7.73), Palayankodan scored maximum with a total score of 34.86.

From this experiment it could be concluded that yield attributes were higher for Palayankodan and Grand naine at 20 days after full bunch emergence, for Njalipoovan at 15 days after full bunch emergence and for Nendran at 25 days after full bunch emergence. However, when the four varieties were subjected to organoleptic evaluation, Palayankodan had the overall consumer acceptance and highest total score under all the three stages of harvest. Also due to its popularity and easy availability, Palayankodan variety was taken for the packaging and storage studies.

Table 5: Effect of variety and harvesting stage on sensory attributes of banana bud

Stage of harvest	Variety	Appearance	Colour	Texture	Odour	Overall acceptability	Total score
15 DAB	Palayankodan	7.73	8.26	7.60	7.53	8.13	39.25
	Grandnaine	8.13	5.46	7.40	6.66	6.26	33.91
	Njalipoovan	6.40	7.66	6.47	7.40	7.40	35.33
	Nendran	5.73	6.26	6.40	7.13	7.66	33.18
	Kendall's W Test	**0.536**	**0.886**	**0.223**	**0.067**	**0.606**	
20 DAB	Palayankodan	6.40	7.20	7.13	8.26	7.53	36.52
	Grandnaine	7.26	6.66	6.80	7.66	7.40	35.78
	Njalipoovan	6.33	5.93	6.40	6.26	7.13	32.05
	Nendran	5.33	5.07	5.93	5.33	6.66	28.32
	Kendall's W Test	**0.383**	**0.373**	**0.150**	**0.790**	**0.099**	
25 DAB	Palayankodan	6.33	7.20	7.20	6.40	7.73	34.86
	Grandnaine	7.73	6.00	6.53	7.13	6.33	33.72
	Njalipoovan	6.13	6.20	6.47	5.93	6.13	30.86
	Nendran	6.00	6.66	6.80	6.33	7.13	32.92
	Kendall's W Test	**0.202**	**0.273**	**0.190**	**0.129**	**0.159**	

DAB – days after full bunch emergence

4.2 STANDARDIZATION OF PACKAGING AND STORAGE METHODS

Shelf life of a produce can be enhanced through effective packaging and storage methods. The refrigeration and cold storage treatments help to reduce respiration rate and thereby retards ripening. Also it helps to control the enzyme aided decomposition and disintegration of tissues. Hence banana buds were given pre-packaging treatments and stored under ambient and controlled temperature conditions and resorted to the study. The observations made are given below.

4.2.1 Physiological loss in weight (%)

The weight of the buds gets reduced during storage due to the physiological activities taking place even after harvest and this in turn affect the quality of the produce. Physiological loss in weight of male buds increased in all the treatments during storage under ambient, refrigerated and cold storage conditions, except those wrapped in cling films (Table 6).

While comparing the packaging treatments one week after storage, PLW (0.09 %) was lowest in cling film wrapped buds under cold storage condition. Also both shrink wrapping and buds packed in polyethylene cover showed minimum PLW (0.12 %) under refrigerated condition. While under ambient condition, shrink wrapping was found to reduce the PLW (4.78 %) compared to other packaging treatments.

4.2.2 Shelf life (days)

Shelf life was calculated as number of days for which the buds remained marketable from the day of harvest.

The shelf life of buds packed up by shrink film, cling film and polyethylene cover was compared with buds kept without packaging when kept under ambient,

Table 6: Effect of packaging treatments and storage conditions on PLW (%) of banana male bud

PLW (%)									
Treatments	Ambient	Refrigerated storage				Cold storage			
	1 WAS	**1 WAS**	**2 WAS**	**3 WAS**	**4 WAS**	**1 WAS**	**2 WAS**	**3 WAS**	**4 WAS**
P0	16.16	3.93	4.32	-	-	3.61	3.97	-	-
P1	4.78	0.12	0.18	0.20	-	0.19	0.39	0.44	-
P2	6.11	1.79	3.81	3.02	3.46	0.09	0.68	0.65	0.67
P3	5.23	0.12	0.15	0.18	0.21	0.40	3.29	4.11	-
CD for factor A	0.055								
CD for factor B	0.048								
CD for interaction	0.095								

Table 7: Effect of packaging treatments and storage conditions on shelf life (days) of banana male bud

Shelf life (days)			
Treatments	Ambient	Refrigerated	Cold storage
P0	7	14	18
P1	11	25	22
P2	10	28	30
P3	13	43	27
CD for factor A	1.019		
CD for factor B	0.882		
CD for interaction	1.764		

P0 – Control

P1 – Shrink wrapping

P2 – Cling film wrapping

P3 – Packaging in polyethylene cover

WAS – Week after storage

Factor A – Packaging treatments

Factor B – Storage conditions

refrigerated and cold storage condition (Table 7). Among the treatments, buds stored under ambient condition exhibited a lower shelf life when compared to refrigerated and cold storage condition. Under cold storage condition, cling film wrapped buds had a longer shelf life (30 days) whereas under refrigerated condition the buds in polyethylene cover exhibited a significantly longer shelf life (43 days).

On comparing the packaging treatments, buds packed in polyethylene cover had the longest shelf life both under ambient (13 days) and refrigerated condition (43 days), whereas under cold storage, cling film wrapped buds (30 days) had the longest shelf life.

4.2.3 Acidity (%)

The acidity in the male buds showed an increasing trend under all the three storage conditions (Table 8). On comparing the storage conditions, cling film wrapped buds had the lowest acidity (0.673 %) after one week of storage under all the three storage conditions. Whereas the highest acidity was observed in unwrapped buds (2.653 %) stored under ambient condition.

When the treatments were compared after one week of storage, only the unwrapped buds and the buds in poly ethylene cover showed significant variation under ambient condition. And there was no significant difference in titrable acidity among buds stored under refrigerated and cold storage conditions. Lower acidity (0.673 %) was observed in cling film wrapped buds under all three storage conditions. Higher acidity (2.653 %) was shown by control sample under ambient storage while under refrigerated and cold storage conditions, higher values were observed for buds packed in polyethylene cover (1.344 %).

Table 8: Effect of packaging treatments and storage conditions on acidity (%) of banana male bud

Acidity(%)									
Treatments	Ambient	Refrigerated storage				Cold storage			
	1 WAS	1 WAS	2 WA	3 WAS	4 WAS	1 WAS	2 WAS	3 WAS	4 WAS
P0	2.653	1.342	1.34	-	-	1.342	1.345	-	-
P1	1.345	0.675	0.67	1.340	-	0.674	0.675	0.670	-
P2	0.673	0.673	0.67	1.340	1.343	0.673	0.675	0.670	1.021
P3	1.344	1.344	2.68	2.683	2.721	1.344	2.022	2.700	-
CD for factor A	0.012								
CD for factor B	0.010								
CD for interaction	0.021								

Table 9: Effect of packaging treatments and storage conditions on ascorbic acid content (mg 100^{-1}) of banana male bud

Ascorbic acid (mg 100^{-1})									
Treatments	Ambient	Refrigerated storage				Cold storage			
	1 WAS	1 WAS	2 WAS	3 WAS	4 WAS	1 WAS	2 WAS	3 WA	4 WAS
P0	297.73	255.19	212.65	-	-	318.99	297.73	-	-
P1	120.13	63.60	53.17	42.55	-	99.03	95.40	49.63	-
P2	127.60	106.33	85.06	85.06	85.06	148.86	127.60	85.06	85.06
P3	170.13	148.86	127.60	127.60	99.26	127.60	106.30	85.06	-
CD for factor A	0.170								
CD for factor B	0.147								
CD for interaction	0.294								

P0 – Control
P1 – Shrink wrapping
P2 – Cling film wrapping
P3 – Packaging in polyethylene cover
WAS – Week after storage

4.2.4 Ascorbic acid (mg 100^{-1})

A declining trend was observed in ascorbic acid content in male buds with significant variation in all the treatments under three different storage conditions (Table 9). On comparing the storage conditions, ascorbic acid retention was found to be greater (318.99 mg 100^{-1}) in case of unwrapped buds stored for one week under cold storage and the least retention was seen in shrink wrapped buds (63.6 mg 100^{-1}) under refrigerated condition one week after storage.

When the treatments were compared, the control sample exhibited maximum retention of ascorbic acid one week after storage under ambient (297.73 mg 100^{-1}), refrigerated (255.19 mg 100^{-1}) and cold storage (318.99 mg 100^{-1}) conditions. However, one week after storage under ambient (120.13 mg 100^{-1}), refrigerated (63.60 mg 100^{-1}) and cold storage (99.03 mg 100^{-1}) conditions, the least ascorbic acid content was observed in buds with shrink wrapping.

4.2.5 Total phenol (mg 100^{-1})

Total phenol content had shown an increasing trend upon packaging and storage under all the treatments, with significant variation (Table 10). On comparing the storage conditions one week after storage, total phenol content was recorded highest (7.21 mg 100^{-1}) in control sample without any package stored under cold storage condition and lowest (0.181 mg 100^{-1}) in shrink wrapped buds stored under ambient condition.

When the treatments were compared, unwrapped control sample had the highest phenol content and the shrink wrapped buds had the lowest, after one week of storage under ambient (4.532 mg 100^{-1}; 0.181 mg 100^{-1}) refrigerated (4.59 mg 100^{-1}; 0.195 mg 100^{-1}) and cold storage (7.21 mg 100^{-1}; 0.520 mg 100^{-1}) conditions.

Table 10: Effect of packaging treatments and storage conditions on Total phenol content (mg 100^{-1}) of banana male bud

Total phenols (mg 100^{-1})									
Treatments	Ambient	Refrigerated storage				Cold storage			
	1 WAS	**1 WAS**	**2 WAS**	**3 WAS**	**4 WAS**	**1 WAS**	**2 WAS**	**3 WAS**	**4 WAS**
P0	4.532	4.59	5.23	-	-	7.21	7.36	-	-
P1	0.181	0.195	0.389	0.733	-	0.520	0.661	1.170	-
P2	1.961	0.569	1.258	1.291	2.37	0.833	0.855	0.979	1.725
P3	0.386	0.648	0.680	1.347	2.58	0.621	0.784	2.015	-
CD for factor A	0.018								
CD for factor B	0.015								
CD for interaction	0.031								

P0 – Control

P1 – Shrink wrapping

P2 – Cling film wrapping

P3 – Packaging in polyethylene cover

WAS – Week after storage

Shrink wrapping

Cling film wrapping

Polyethylene cover

Ambient Cold storage Refrigerated

Plate 2: Effect of packaging treatments on buds under different storage conditions (1 WAS)

4.2.6 Sensory evaluation

The mean rank scores for appearance, colour, texture, odour and overall acceptability of the male buds subjected to different packaging treatments were recorded separatelyfor three different storage conditions and given in Table 11.

One week after storage under ambient condition, the mean rank scores for appearance (7.00) and texture (6.73) were highest for cling film wrapped buds, whereas the highest mean rank score for colour (7.13) was recorded in the buds packed in polyethylene cover, and the odour (6.73) had highest mean score in unwrapped buds. However, the mean rank score for overall acceptability (6.80) was maximum for buds packed in polyethylene cover with a total score of 33.73.

After one week of storage under refrigerated condition, the mean rank score for odour (6.53) was maximum for unwrapped control sample, whereas for appearance (7.73), colour (7.60) and texture (7.20) the highest mean score was for polyethylene covered buds with an overall acceptability of 7.27 and a total score of 36.07.

Buds stored for one week under cold storage condition had the highest total score (37.13) for cling film wrapped buds with a maximum mean scores for appearance (7.80), texture (7.60), 0dour (6.67) and overall acceptability (7.60). The mean rank score for colour (7.60) highest for buds packed in polyethylene cover.

From this experiment it can be concluded that banana buds packed in polyethylene cover and stored under refrigerated condition had the highest shelf life (43 days) and lower physiological loss in weight along with biochemical parameters like ascorbic acid (148.86 mg 100^{-1}) and total phenols (0.648 mg 100^{-1}) and it also had highest scores in organoleptic evaluation with a total of 36.07.

Table 11: Effect of packaging treatments and storage conditions on sensory attributes of banana male bud

Storage conditions	Treatments	Appearance	Colour	Texture	Odour	Overall acceptability	Total Score
Ambient storage (S0)	P0	6.53	6.73	6.40	6.73	6.66	33.06
	P1	5.93	6.33	6.20	5.73	6.00	30.20
	P2	7.00	6.13	6.73	6.26	6.66	32.78
	P3	6.67	7.13	6.66	6.47	6.80	33.73
	Kendall's W Test	**0.115**	**0.103**	**0.056**	**0.100**	**0.087**	
Cold storage (S1)	P0	6.20	6.67	5.80	6.13	6.47	31.27
	P1	7.00	6.87	6.67	6.53	6.80	33.87
	P2	7.80	7.40	7.60	6.67	7.60	37.13
	P3	7.66	7.60	7.40	6.66	7.40	36.72
	Kendall's W Test	**0.246**	**0.034**	**0.213**	**0.098**	**0.127**	
Refrigerated storage (S2)	P0	6.87	6.87	6.33	6.53	6.73	33.34
	P1	6.73	6.53	6.53	6.00	6.40	32.20
	P2	7.20	6.80	6.73	6.33	7.00	34.07
	P3	7.73	7.60	7.20	6.27	7.27	36.07
	Kendall's W Test	**0.118**	**0.124**	**0.126**	**0.061**	**0.186**	

P0 – Control

P1 – Shrink wrapping

P2 – Cling film wrapping

P3 – Packaging in polyethylene cover

4.3 STANDARDIZATION OF MINIMAL PROCESSING TECHNIQUES FOR BANANA MALE BUD

Minimal processing includes operations like washing, peeling, chopping and packaging it in suitable containers. It helps to maintain the original fresh like appearance without any loss of quality. It is convenient for the consumer as they require little or no secondary processing and cooking before consumption. Packing in suitable packaging materials is also important as it aids in protection and preservation of the minimally processed produce. Here the deveined male buds were washed after removing the outer bracts and then given separate pretreatments with 0.2 percent ascorbic acid, citric acid and turmeric and salt for 30 minutes and then packed in different packaging materials. They were stored under cold storage condition and the observations were recorded which are given below.

4.3.1 Shelf life (days)

Minimally processed male buds after given different pretreatments and packaged in paper plates overwrapped with cling film, polystyrene trays overwrapped with cling film and polyethylene punnets exhibited a shelf life of one week when stored under cold storage condition.

4.3.2 Physiological loss in weight (PLW) (%)

PLW exhibited an increasing trend with significant variation for all the treatments during storage (Table 12). On comparing different packaging treatments two days after storage, the minimum PLW (1.046 %) was observed in buds pretreated with 0.2 percent ascorbic acid and packed in polyethylene punnets. Control sample packed in polystyrene trays overwrapped with cling film showed the highest PLW (2.546 %).

Table 12: Effect of minimal processing and packaging treatments on PLW (%) 1 WAS

Treatments	PLW(%)			
	Control	Ascorbic acid (0.2%)	Citric acid (0.2%)	Turmeric + salt (0.2%)
C1	2.074	1.862	1.933	1.340
C2	2.546	2.054	1.543	1.441
C3	1.863	1.046	1.474	1.247
CD for factor A	0.028			
CD for factor B	0.024			
CD for interaction	0.049			

Table 13: Effect of minimal processing and packaging treatments on Respiration rate (CO_2%) 1 WAS

Treatments	Respiration rate (CO_2%)							
	Control		Ascorbic acid (0.2%)		Citric acid (0.2%)		Turmeric + salt (0.2%)	
	Initial	**1 WAS**	**Initial**	**1 WAS**	**Initial**	**1 WAS**	**Initial**	**1 WAS**
C1	0.2	0	0.2	0.1	0.2	0.1	0.2	0.1
C2	0.1	0	0.1	0	0.2	0.1	0.1	0
C3	0.1	0	0.1	0	0.1	0	0.1	0
CD for factor A	NS							
CD for factor B	NS							
CD for interaction	NS							

C1 – paper plate overwrapped with cling film
C2 – polystyrene trays overwrapped with cling film
C3 – polyethylene punnets
WAS – week after storage
Factor A – Packaging treatments
Factor B – Pretreatments

On comparing the pretreatments, control sample exhibited the maximum PLW, when packed in paper plate overwrapped with cling film (2.074 %), polystyrene trays overwrapped with cling film (2.546 %) and polyethylene punnets (1.863 %) after two days of storage under cold storage condition. Minimum PLW was seen in buds pretreated with 0.2 percent turmeric and salt in paper plate overwrapped with cling film (1.340 %) and polystyrene trays overwrapped with cling film (1.441 %) whereas in polyethylene punnets the minimum Physiological loss in weight was recorded for 0.2 percent ascorbic acid pretreatment (1.046 %).

4.3.3 Respiration rate (CO_2 %)

No significant variation was observed in the respiration rate in all the treatments stored in cold storage condition for one week (Table 13). Except in control sample, all the three pretreatments had a respiration rate of 0.1 percent one week after storage in paper plate overwrapped with cling film. Whereas, in polystyrene traysoverwrapped with cling film, only the 0.2 percent citric acid pretreatment had 0.1 percent respiration rate after one week of storage under cold storage.

4.3.4 Moisture (%)

The moisture content showed a declining trend in all the treatments after one week of storage under cold storage condition with significant variation among values (Table 14). On comparing the packaging materials, one week after storage under cold storage, maximum moisture retention was observed in control sample (94.22 %) in paper plate overwrapped with cling film and minimum retention was seen in buds pretreated with 0.2 percent citric acid (92.85 %) in polyethylene punnets.

When the pretreatments were compared, highest moisture content was noted in control sample after one week of storage in paper plateoverwrapped with cling film (94.22 %), polystyrene trayoverwrapped with cling film (94.05 %) and polyethylene punnets (93.84 %) under cold storage condition. However, lower moisture content was observed in buds pretreated with 0.2 percent ascorbic acid in paper

plateoverwrapped with cling film (93.22 %) and polystyrene traysoverwrapped with cling film (93.45 %). In polyethylene punnets, minimum moisture retention was seen in 0.2 percent citric acid pretreated buds.

4.3.5 Acidity (%)

The minimally processed male buds in all the packaging materials after different pretreatments showed an increasing trend in acidity after one week of storage in cold storage condition (Table 15). In control and ascorbic acid pretreated samples, only the buds in paper plate overwrapped with cling film showed significant variation in acid content, whereas in turmeric and salt pretreatment, buds in polyethylene punnets showed significant difference.

On comparing the packaging materials, minimum acidity was noted in 0.2 percent turmeric and salt pretreated sample (0.890 %) in polyethylene punnets and maximum acidity in control sample (2.345 %) in paper plateoverwrapped with cling film. When pretreatments were compared, turmeric and salt pretreated buds in paper plate and polyethylene punnets had lowest acidity (1.005 %) whereas in polystyrene traysoverwrapped with cling film, buds pretreated with 0.2 percent ascorbic acid showed minimum acidity (0.893 %). Maximum acidity was seen in control sample in all the three packaging treatments. The increase in acidity may be due to the production of organic acids during minimal processing.

4.3.6 Ascorbic acid (mg 100 g^{-1})

Ascorbic acid content of minimally processed and pretreated buds packed in different packaging materials had shown either a constant value or a decreasing trend after been stored for two day under cold storage condition (Table 16). The initial ascorbic acid content was found maximum in buds pretreated with 0.2 percent ascorbic acid (212.28 mg 100 g^{-1}) and minimum in 0.2 percent turmeric and salt pretreated buds (99.34 mg 100 g^{-1}).

Ambient

0.2 % Ascorbic acid

0.2 % Citric acid

0.2 % Turmeric + Salt

Initial 1 WAS

Plate 3: Effect of pretreatments on the quality of minimally processed banana male buds in different packages

One week after storage under cold storage condition, significant difference in ascorbic acid content was observed in control sample in paper plate overwrapped with cling film, and in ascorbic acid pretreated sample in polyethylene punnets. Highest ascorbic acid retention was observed in buds in polyethylene punnets (127.62 mg 100 g^{-1}) pretreated with 0.2 percent ascorbic acid and lowest retention in 0.2 percent turmeric and salt pretreated buds in paper plate overwrapped with cling film (85.10 mg 100 g^{-1})

When the pretreatments were compared, maximum ascorbic acid retention was recorded in polyethylene punnets and minimum retention in paper plates overwrapped with cling film, with 0.2 percent ascorbic acid (127.62 mg 100 g^{-1}; 85.11 mg 100 g^{-1}), citric acid (85.13 mg 100 g^{-1}; 85.11 mg 100 g^{-1}) and turmeric and salt (85.15 mg 100 g^{-1}; 85.10 mg 100 g^{-1}) pretreatments. However, the untreated control sample had the highest ascorbic acid content in paper plateoverwrapped with cling film (127.61 mg 100 g^{-1}) and the lowest in polystyrene trayoverwrapped with cling film (85.12 mg 100 g^{-1}).

4.3.7 Total phenol (mg 100 g^{-1})

Total phenol content with significant variation in the minimally processed buds pretreated and packed in different packaging materials showed an increasing trend one week after storage in cold storage condition (Table 17).

Initially the total phenol content was maximum (0.162 mg 100 g^{-1}) in buds pretreated with 0.2 percent ascorbic acid and minimum (0.063 mg 100 g^{-1}) in 0.2 percent citric acid pretreated buds. One week of storage under cold storage condition, highest phenol content was recorded in control sample in polyethylene punnets (0.501 mg 100 g^{-1}) and lowest in 0.2 percent turmeric and salt pretreated sample in polystyrene tray (0.150 mg 100 g^{-1}).

Table 14: Effect of minimal processing and packaging treatments on Moisture (%) 1 WAS

Treatments	Moisture (%)			
	Control	Ascorbic acid (0.2%)	Citric acid (0.2%)	Turmeric + salt (0.2%)
C1	94.22	93.22	93.44	93.26
C2	94.05	93.45	93.65	93.84
C3	93.84	93.83	92.85	93.05
CD for factor A	0.025			
CD for factor B	0.022			
CD for interaction	0.043			

Table 15: Effect of minimal processing and packaging treatments on Acidity (%) 1 WAS

Treatments	Acidity(%)			
	Control	Ascorbic acid (0.2%)	Citric acid (0.2%)	Turmeric + salt (0.2%)
	Initial = 0.67			
C1	2.345	1.675	1.340	1.005
C2	1.116	0.893	1.115	1.005
C3	1.116	0.893	1.005	0.890
CD for factor A	0.011			
CD for factor B	0.009			
CD for interaction	0.018			

C1 – paper plate overwrapped with cling film
C2 – polystyrene trays overwrapped with cling film
C3 – polyethylene punnets
WAS – week after storage

On comparing the pretreatments, maximum phenol content was found in buds pretreated with turmeric and salt in paper plate overwrapped with cling film (0.441 mg 100 g^{-1}), ascorbic acid pretreatment in polystyrene trayoverwrapped with cling film (0.229 mg 100 g^{-1}) and untreated buds in polyethylene punnets (0.501 mg 100 g^{-1}). Whereas minimum phenol content was recorded in control sample in paper plate overwrapped with cling film (0.151 mg 100 g^{-1}), turmeric and salt pretreatment in polystyrene trayoverwrapped with cling film (0.150 mg 100 g^{-1}) and in citric acid pretreatment in polyethylene punnets (0.432 mg 100 g^{-1}).

4.3.8 Microbial load (cfu g^{-1})

Microbial population in the buds were studied twice, initially after giving different pretreatments to the minimally processed buds, and then after packing in different packaging materials and storing under cold storage condition for one week. The microbial load was studied in terms of bacterial, fungal and yeast population and given in Table 18.

4.3.8.1 Bacterial load (cfu g^{-1})

The buds pretreated with ascorbic acid and citric acid had no bacterial population initially whereas in turmeric and salt pretreatment, a few colonies (0.03 x 10^6 cfu g^{-1}) were observed. However, control sample without any pretreatment showed the highest number of bacterial colonies (0.06 x 10^6 cfu g^{-1}).

One week after storage under cold storage, the bacterial load was observed to be minimum in citric acid pretreatment in paper plate overwrapped with cling film (3.13 x 10^6 cfu g^{-1}), polystyrene tray overwrapped with cling film (0.21 x 10^6 cfu g^{-1}) and polyethylene punnets (0.98 x 10^6 cfu g^{-1}). Whereas, maximum bacterial load was noted in control sample in paper plate overwrapped with cling film (27.06 x 10^6 cfu g^{-1}), in ascorbic acid pretreatment in polystyrene trayoverwrapped with cling film

Table 16: Effect of minimal processing and packaging treatments on Ascorbic acid (mg 100 g^{-1})

Treatments	Ascorbic acid (mg 100 g^{-1})			
	Control	Ascorbic acid (0.2%)	Citric acid (0.2%)	Turmeric + salt (0.2%)
	Initial			
	127.63	212.28	99.26	99.34
	1 WAS			
C1	127.61	85.11	85.11	85.10
C2	85.12	85.13	85.12	85.13
C3	85.15	127.62	85.13	85.15
CD for factor A	0.031			
CD for factor B	0.027			
CD for interaction	0.053			

Table 17: Effect of minimal processing and packaging treatments on Total phenol (mg 100 g^{-1})

Treatments	Total phenol (mg 100 g^{-1})			
	Control	Ascorbic acid	Citric acid(0.2%)	Turmeric + salt
	Initial			
	0.112	0.150	0.118	0.134
	1 WAS			
C1	0.151	0.337	0.188	0.441
C2	0.276	0.299	0.276	0.150
C3	0.501	0.455	0.432	0.459
CD for factor A	0.003			
CD for factor B	0.003			
CD for	0.005			

C1 – paper plate overwrapped with cling film

C2 – polystyrene trays overwrapped with cling film

C3 – polyethylene punnets

WAS – week after storage

(11.06×10^6 cfu g^{-1}) and in turmeric and salt pretreatment in polyethylene punnets (9.10×10^6 cfu g^{-1}).

4.3.8.2 Fungal load (cfu g^{-1})

Buds pretreated with citric acid and turmeric and salt was free from fungal attack initially, whereas the control sample had a few colonies (0.34×10^3 cfu g^{-1}) and the ascorbic acid pretreatment had the maximum fungal load (1×10^3 cfu g^{-1}).

After storing for one week under cold storage, fungal attack was observed to be absent in citric acid pretreatment in polystyrene tray overwrapped with cling film and turmeric and salt pretreatment in paper plates overwrapped with cling film. Whereas, in polyethylene punnets minimum fungal population (1×10^3 cfu g^{-1}) was observed in citric acid pretreatment. However, more number of fungal colonies was seen in the control sample in paper plate overwrapped with cling film (6.33×10^3 cfu g^{-1}) and polyethylene punnets (5.67×10^3 cfu g^{-1}) and in ascorbic acid pretreated buds in polystyrene tray overwrapped with cling film (1.01×10^3 cfu g^{-1}).

4.3.8.3 Yeast load (cfu g^{-1})

All the treatments were free from yeast attack except citric acid pretreated buds in polyethylene punnets (0.34×10^4 cfu g^{-1}) and turmeric and salt pretreatment in polystyrene traysoverwrapped with cling film (0.67×10^4 cfu g^{-1}) one week after storage.

4.3.9 Sensory evaluation

The mean rank scores for appearance, colour, texture, odour and overall acceptability of minimally processed buds subjected to different pretreatments were recorded separately and is given in Table 19. The mean rank score for appearance (8.13) was highest for ascorbic acid pretreatment while the citric acid pretreatment

Table 18: Effect of minimal processing and packaging treatments on microbial load (cfu g^{-1}) of minimally processed bud

Microbial load	Treatments	Control	Ascorbic acid (0.2%)	Citric acid (0.2%)	Turmeric + salt (0.2%)
Bacterial load (10^6 cfu g^{-1})	Initial	0.06	ND	ND	0.33
	1 WAS				
	C1	27.06	23.21	3.13	3.20
	C2	2.41	11.06	0.21	1.41
	C3	4.23	4.66	0.98	9.10
Fungal load (10^3 cfu g^{-1})	Initial	0.34	0.10	ND	ND
	1 WAS				
	C1	6.33	1.34	3.34	ND
	C2	0.34	1.01	ND	0.33
	C3	5.67	1.12	1.00	3.67
Yeast load (10^4 cfu g^{-1})	Initial	ND	ND	ND	ND
	1 WAS				
	C1	ND	ND	ND	ND
	C2	ND	ND	ND	0.67
	C3	ND	ND	0.34	ND

C1 – paper plate overwrapped with cling film

C2 – polystyrene trays overwrapped with cling film

C3 – polyethylene punnets

WAS – week after storage

had the highest mean scores for colour (8.26), texture (7.60), odour (7.53) and overall acceptability (7.80) with a total score of 38.92.

Effect of minimal processing on sensory attributes of cooked buds was studied and is shown in Table 20. For this, 40 g minimally processed and pretreated buds were taken separately in a vessel, 2 g salt was added and boiled for 5 minutes in 30 ml of water. The mean rank scores for appearance, colour, texture, flavour, taste, after taste, odour and overall acceptability were recorded separately. The highest mean rank score for appearance (7.26) and colour (7.20) was in citric acid pretreatment. However, ascorbic acid pretreatment had the highest mean rank scores for texture (7.13), flavor (6.73), taste (7.20), after taste (7.20), odour (6.53) and overall acceptability (7.20) with a total score of 54.65.

Among the different pretreatments and packaging methods subjected to study, minimal processed buds with 0.2 % citric acid pretreatment packed in polystyrene trays had a shelf life of one week and microbial load within the permissible limit along with better retention of ascorbic acid (6.81 mg/ 100g) and total phenols (0.276 mg/ 100 g). The scores of organoleptic evaluation also suggest that 0.2 percent citric acid pretreatment is the best. However, in cooked form 0.2 percent ascorbic acid pretreated buds had the overall acceptability with the highest total score of 54.65.

Table 19: Effect of pretreatments on sensory attributes of minimally processed male bud

Treatments	Appearance	Colour	Texture	Odour	Overall acceptability	Total score
Ascorbic acid (0.2%)	8.13	7.66	7.40	7.52	7.53	38.24
Citric acid (0.2%)	7.73	8.26	7.60	7.53	7.80	38.92
Turmeric + salt (0.2%)	6.40	6.26	6.66	7.13	6.40	32.85
Control	5.73	5.46	6.40	6.66	5.93	30.18
Kendall's W Test	**0.729**	**0.886**	**0.302**	**0.186**	**0.666**	

Table 20: Effect of pretreatments on sensory attributes of minimally processed and cooked male bud

Treatments	Appearance	Colour	Texture	Flavour	Taste	After taste	Odour	Overall acceptability	Total score
Ascorbic acid (0.2%)	6.33	6.33	7.13	6.73	7.20	7.20	6.53	7.20	54.65
Citric acid (0.2%)	7.26	7.20	6.66	6.06	6.66	6.80	6.40	6.87	53.90
Turmeric + salt (0.2%)	6.33	5.86	6.40	6.33	6.20	6.47	6.52	6.33	50.50
Control	5.33	5.06	5.86	6.13	6.00	6.00	6.40	5.80	46.58
Kendall's W Test	**0.403**	**0.447**	**0.247**	**0.060**	**0.273**	**0.197**	**0.010**	**0.304**	

DISCUSSION

5. DISCUSSION

Banana male bud, known in vernacular as *Vazhapoovu*, also known as banana heart, banana blossom, navel, or banana bell is one of the important by product in banana cultivation. It is consumed either raw or cooked by ethnics of Asian, African and Latin American countries. Banana flower can also be used in treating dysentery, diabetes and menorrhagia (Ghani, 2003). As reported by Singh, 2017 banana male bud can be considered as a good functional food as it provides therapeutic value due to the presence of nutrients like fibre, protein, potassium, calcium, copper, phosphorus, iron, magnesium, vitamin E, A and C along with various antioxidants. The processed flower bud shows higher phenols and tannins which make it a promising constituent in nutritional and medicinal preparations (Joy *et al.*, 2016).

In the present day world, foods possessing both nutritional and medicinal properties are in high demand and have a higher economic value. But the use is much limited due to its short shelf life and less accepted sensory qualities. In order to overcome these limitations, the study on "Characterization and value addition of male buds of banana cultivars" was carried out in the Department of Post Harvest Technology, College of Horticulture, Vellanikkara during 2017-2019.

The discussions pertaining to the study are presented under the following sections.

5.1 Characterization of male buds of banana cultivars and standardizing their harvesting stage

5.2 Standardization of packaging and storage methods

5.3 Standardization of minimal processing techniques for banana male bud

5.1 CHARACTERIZATION OF MALE BUDS OF BANANA CULTIVARS AND STANDARDIZING THEIR HARVESTING STAGE

Banana male buds of Palayankodan, Grand naine, Njalipoovan and Nendran harvested at 15, 20 and 25 days after full bunch emergence were characterized based on physic-morphological and biochemical parameters.

5.1.1 Physical parameters

Physical characterization was done by observing bud weight (g), bud length (cm), bud diameter (cm), recovery (%), firmness (kg cm^{-2}), shape and colour of the bud.

5.1.1.1 Bud weight (g)

The weight of the bud harvested at different maturity stages varied significantly with varieties (Fig 1). Among the buds harvested at different stages, Grand naine recorded highest weight (1215 g) at 20 DAB followed by the stage of 25 DAB (945 g). In Palayankodan 20 DAB showed highest bud weight (550g) and in Njalipoovan the highest bud weight of 275 g was observed at 15 DAB. The variation in bud weight is a varietal character as observed in other characters of banana. Banana cultivars grown under Kerala conditions showed significant difference with respect to morphological and yield characters as reported by George *et al.* (1991).

5.1.1.2 Bud length (cm)

Among the buds harvested at different stages, bud length was maximum for Grand naine (32 cm) followed by Palayankodan (22.5 cm) when harvested at 20 days after full bunch emergence, 25 cm at 25 days after full bunch emergence for Nendran and 19.8 cm for Njalipoovan at 15 days after full bunch emergence. As per the descriptors by Simmonds and Shepherd (1955), Grand naine bud can be classified as

large, which is more than or equal to 31 cm , Palayankodan and Nendran as intermediate between 21 to 30 cm and Njalipoovan as small which is less than or equal to 20 cm. The bud length of Grand naine confirm to the findings of Tak (2012) where the male bud length in Grand naine variety was 31.18 cm. The observed variation in bud length may be attributed to the genotypic characters.

5.1.1.3 Bud Diameter (cm)

Significant variation was observed among the buds harvested at different stages. Bud diameter was recorded to be highest at 20 days after full bunch emergence for Palayankodan (9.07 cm) and Grand naine (10.73 cm) whereas at 15 days after full bunch emergence for Njalipoovan (6.49 cm) and at 25 days after full bunch emergence for Nendran (11.62 cm). Maximum diameter of male bud should be less than or equal to 20 cm, intermediate 21 to 30 cm and more than or equal to 31 cm as per the banana descriptors by Simmonds and Shepherd (1955). Tak (2012) has also reported 30.70 cm diameter for male bud in Grand naine variety. Increase in bud weight, length and diameter of male bud may be due to the translocationof assimilates from the source like primary and secondary corms to the fingers and male bud during shooting stage and half maturity stage of bunch (John, 2011).

5.1.1.4 Bud shape

The male buds of Palayankodan and Nendran variety were broadly ovate and not tapering sharply whereas Grand naine and Njalipoovan were lanceolate or narrowly ovate and tapering sharply from the shoulder. Male bud shape of banana should be like a top, lanceolate, intermediate, and ovoid or rounded (Simmonds and Shepherd 1955). Kumar *et al.* (2014) has also described the shape of male bud in Grand naine as lanceolate.

5.1.1.5 Bract colour

Among the varieties harvested at different stages, Palayankodan and Nendran variety had a distinctive brownish purple outside and bright crimson inside. Grand naine and Njalipoovan had red, dull purple or yellow outside and pink, dull purple or yellow inside. Colour of bract external face could be yellow, green, red, red-purple, purple-brown, purple, blue, pink-purple, orange-red or others and the inner bract colour could be whitish, yellow or green, orange red, red, purple, purple brown, pink purple or others (Simmonds and Shepherd 1955).

5.1.1.6 Bud recovery (%)

The removal of loose bracts reduced the weight of bud finally obtained for use and it was expressed as recovery percent. Significant variation was found in recovery percentage among varieties harvested at different stages. The highest recovery percentage of 99.3 percent was observed in Grand naine when harvested 15 days after full bunch emergence and Nendran had a lowest recovery percentage of 69.2 percent when harvested 25 days after full bunch emergence. In Palayankodan it was maximum (97.8 %) at 25 days after full bunch emergence, 87.2 percent for Njalipoovan and for Nendran it was 77.9 percent at 15 days after full bunch emergence. Similar studies were done in cabbage and cauliflower where loose leaves are removed after harvest.

5.1.1.7 Bud firmness (kg cm^{-2})

Bud firmness is related to the texture which in turn determines the acceptability of the produce. Firmness is a varietal character and in banana fruits it differed significantly from 1.1 kg cm^{-2} to 1.9 kg cm^{-2} (Ngalani *et al.*, 1998) and Amin *et al.* (2015) reported a decreasing trend in fruit firmness with the advancement of maturity. Lowest bud firmness was observed in Njalipoovan (0.790 kg cm^{-2}) harvested at 25 days after full bunch emergence.

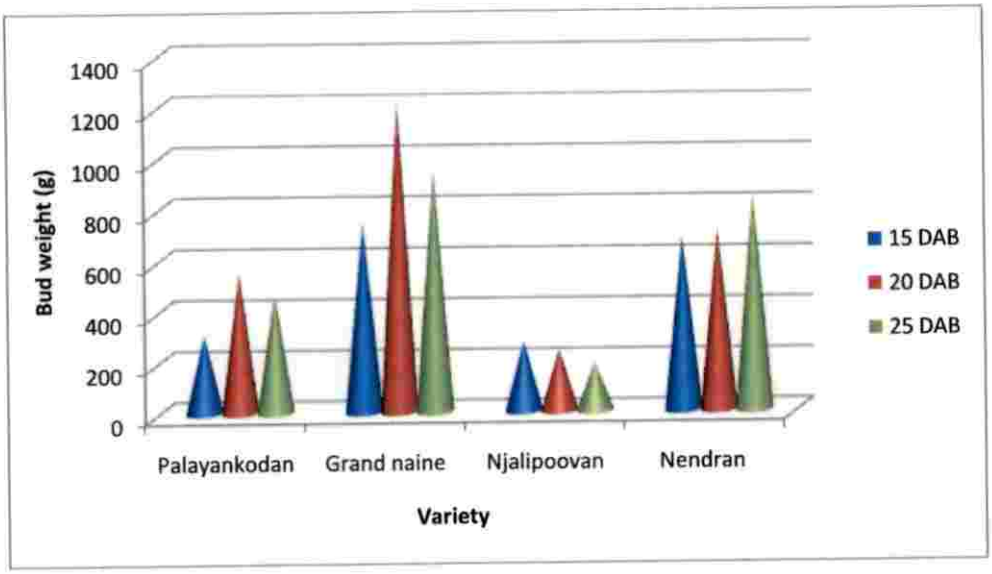

Fig 1: Effect of harvesting stage on bud weight of different cultivars

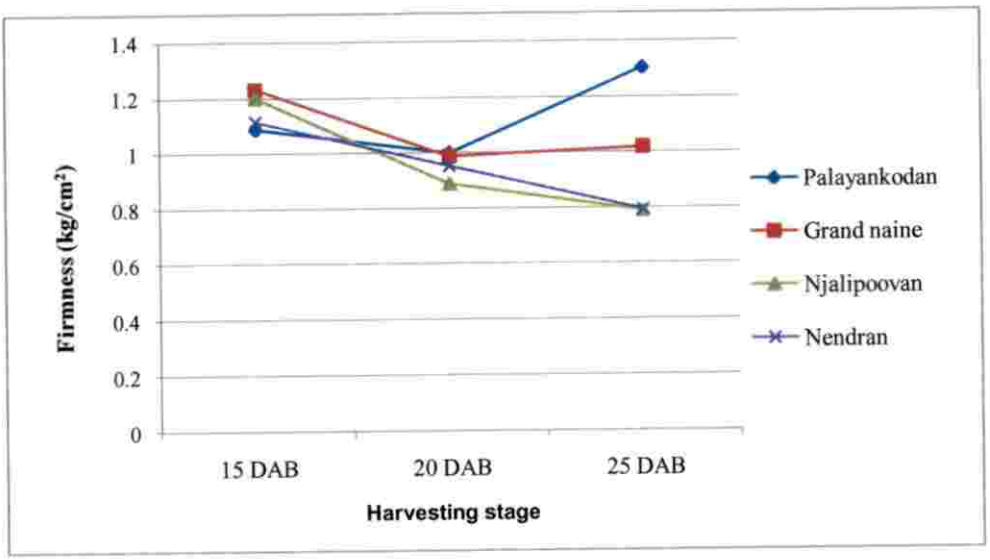

Fig 2: Effect of harvesting stage on bud firmness of different cultivars

5.1.2 Biochemical parameters

Singh (2017) remarked that banana male bud is loaded with lots of nutrients like fibre, protein, vitamin E, A and C, minerals like potassium, phosphorus, calcium, iron *etc*., along with various antioxidants. To characterize male buds of different cultivars, biochemical parameters were studied at different stages of harvest.

5.1.2.1 Acidity (%)

The amount of titrable acidity in the male bud of four banana varieties at different stages of harvest was 0.67 percent. This was in concordance with the acidity of banana fruits (0.502 %) of variety Palayankodan fruits as reported by Sheela (1982). Rajeevan and Mohanakumaran (1983) reported 0.3 to 0.48 percent acidity in four plantain cultivars cultivated in Kerala. In Nendran variety, Ancy (1997) observed an acidity of 0.354 percent and Sabeena (2000) reported 0.15 percent acidity. Agarwal *et al*. (1997) reported an acidity of 0.48 percent in Robusta.

5.1.2.2 Ascorbic Acid (mg 100 g^{-1})

Ascorbic acid content was highest at 25 days after full bunch emergence for Palayankodan (106.332 mg 100 g^{-1}) and Nendran (106.350 mg 100 g^{-1}), at 20 days after full bunch emergence for Grand naine (106.52 mg 100 g^{-1}) and at 15 days after full bunch emergence for Njalipoovan (106.366 mg 100 g^{-1}). Whereas, the lowest ascorbic acid content was observed in Grand naine (63.822 mg 100 g^{-1}) at 15 days after full bunch emergence. Investigations by Dube (1988) revealed that ripe banana contains 7 mg $100g^{-1}$ of ascorbic acid. Varietal influence on ascorbic acid content are on par with the findings of Zaki *et al*. (2015) in broccoli. A reduction in quality was observed with respect to the reduction in ascorbic acid that was associated with surface browning and degradation in fruit quality (Azlin *et al*., 2014).

5.1.2.3 Protein (g 100 g^{-1})

Banana male buds of all varieties under study contain protein in reasonable quantities. It was maximum at 25 days after full bunch emergence for Grand naine (13.577 g 100 g^{-1}) and Palayankodan (7.855 g 100 g^{-1}) and at 20 days after full bunch emergence for Njalipoovan (13.454 g 100 g^{-1}) and at 15 days after full bunch emergence for Nendran (10.763 g 100 g^{-1}) variety. Banana male buds contain high quality protein because of its well balanced essential amino acid content (Sheng *et al.*, 2010). The total protein content in male buds varied from 8.89 percent in AAB to 10.35 percent in AAA genotype (Florenta *et al.*, 2015).

5.1.2.4 Carbohydrate (g 100 g^{-1})

Carbohydrates are essential constituents of horticultural commodities and they are considered as a class of chemical compounds yielding energy. It is also important because of their contribution to texture, flavor, color, and nutritional value (Yahia *et al.*, 2019). Carbohydrate content in male buds harvested with the bracts from different varieties at different stages exhibited significant variation. Highest carbohydrate content was recorded at 15 days after full bunch emergence for Palayankodan (21.694 g 100 g^{-1}), Nendran (10.345 g 100 g^{-1}) and Grand naine (7.502 g 100 g^{-1}) whereas at 25 days after full bunch emergence for Njalipoovan (15.381 g 100 g^{-1}). According to Gopalan *et al.* (2009), the carbohydrate content of fresh plantain flower is 5.1 g 100 g^{-1}. The bracts with high cellulose, hemicellulose *etc.* may also have contributed to the total carbohydrate content.

5.1.2.5 Total Phenol (mg 100 g^{-1})

Significant variation was observed in total phenol content among buds harvested at different stages. Total phenol content was found to be maximum at 15 days after full bunch emergence for all the four varieties. The highest value was observed for Grand naine (6.363 mg 100 g^{-1}) at 15 days after full bunch emergence

and lowest for Nendran (1.902 mg 100 g^{-1}) at 25 days after full bunch emergence. According to China *et al.* (2011), the variation in Total Phenolic Content was quite general among different cultivars of banana grown in India. The highest phenolic content of Indian banana flower was noted for cultivar Kacha (11.94 ± 0.03 mg of GAE / g of extract). The processed flower in Kunnan had shown higher phenols and tannins which make it a promising variety for application in nutraceuticals and medicinal preparations (Joy *et al.*, 2016).

5.1.2.6 Minerals (%)

Banana fruits stand superior in terms of nutrient status. Its richness in minerals like potassium, sodium, calcium etc make the fruit helpful in preventing complications like high blood pressure and bone breakdown (Elayabalan *et al.*, 2017). Similarly the buds are also a rich source of minerals with significant variation among varieties. Mineral content was found maximum at 15 days after full bunch emergence in Palayankodan (1.23 %) and at 25 days after full bunch emergence for Grand naine (1.01 %), Njalipoovan (1.45 %) and Nendran (1.32 %) variety.Based on the studies conducted by Ngamsaeng *et al.* (2006), banana flower is most abundant in minerals like potassium and phosphorus followed by calcium, magnesium and sulphur. According to Krishnan and Sinija (2016), banana blossom contain 2.42-3.21 percent minerals. Singh (2017) remarked that banana male bud is loaded with minerals like potassium, phosphorus, calcium, iron *etc*.

5.1.2.7 Potassium (mg 100 g^{-1})

Among the minerals potassium was found to be highest in male buds. The research findings of Elayabalan *et al.* (2017) affirm the presence of high potassium content up to 358 mg 100 $g^{-1}$of banana fruits. As the fruits are rich in potassium, the buds, another prominent part of the plantain may also be a rich source of potassium. However, potassium content varied significantly among varieties harvested at

different stages. Highest potassium content was observed at 15 days after full bunch emergence in Palayankodan (397.41 mg 100 g^{-1}), Grand naine (375.21 mg 100 g^{-1}) and Njalipoovan (411.21 mg 100 g^{-1}). Thus the potassium content decreased with maturity in these three varieties but,in Nendran variety, the potassium content increased with maturity and showed highest value (368.76 mg 100 g^{-1}) at 25days after full bunch emergence. Sheng *et al.* (2010) reported that banana blossom contain 553 mg 100 g^{-1} potassium content. According to Florenta *et al.* (2015), banana and plantain male buds are rich in macrominerals such as potassium.

5.1.2.8 Sodium (mg 100 g^{-1})

Sodium content had significant variation among different varieties and harvesting stages. Sodium content was recorded highest at 15 days after full bunch emergence in Njalipoovan (8.09 mg 100 g^{-1}) and at 20 days after full bunch emergence in Palayankodan (24.34 mg 100 g^{-1}), Grand naine (39.63 mg 100 g^{-1}) and Nendran (19.25 mg 100 g^{-1}). It implies that as maturity increases, sodium content decreases in buds of Njalipoovan variety, whereas in other three varieties medium maturity is preferred. The findings justify the reports of Gopalan *et al.* (2009) that the fresh banana blossom has a sodium content of 20.1 mg 100 g^{-1}.

5.1.2.9 Calcium (mg 100 g^{-1})

Similar to sodium content, calcium content was also recorded to be maximum at 20 days after full bunch emergence for Palayankodan (25.59 mg 100 g^{-1}), Grand naine (28.08 mg 100 g^{-1}) and Nendran (22.53 mg 100 g^{-1}) whereas at 25 days after full bunch emergence for Njalipoovan (19.01 mg 100 g^{-1}). Since these values with significant variation are of fresh male bud, it may agree with the claims of Kanchana *et al.* (2010) that the calcium content of dehydrated banana blossom ranged between 262.00 mg 100 g^{-1} and 282.19 mg 100 g^{-1}.

5.1.2.10 Iron (mg 100 g^{-1})

Singh (2017) highlights the abundance of iron in banana buds which helps in production of RBC thereby increase the blood Haemoglobin level. Iron content varied significantly among male buds of different varieties. In contradiction to the other minerals, the iron content was highest at 15 days after full bunch emergence for Palayankodan (2.1 mg 100 g^{-1}) and Nendran (2.67 mg 100 g^{-1}), at 20 days after full bunch emergence for Njalipoovan (2.10 mg 100 g^{-1}) and at 25 days after full bunch emergence for Grand naine (1.40 mg 100 g^{-1}). Lowest iron content was recorded in Palayankodan (0.35 mg 100 g^{-1}) at 25 days after full bunch emergence. However, these values question the findings of Sheng *et al.* (2010) that each 100 g of banana blossoms contains 56.4 mg iron.

5.1.2.11 Total dietary fibre (%)

Banana male buds are one of the richest sources of soluble dietary fibre (Narayana, 2015). The total dietary fibre content had shown significant variation among different varieties and stages of harvest. The highest dietary fibre content was recorded at 15days after full bunch emergence in Palayankodan (50.753 %), Grand naine (59.370 %) and Nendran (55.287 %) whereas at 25days after full bunch emergence for Njalipoovan (54.100 %). The results support the claim of Florenta *et al.* (2015) that the banana blossoms of AAA genotype are rich in total dietary fibre (50.09 %).The lowest dietary fibre content was observed in Palayankodan (33.637 %) at 25 days after full bunch emergence. These values suggest an inverse relationship between the maturity and dietary fibre content for the varieties Palayankodan, Grand naine and Nendran, and a direct relationship in case of Njalipoovan.

5.1.2.12 Anthocyanin (mg 100 g^{-1})

Anthocyanins are the main phenolic substances present in flowers and fruits that give blue, purple, red and orange hues contributing to the nutritional quality.

Anthocyanins are better radical scavengers than phenolics (Oki *et al.*, 2002). Significant difference in anthocyanin content was observed in Palayankodan and Njalipoovan at 15 days after full bunch emergence, only in Palayankodan at 20 days after full bunch emergence and in Palayankodan and Nendran at 25 days after full bunch emergence. Maximum anthocyanin content was recorded at 15 days after full bunch emergence in Njalipoovan (3.700 mg 100 g^{-1}), at 20 days after full bunch emergence in Palayankodan (5.460 mg 100 g^{-1}) and at 25 days after full bunch emergence in Grand naine (1.090 mg 100 g^{-1}) and Nendran (2.640 mg 100 g^{-1}) variety. Naresh (2016) have remarked that jamun fruits contains high amount of anthocyanin (61.07 mg 100 g^{-1}). In fruits accumulation of anthocyanin mainly occur in skin and flesh and developmental regulation plays a major role in anthocyanin biosynthesis along with the genetic background (Jaakola, 2013). As per the claims of Kitdamrongsont *et al.*, (2008), the bract colour is not determined by the anthocyanin composition alone but is also influenced by the accumulation pattern, vacuolar pH and copigments.

5.1.2.13 Antioxidant (µg ml^{-1})

Elayabalan *et al.* (2017) point out that the phenolic compounds with antioxidant properties are abundant in banana fruits. These properties may also be carried over to the buds. Among the buds harvested at different stages, only Njalipoovan and Nendran varieties harvested at 20 days after full bunch emergence showed significant variation in antioxidant content. Antioxidant content was recorded highest at 15 days after full bunch emergence in Grand naine (0.446 µg ml^{-1}) and Njalipoovan (0.501 µg ml^{-1}), whereas at 25 days after full bunch emergence in Palayankodan (0.388 µg ml^{-1}) and Nendran (0.243 µg ml^{-1}). Palayankodan harvested 20 days after full bunch emergence exhibited the lowest antioxidant content (0.113 µg ml^{-1}). The antioxidant property of rich purple coloured buds justify the prediction of Wu *et al.* (2004) that the brightly coloured plant parts would have high radical

scavenging activity. Schmidt *et al.* (2015) have remarked that the higher quantity of phenolics and flavonoids in the banana inflorescence may be the major reason for its antioxidant potential. It also corroborate with the findings of Narayana (2015).

5.1.2.14 Sensory evaluation

Buds of four different cultivars harvested at 15, 20 and 25 days after full bunch emergence were subjected to sensory evaluation on point 9 hedonic scale. Bini (2003) reported that for judging the consumer acceptability of a product, organoleptic evaluation is the best method.

Under all three harvesting stages, buds of Grand naine had a better appearance. Whereas, buds of Palayankodan variety had the overall acceptability with pleasing texture and odour. On comparing the buds harvested at 15 days after full bunch emergence, highest mean rank score for appearance (8.13) was for Grand naine, whereas mean rank scores for colour (8.26), texture (7.60), odour (7.53) and overall acceptability (8.13) was higher for Palayankodan with a total score of 39.25.

When buds harvested at 20days after full bunch emergence were compared, mean rank score for appearance (7.26) was highest for Grand naine but colour (7.20), texture (7.13), odour (8.26) and overall acceptability (7.53) scores were maximum for Palayankodan with a total score of 36.52. When the buds were harvested at 25 days after full bunch emergence, higher mean rank scores were exhibited by Grand naine for appearance (6.73) and odour (7.13), whereas for colour (7.20), texture (7.20 and overall acceptability (7.73), Palayankodan scored maximum with a total score of 34.86.

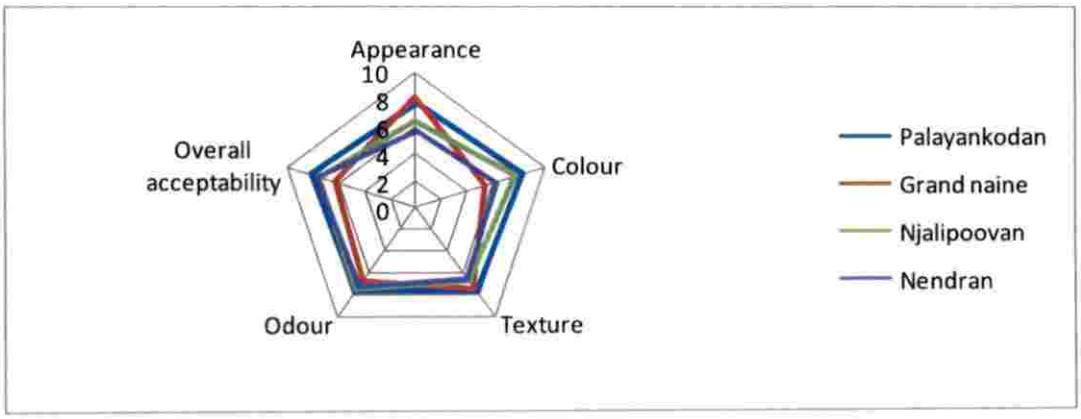

Fig 3: Effect of harvesting stage (15 DAB) on sensory attributes of buds of different cultivars

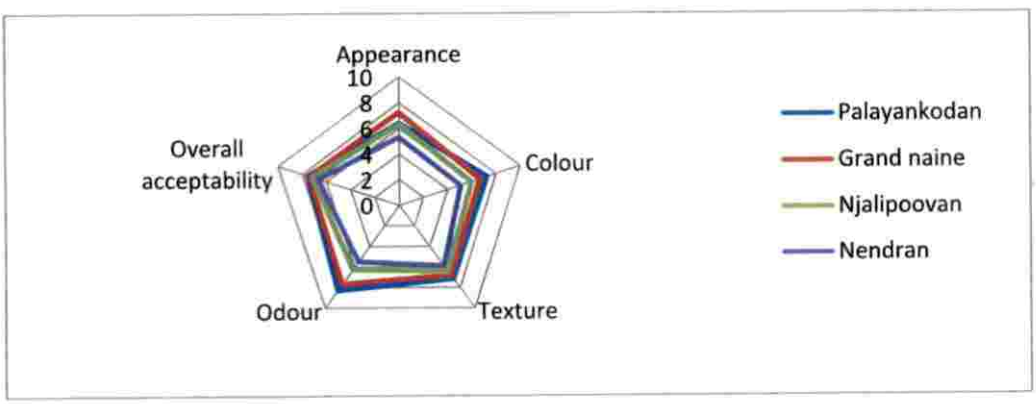

Fig 4: Effect of harvesting stage (20 DAB) on sensory attributes of buds of different cultivars

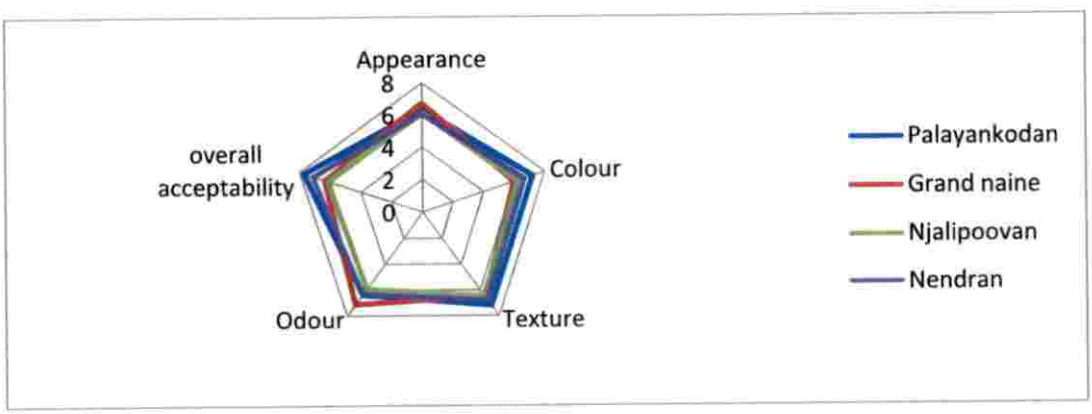

Fig 5: Effect of harvesting stage (25 DAB) on sensory attributes of buds of different cultivars

5.2 STANDARDIZATION OF PACKAGING AND STORAGE METHODS

Banana male bud being a good source of health promoting and protecting compounds with unique taste, attract consumers. Since they start deterioration soon after harvest, proper packaging and storage is a must to retain maximum quality parameters for good market value. Storage conditions are also required to prevent growth of micro flora and to maintain the nutritional value. Retailers want to move towards cheaper ways to increase the shelf life and quality for better consumer preference. Hence in this study, banana male buds were given different packaging treatments and stored under ambient and controlled temperature conditions to find out the changes in physico chemical characters and organoleptic quality.

5.2.1 Physiological loss in weight (%)

Once harvested, the weight of the buds gets reduced during storage and this loss in weight would in turn affect the quality of the produce. About 3-10 percent weight loss may occur as claimed by Yehoshua and Rodov (2002). PLW of male buds increased in all the treatments during storage under ambient, refrigerated and cold storage conditions, except those wrapped in cling films. The buds with cling film wrapping showed an increase in PLW for first two weeks, then a slight decrease in third week, followed by a further increase in the fourth week both under cold and refrigerated storage condition. Buds without any package, kept as control sample recorded significantly higher PLW during storage under all the three storage conditions.

On comparing the storage conditions, least PLW was observed in male buds wrapped in cling film (0.09 %) and stored under cold storage condition (10-14 °C) and maximum PLW was recorded in buds stored under ambient condition without any package (16.16 %). This result is in confirmation with the findings of Bosland and Votava (2000) where the fruits stored at ambient condition were highly

susceptible to water loss, wrinkle and colour change within a few days after harvest. The modified atmospheric condition created a low O_2 environment around the produce by wrapping the buds tight and thus reducing the respiration rate consequently reducing PLW when compared to unwrapped buds.

While comparing the packaging treatments stored under ambient condition, shrink wrapped buds had the minimum PLW (4.78 %), whereas the control sample had the maximum PLW (16.16 %) after one week of storage. Under refrigerated condition, both shrink wrapped buds and buds packed in polyethylene cover showed minimum PLW (0.12 %) and the control sample had the maximum PLW (3.93 %) after one week of storage. When the buds were stored for one week under cold storage condition, the minimum PLW (0.09 %) was noticed in cling film wrapped buds and maximumin control sample (3.61 %). These findings are in parity with the prediction of Hameed *et al.* (2013) that the weight loss at 15 °C (30.57 %) was significantly lower compared to ambient conditions (39.61 %).

Brar *et al.* (2000) reported lowest PLW (5.5 %) in fruits packaged in 100 gauge polyethylene after 25 days of storage. Based on the studies of Koraddi and Devendrappa (2011), minimum PLW was observed in polyethylene bags. Higher PLW percent at ambient condition could be due to cell wall degradation, membrane permeability, faster metabolism and ripening at high temperature (Dumville and Fry, 2000).

5.2.2 Shelf life (days)

In all the packaging treatments, buds stored under ambient condition exhibited a lower shelf life. Under cold storage condition, control (18 days) and cling film wrapped buds (30 days) had a longer shelf life whereas shrink wrapped buds (25 days) and the buds in polyethylene cover (43 days) exhibited a significantly longer shelf life under refrigerated condition.

On comparing the packaging treatments, buds packed in polyethylene cover had the longest shelf life both under ambient (13 days) and refrigerated condition (43 days), whereas under cold storage, cling film wrapped buds (30 days) had the longest shelf life.

Shelf life was found to decrease exponentially with increasing temperature (Peacock, 1980). Shaun and Ferris (1997) stated that at ambient tropical temperatures, bananas have an average market life of 1 to 10 days depending on genotype, maturity stage at harvest and storage and handling conditions. Packaging retards the proliferation of microorganisms and thereby enhances the shelf life of the produce (Galet *et al.*, 2012). Narayana (2015) opined that storage temperature influences the post harvest physiology of banana.

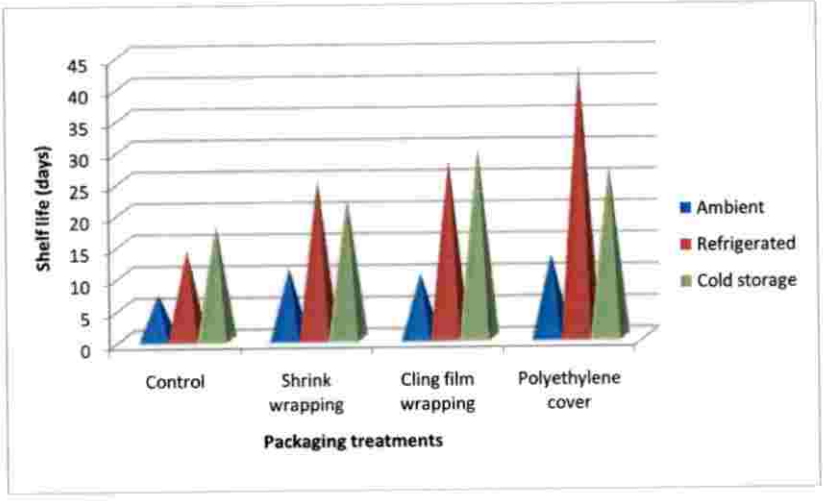

Fig 6: Effect of packaging treatments and storage conditions on shelf life of male bud

5.2.3 Acidity (%)

The acidity in the male buds showed an increasing trend under all the three storage conditions. On comparing the storage conditions, cling film wrapped buds had the lowest acidity (0.673 %) after one week of storage under all the three storage conditions. Whereas the highest acidity was observed in unwrapped buds (2.653 %) stored under ambient condition. This is in confirmation with the findings of Hameed *et al.* (2013) that titrable acidity was higher in ambient conditions than low temperature storage.

When the treatments were compared after one week of storage, only the unwrapped buds and the buds in poly ethylene cover showed significant variation under ambient condition. And there was no significant difference in titrable acidity among buds stored under refrigerated and cold storage conditions. Lower acidity (0.673 %) was observed in cling film wrapped buds under all three storage conditions. High acidity (2.653 %) was shown by control sample under ambient storage while under refrigerated and cold storage conditions, higher values were observed for buds packed in polyethylene cover (1.344 %).

Azlin *et al.* (2014) observed a gradual increase in total titrable acidity up to 3 weeks of storage and thereafter fluctuated until the end of storage. Increase in acidity during storage may be due to lower respiration rate. According to Rao and Shivashankara, 2015 shrink wrapping may not reduce the ability to metabolize acids during storage.

5.2.4 Ascorbic acid (mg 100 g^{-1})

A declining trend was observed in ascorbic acid content in male buds with significant variation in all the treatments under three different storage conditions supporting the results of Suthar *et al* (1998) in tomato. The enzyme ascorbate oxidase which converts ascorbic acid to dehydro ascorbic acid is responsible for decrease in

ascorbic acid content during storage (Lee and Kader, 2000). On comparing the storage conditions, ascorbic acid retention was found to be greater (318.99 mg 100 g^{-1}) in case of unwrapped buds stored for one week under cold storage and the least retention was seen in shrink wrapped buds (63.6 mg 100 g^{-1}) under refrigerated condition one week after storage.

When the treatments were compared one week after storage, the control sample exhibited maximum retention of ascorbic acid and the shrink wrapped buds had minimum retention under all the three storage conditions. Babarinde and Fabunmi (2009) reported highest ascorbic acid content, lowest weight loss and an extended shelf life up to 9 days in okra packed in polyethylene and stored under refrigerated temperature. Hameed *et al.* (2013) opined that ascorbic acid content was observed higher in ambient conditions than low temperature storage at 0 °C, 5 °C, 10 °C and 15 °C.

Azlin *et al.* (2014) observed an increase in concentration of ascorbic acid up to 4 weeks of storage. A reduction in quality was observed with respect to the reduction in ascorbic acid that was associated with surface browning and degradation in fruit quality.

5.2.5 Total phenol (mg 100 g^{-1})

Total phenol content had shown an increasing trend upon packaging and storage under all the treatments, with significant variation. On comparing the storage conditions one week after storage, total phenol content was recorded highest (7.21 mg 100 g^{-1}) in control sample without any package stored under cold storage condition and lowest (0.181 mg 100 g^{-1}) in shrink wrapped buds stored under ambient condition.

When the treatments were compared, unwrapped control sample had the highest phenol content and the shrink wrapped buds had the lowest, after one week of storage under ambient (4.532 mg 100 g^{-1}; 0.181 mg 100 g^{-1}) refrigerated (4.59 mg 100 g^{-1}; 0.195 mg 100 g^{-1}) and cold storage (7.21 mg 100 g^{-1}; 0.520 mg 100 g^{-1}) conditions.

As per the findings of Yang *et al.* (2011), phenolic compounds are synthesized during storage. However, during prolonged storage, phenolic compounds get decreased due to oxidation.

5.2.6 Sensory evaluation

One week after storage under ambient condition, the mean rank scores for appearance (7.00) and texture (6.93) were highest for cling film wrapped buds, whereas the highest mean rank score for colour (7.13) was recorded in the buds packed in polyethylene cover, and the odour (6.73) had highest mean score in unwrapped buds. However, the mean rank score for overall acceptability (6.80) was maximum for buds packed in polyethylene cover with a total score of 33.67.

After one week of storage under refrigerated condition, the mean rank score for odour (6.53) was maximum for unwrapped control sample, whereas for appearance (7.73), colour (7.60) and texture (7.20) the highest mean score was for polyethylene covered buds with an overall acceptability of 7.27 and a total score of 36.07.

Buds stored for one week under cold storage condition had the highest total score (37.13) for cling film wrapped buds with a maximum mean scores for appearance (7.80), texture (7.60), odour (6.67) and overall acceptability (7.60). The mean rank score for colour (7.60) highest for buds packed in polyethylene cover.

Kavitha (2011) remarked that low temperature was rated excellent for organoleptic quality. The loss of flavour and conversion of vitamin C and polyphenols into di and polycarbonyl compounds may be responsible for decreasing trend in organoleptic scores. According to Geethu (2018), overall acceptability were higher for fruits stored under cold storage and refrigerated condition. This corroborate with the findings of Xavier (2017).

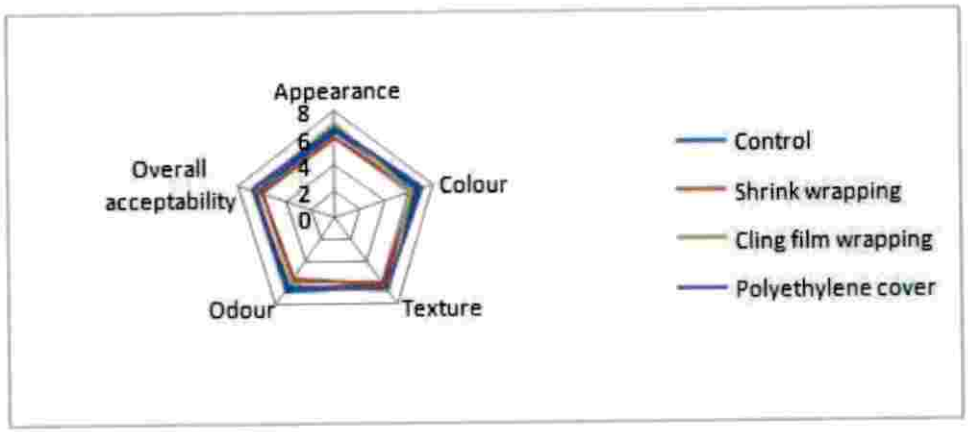

Fig 7: Effect of packaging treatments on sensory attributes of male bud stored under ambient condition

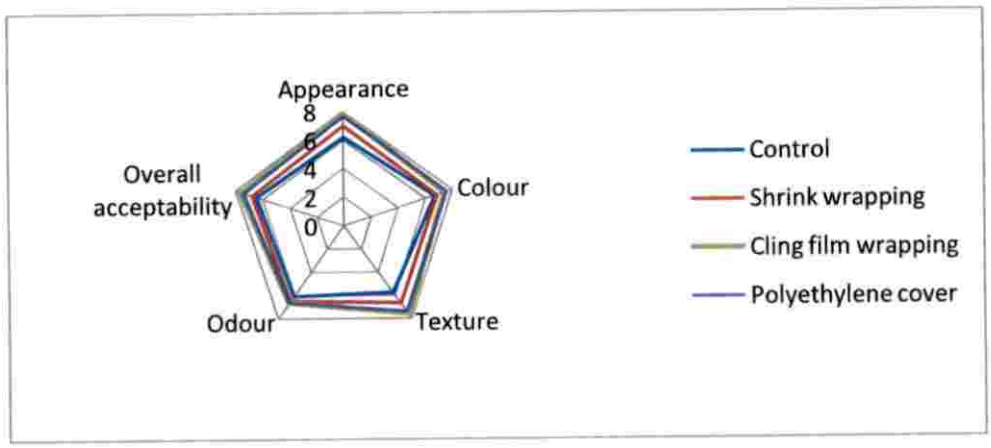

Fig 8: Effect of packaging treatments on sensory attributes of male bud stored under cold storage condition

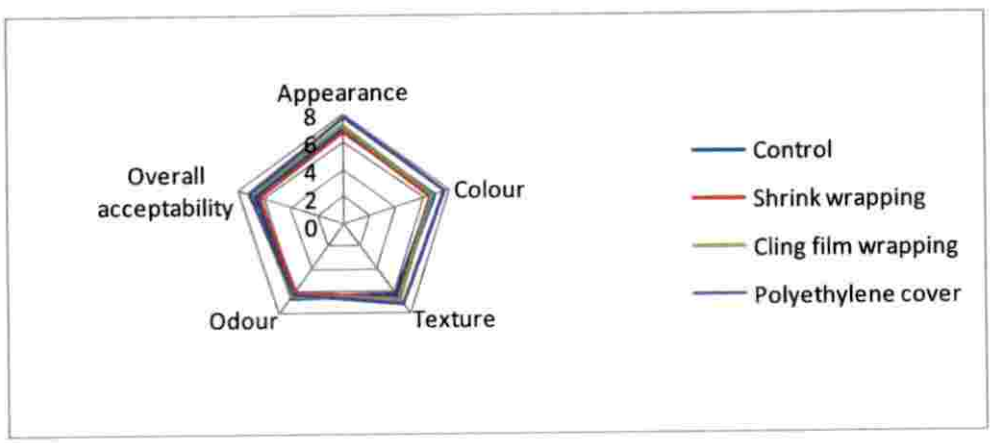

Fig 9: Effect of packaging treatments on sensory attributes of male bud stored under refrigerated condition

5.3 STANDARDIZATION OF MINIMAL PROCESSING TECHNIQUES FOR BANANA MALE BUD

Convenience food has gained due popularity as minimal processed products require little or no secondary processing and cooking before consumption. But the banana male buds once chopped undergo polyphenolic oxidation and turn brown in colour and lose its marketability.Hence it is important to prevent the undesirable darkening of the minimally processed buds.Also finding suitable packages that can retain the quality and freshness of minimally processed banana male buds even for a day or two will have great influence in enhancing its marketability and consumer acceptance. Hence an attempt was made by adopting different pretreatments and packaging methods to enhance the shelf life and to improve the market value. According to Ambotu (2011) adoption of various technologies like modified atmosphere packaging, cold storage and dipping of fruits in chemicals can reduce the post harvest losses of fruits.

5.3.1 Shelf life (days)

Minimally processed male buds after given different pretreatments and packaged in paper plates overwrapped with cling film, polystyrene trays overwrapped with cling film and polyethylene punnets exhibited an extended shelf life of one week when stored under cold storage condition. Modified Atmosphere Packaging is reported to be very efficient in increasing storage life of fresh as well as minimally processed commodities like tomato, shredded cabbage, potato *etc.* (Church, 1994; Charles *et al.*, 2003; Dhall *et al.*, 2010).

Minimal processed products possess higher rate of respiration, which generally leads the ageing of the products by using the energy reserve during oxidative- reduction process (Ryle, 1984; Watada *et al.*, 1986). Minimal processing

increases the perishability rather than the stability of fruits and vegetables (Rolle and Chism, 1987; Shewfelt, 1987).

5.3.2 Physiological loss in weight (%)

Physiological loss in weight exhibited an increasing trend with significant variation for all the treatments during storage. On comparing different packaging treatments one week after storage, the minimum Physiological loss in weight (1.046 %) was observed in buds pretreated with 0.2 percent ascorbic acid and packed in polyethylene punnets. Control sample packed in polystyrene trays overwrapped with cling film showed the highest Physiological loss in weight (2.546 %).

On comparing the pretreatments, control sample exhibited the maximum physiological loss in weight, when packed in paper plate overwrapped with cling film (2.074 %), polystyrene traysoverwrapped with cling film (2.546 %) and polyethylene punnets (1.863 %) after one week of storage under cold storage condition. Minimum Physiological loss in weight was seen in buds pretreated with 0.2 percent turmeric and salt in paper plate overwrapped with cling film (1.340 %) and polystyrene trays overwrapped with cling film (1.441 %) whereas in polyethylene punnets the minimum PLW was recorded for 0.2 percent ascorbic acid pretreatment (1.046 %).

As per the findings of Pahel (2013), different types of wrapping material have significant effect on PLW of sapota fruits during storage. Chandran (2013) reported that, in beetroot, polystyrene tray overwrapped with cling film reduced the physiological loss in weight, while micro ventilated polyethylene and polypropylene was effective in shredded vegetables like beans and cabbage respectively.

5.3.3 Respiration rate (CO_2 %)

A steady decline in the rate of respiration was observed in all the treatments stored in cold storage condition for one week. Except in control sample, all the three pretreatments had a respiration rate of 0.1 percent one week after storage in paper plate overwrapped with cling film. Whereas, in polystyrene traysoverwrapped with cling film, only the 0.2 percent citric acid pretreatment had 0.1 percent respiration rate after one week of storage under cold storage.

Once harvested, fruits and vegetables respire faster resulting in loss of nutrients, moisture and quality degradation. To maintain the post harvest quality and to extend the shelf life, a reduced respiration rate is desirable. All chilli varieties in MAP showed a decrease in respiration rate during storage (Krajaklang *et al*., 2000). According to Thompsom (2010), MA packaging can alter the composition of gases in and around fresh produce by respiration and transpiration when such commodities are sealed in plastic films. Singh *et al*. (2014) reported that MAP and storage under low temperature extended the shelf life by the interaction of respiration of the produce with the restricted gas exchange across the package.

5.3.4 Moisture (%)

Banana blossoms have moisture content above 90 percent which implies its shorter shelf life (Krishnan and Sinija, 2016). The moisture content showed a declining trend in all the treatments after one week of storage under cold storage condition with significant variation among values. On comparing the packaging materials, one week after storage under cold storage, maximum moisture retention was observed in control sample (94.22 %) in paper plate overwrapped with cling film and minimum retention was seen in buds pretreated with 0.2 percent citric acid (92.85 %) in polyethylene punnets.

When the pretreatments were compared, highest moisture content was noted in control sample after one week of storage in paper plateoverwrapped with cling film (94.22 %), polystyrene trayoverwrapped with cling film (94.05 %) and polyethylene punnets (93.84 %) under cold storage condition. However, lower moisture content was observed in buds pretreated with 0.2 percent ascorbic acid in paper plateoverwrapped with cling film (93.22 %) and polystyrene traysoverwrapped with cling film (93.45 %). In polyethylene punnets, minimum moisture retention was seen in 0.2 percent citric acid pretreated buds.

According to Miller *et al.* (1988), the film wrapping reduced moisture loss, retarded softening and maintained freshness with reduced colour development during extended periods of storage and marketing. Presence of moisture makes the environment congenial for microbial growth. Reduced moisture content is desirable for long term storage. Acedo *et al.* (2009) reported that higher moisture condensation inside the package during MAP resulted in the decay of more than 50 per cent fruits. According to Brar *et al.* (2000), fruits packaged in polyethylene had higher moisture content under all storage conditions. Rux *et al.* (2016) remarked that lower water vapour transmission in polymer material resulted in high relative humidity and condensation of vapour inside the package.

5.3.5 Acidity (%)

The minimally processed male buds in all the packaging materials after different pretreatments showed an increasing trend in acidity after one week of storage in cold storage condition. In control and ascorbic acid pretreated samples, only the buds in paper plate overwrapped with cling film showed significant variation in acid content, whereas in turmeric and salt pretreatment, buds in polyethylene punnets showed significant difference.

On comparing the packaging materials, minimum acidity was noted in 0.2 percent turmeric and salt pretreated sample (0.890 %) in polyethylene punnets and maximum acidity in control sample (2.345 %) in paper plate overwrapped with cling film. When pretreatments were compared, turmeric and salt pretreated buds in paper plate and polyethylene punnets had lowest acidity (1.005 %) whereas in polystyrene traysoverwrapped with cling film, buds pretreated with 0.2 percent ascorbic acid showed minimum acidity (0.893 %). Maximum acidity was seen in control sample in all the three packaging treatments.

5.3.6 Ascorbic acid (mg 100 g^{-1})

Ascorbic acid content of minimally processed and pretreated buds packed in different packaging materials had shown either a constant value or a decreasing trend after been stored for one week under cold storage condition. Cutting or bruising the tissue enhances the enzymatic activity leading to cellular disruption resulting in loss of vitamin C (Klein, 1987). Tissue damage occurs while chopping the buds during minimal processing causing the oxidation of ascorbic acid and in turn its reduction during storage. The decrease in ascorbic acid during storage may be due to inversion of ascorbic acid into dehydro ascorbic acid (Mahajan *et al.*, 2005).

The initial ascorbic acid content was found maximum in buds pretreated with 0.2 percent ascorbic acid (212.28 mg 100 g^{-1}) and minimum in 0.2 percent turmeric and salt pretreated buds (99.34 mg 100 g^{-1}).

One week after storage under cold storage condition, significant difference in ascorbic acid content was observed in control sample in paper plate overwrapped with cling film, and in ascorbic acid pretreated sample in polyethylene punnets. Highest ascorbic acid retention was observed in buds in polyethylene punnets (127.62 mg 100 g^{-1}) pretreated with 0.2 percent ascorbic acid and lowest retention in 0.2

percent turmeric and salt pretreated buds in paper plate overwrapped with cling film (85.10 mg 100 g^{-1})

When the pretreatments were compared, maximum ascorbic acid retention was recorded in polyethylene punnets and minimum retention in paper platesoverwrapped with cling film, with 0.2 percent ascorbic acid (127.62 mg 100 g^{-1}; 85.11 mg 100 g^{-1}), citric acid (85.13 mg 100 g^{-1}; 85.11 mg 100 g^{-1}) and turmeric and salt (85.15 mg 100 g^{-1}; 85.10 mg 100 g^{-1}) pretreatments. However, the untreated control sample had the highest ascorbic acid content in paper plateoverwrapped with cling film (127.61 mg 100 g^{-1}) and the lowest in polystyrene trayoverwrapped with cling film (85.12 mg 100 g^{-1}).

Under refrigerated storage, sweet lovi-lovi packed with cling film in polystyrene box retained the ascorbic acid best followed by shrink wrap packaging in areca plates (Karishma, 2017). As per the findings of Geethu (2018), ascorbic acid retention was highest in shrink wrapped fruits and polyethylene cover. Chandran (2013) remarked that polystyrene trays retained the vitamin C content in shredded beans and carrot.

5.3.7 Total phenol (mg 100 g^{-1})

Total phenol content with significant variation in the minimally processed buds pretreated and packed in different packaging materials showed an increasing trend one week after storage in cold storage condition. The increase in phenol content can be due to increased synthesis of anthocyanin and carotenoids which are of polyphenol in nature (Ram *et al.*, 2004).

Initially the total phenol content was maximum (0.162 mg 100 g^{-1}) in buds pretreated with 0.2 percent ascorbic acid and minimum (0.063 mg 100 g^{-1}) in 0.2 percent citric acid pretreated buds. One week of storage under cold storage condition, highest phenol content was recorded in control sample in polyethylene punnets (0.501

mg 100 g^{-1}) and lowest in 0.2 percent turmeric and salt pretreated sample in polystyrene tray (0.150 mg 100 g^{-1}).

On comparing the pretreatments, maximum phenol content was found in buds pretreated with turmeric and salt in paper plate overwrapped with cling film (0.441 mg 100 g^{-1}), ascorbic acid pretreatment in polystyrene trayoverwrapped with cling film (0.229 mg 100 g^{-1}) and untreated buds in polyethylene punnets (0.501 mg 100 g^{-1}). Whereas minimum phenol content was recorded in control sample in paper plate overwrapped with cling film (0.151 mg 100 g^{-1}), turmeric and salt pretreatment in polystyrene trayoverwrapped with cling film (0.150 mg 100 g^{-1}) and in citric acid pretreatment in polyethylene punnets (0.432 mg 100 g^{-1}).

5.3.8 Microbial load (cfu g^{-1})

Though studies have clarified that the presence of certain bioactive compounds render antibacterial properties to the male bud (Mokbel and Hashinaga, 2005), the microbial analysis revealed that the pretreated buds are more prone to bacterial contamination in all the packages. The fungal attack was controlled to some extent by citric acid and turmeric and salt pretreatment in paper plate and polystyrene tray overwrapped with cling film. Also the yeast population was negligible in all the treatments under cold storage. Increased bacterial and fungal load might be due to weakening of the defense system against microbial attack (Jawandha *et al.*, 2009). According to Xavier (2017), rate of growth and multiplication of microorganisms is slowed down under low temperature storage. Modified Atmosphere Packaging suppress the microbial spoilage thereby retains the quality and extends the shelf life of perishable produce (Rahman *et al.*, 2012).

Initially, bacterial population was absent in citric and ascorbic acid pretreatments, citric and turmeric and salt pretreatments were free from fungal attack and there were no yeast colonies found in any of the treatments. Chandra *et al.* (2013)

remarked that the chlorine and citric acid treatments could reduce the yeast and mould attack.

One week after storage under cold storage, untreated control sample was more prone to microbial attack. Xavier (2017) suggested that bacterial attack could be more in unwrapped fruits stored under ambient condition.The buds in polyethylene punnets had minimum bacterial and fungal population. Maximum bacterial and fungal attack was observed in buds in paper plate overwrapped with cling film whereas yeast attack was more when packed in polystyrene tray overwrapped with cling film. For minimal processed vegetables, packaging in polystyrene tray overwrapped with cling film enhanced visual appearance and keeping quality with low microbial count both under ambient and refrigerated storage (Varghese, 2006). Packaging retards the proliferation of microorganisms and thereby enhances the shelf life of the produce (Galet *et al.*, 2012). As per the findings of Srilakshmi (2012), condensation of moisture inside the packages favoured microbial growth.

5.3.9 Sensory evaluation

In the organoleptic evaluation of minimally processed buds, the mean rank score for appearance (8.13) was highest for ascorbic acid pretreatment while the citric acid pretreatment had the highest mean scores for colour (8.26), texture (7.60), odour (7.53) and overall acceptability (7.80) with a total score of 38.92.

In the minimally processed and partially cooked buds, the highest mean rank score for appearance (7.26) and colour (7.20) was in citric acid pretreatment. However, ascorbic acid pretreatment had the highest mean rank scores for texture (7.13), flavor (6.73), taste (7.20), after taste (7.20), odour (6.53) and overall acceptability (7.20) with a total score of 54.65.

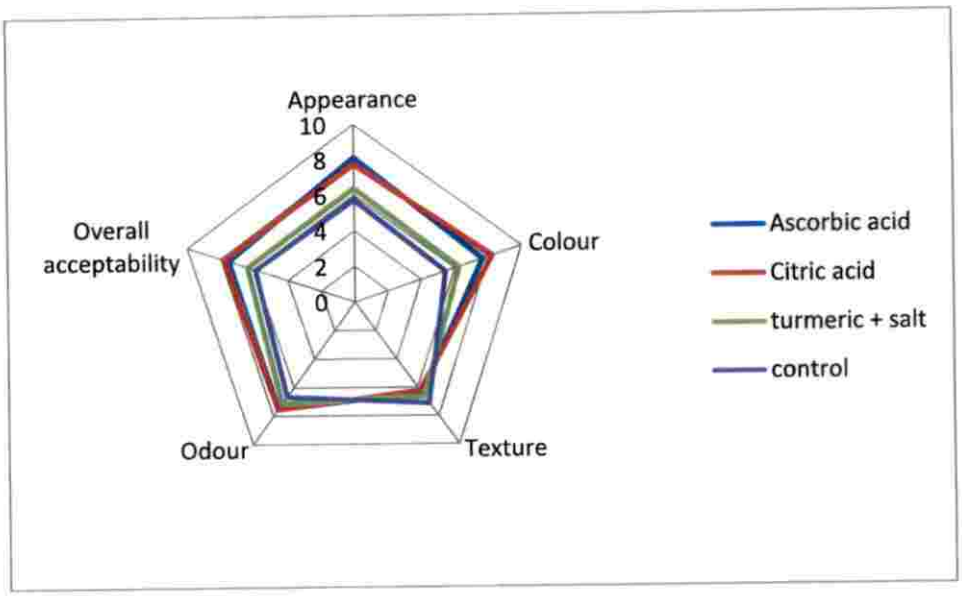

Fig 10: Effect of pre-treatments on sensory attributes of minimal processed bud

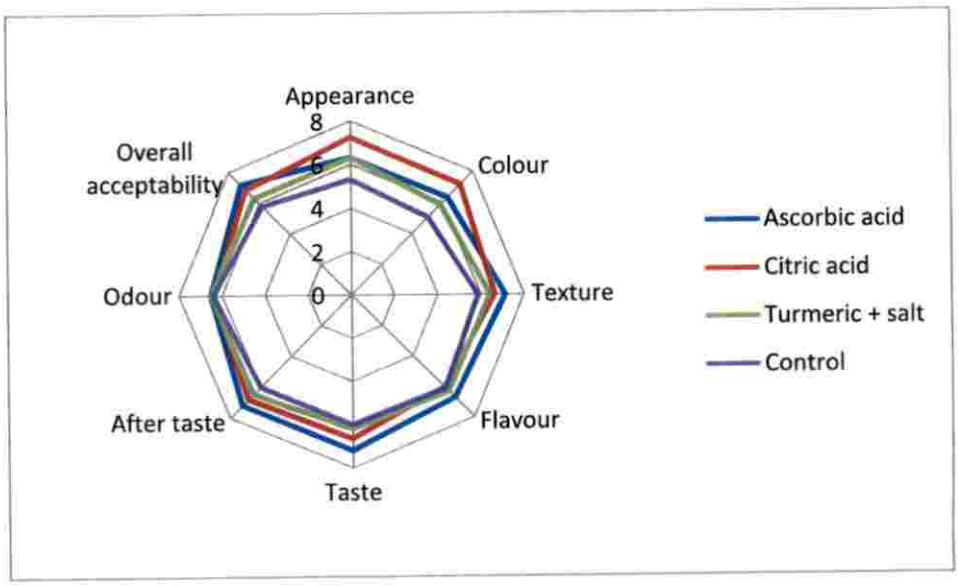

Fig 11: Effect of pre-treatments on sensory attributes of minimal processed and cooked bud

SUMMARY

6. SUMMARY

The main objectives of the study were characterization of male buds of banana cultivars and standardization of their harvesting stage, minimal processing techniques and packaging and storage methods. The experiment was carried out in the Department of Post Harvest Technology during 2017-19.

In the first experiment, banana male buds of Palayankodan, Grand naine, Njalipoovan and Nendran harvested at 15, 20 and 25 days after full bunch emergence were characterized based on physic-morphological and biochemical parameters. Palayankodan and Grand naine had the highest bud weight, length and diameter when harvested at 20 days after full bunch emergence and Nendran at 25 days after full bunch emergence. Whereas, the recovery and firmness was found to be higher when harvested at 25 days after full bunch emergence in Palayankodan and at 15 days after full bunch emergence in Grand naine and Nendran. However, Njalipoovan had the highest value for all the five parameters when harvested at 15 days after full bunch emergence.Considering the biochemical parameters, in all the four varieties more number of desirable constituents was found highest when harvested at 15 days after full bunch emergence. When subjected to organoleptic evaluation, Palayankodan had the overall consumer acceptance and highest total score under all the three stages of harvest. Also due to its popularity and easy availability, Palayankodan variety was taken for the packaging and storage studies.

In the second experiment, banana male buds were given different packaging treatments (wrapping in shrink film, cling film and polyethylene cover) and stored under ambient,cold storage and refrigerated conditions and studied the physico chemical changes and organoleptic quality. The studies revealed that banana buds packed in polyethylene cover and stored under refrigerated condition had the highest

shelf life (43 days) and lower physiological loss in weight along with biochemical parameters like ascorbic acid (11.9 mg/ 100g) and total phenols (0.648 mg/ 100 g). Also it had scored highest in organoleptic evaluation with a total of 36.07.

Third experiment consisted of standardizing minimal processing techniques for banana male bud. An attempt was made by adopting different pretreatments (0.2 % ascorbic acid, 0.2 % citric acid, 0.2 % turmeric + salt) and packaging methods (paper plate overwrapped with cling film, polystyrene trays overwrapped with cling film, polyethylene punnets) to enhance the shelf life and to improve the market value of banana buds. Lowest Physiological Loss in Weight and acidity was observed when the minimally processed buds were packed in polyethylene punnets along with better retention of ascorbic acid and total phenols. The scores of organoleptic evaluation suggest that 0.2 percent ascorbic acid pretreatment is the best.

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APPENDICES

APPENDIX 1

Media composition

1. **NUTRIENT AGAR MEDIA** (FOR BACTERIA)

Beef extract	: 3 g
Peptone	: 5 g
Sodium chloride	: 5 g
Agar	: 18 g
Distilled water	: 1000 ml
pH	: 6.8-7.2

2. **ROSE BENGAL AGAR MEDIA** (FOR FUNGUS)

Papaic digest of soyabean meal	: 5 g
Dextrose	: 10 g
Monopotassium phosphate	: 1 g
Magnesium sulphate	: 0.5 g
Rose Bengal	: 0.05 g
Agar	: 15 g
pH	: 5.6

3. **SABAURAUD DEXTROSE AGAR** (FOR YEAST)

Mycological peptone	: 10 g
Dextrose	: 40 g
Agar	: 15 g
Distilled water	: 1000 ml
pH	: 5.6

APPENDIX 2

Score card for organoleptic evaluation of banana male bud

Name of the judge:

Date:

Characteristics	Score			
	A	B	C	D
Appearance				
Colour				
Texture				
Odour				
Overall acceptability				

9 point Hedonic scale

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

Signature

APPENDIX 3

Score card for organoleptic evaluation of minimally processed and cooked bud

Name of the judge:

Date:

Characteristics	Score			
	A	B	C	D
Appearance				
Colour				
Texture				
Flavor				
Taste				
After taste				
Odour				
Overall acceptability				

9 point Hedonic scale

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

Signature

APPENDIX 4

Cost of packaging whole male bud

Items	Materials used for packing		
	Polythene cover	Cling film	Polyoleifin for shrink packing
Material cost(Rs)	4.50	2.33	3.25
Electricity charge	-	-	2.00
Labour cost /unit(Rs)	2.50	6.25	12.50
Total cost	**7.00**	**8.58**	**17.75**

CHARACTERIZATION AND VALUE ADDITION OF MALE BUDS OF BANANA CULTIVARS

By

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(2017-12-014)

ABSTRACT OF THE THESIS

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ABSTRACT

India is the largest producer of banana in the world and Kerala is rich with wide array of banana varieties. The banana plant in whole is useful for its fruits, peel, fibre, corm, male bud and pseudo stem. Banana inflorescence also known as navels is removed in commercial banana cultivation, by a practice called denavelling, for quality assurance of fruits. These male buds loaded with lots of nutrients are used as vegetable and also for the preparation of nutraceuticals. The stages of harvest after bunch emergence influence the quality of the male bud. Hence the study was carried out in the Department of Post-Harvest Technology, during 2017-2019,with the objectives to characterize the male buds of banana cultivars and to standardize their harvesting stage, packaging and storage methods and minimal processing techniques .

Palayankodan, Grand naine, Njalipoovan and Nendran varieties of banana were selected for the first experiment. They were harvested at 15, 20 and 25 days after full bunch emergence (DAB) and characterized based on physico-morphological and biochemical parameters. Palayankodan and Grand naine had the highest bud weight, length and diameter when harvested at 20 DAB and Nendran at 25 DAB. The recovery and firmness was found to be highest when harvested at 25 DAB in Palayankodan and at 15 DAB in Grand naine and Nendran. However, Njalipoovan had the highest value for all the four parameters (275 g weight, 19.8 cm length, 20.4 cm diameter, 87.2 % recovery) when harvested at 15 DAB.

Considering the biochemical parameters, in all the four varieties the desirable constituents like carbohydrate, protein, dietary fibre, potassium *etc*. were found to be highest when harvested at 15 DAB. When subjected to organoleptic evaluation, Palayankodan had the overall consumer acceptance and highest total score under all the three stages of harvest. Also due to its popularity and easy availability, Palayankodan variety was selected for the packaging and storage studies.

In the second experiment, banana male buds were given different packaging treatments (wrapping in shrink film, cling film and perforated polyethylene cover) and stored under ambient, cold storage and refrigerated conditions. Physico chemical changes and organoleptic quality were observed. The studies revealed that banana male buds packed in polyethylene cover of 150 gauge and stored under refrigerated condition had the highest shelf life (43 days) and lower physiological loss in weight along with biochemical parameters like ascorbic acid (11.9 mg/ 100g) and total phenols (0.648 mg/ 100 g). Also it had scored highest in organoleptic evaluation with a total of 36.07.

Third experiment consisted of standardizing minimal processing techniques for banana male bud. An attempt was made by adopting different pre-treatments (0.2 % ascorbic acid, 0.2 % citric acid, 0.2 % turmeric + salt) and packaging methods (paper plate overwrapped with cling film, polystyrene trays overwrapped with cling film, polyethylene punnets) to enhance the shelf life and to improve the market value of sliced banana buds. Minimal processed buds with 0.2 % citric acid pretreatment packed in polystyrene trays had a shelf life of one week and microbial load within the permissible limit along with better retention of ascorbic acid (6.81 mg/ 100g) and total phenols (0.276 mg/ 100 g).

The present study found that the harvesting stage of buds in Palayankodan and Grand naine was 20 days after full bunch emergence and in Njalipoovan and Nendran it was 15 and 25 days after full bunch emergence respectively. The buds of all four varieties are nutrient rich and organoleptically acceptable with mean rank scores above 6. Packaging in perforated polyethylene cover and storage under refrigerated condition increases the shelf life of whole male bud with retention of desirable qualities. Also 0.2% citric acid pretreatment and packaging in polystyrene trays enhance the market value of minimal processed buds.