EFFECT OF VACUUM AND SHRINK PACKAGING ON SHELF LIFE OF BANANA (*Musa paradisica*)

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PROJECT REPORT

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On behalf of

Agricultural Engineers

to

God Almighty

DECLARATION

We hereby declare that this project report entitled **“EFFECT OF VACUUM AND SHRINK PACKAGING ON SHELF LIFE OF BANANA (*Musa paradisica*)”** is a bona fide record of project work done by us during the course of study and that the report has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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(2011-02-034)

CERTIFICATE

Certified that this project report, entitled, **"EFFECT OF VACUUM AND SHRINK PACKAGING ON SHELF LIFE OF BANANA (*Musa paradisica*)"** is a record of project work done jointly by Claudia K.L. and Sunisha K. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, associate ship or other similar title of any other University or Society.

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CLAUDIA K.L.

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SYMBOLS AND ABBREVIATIONS

%	percentage
/	per
^{0}Brix	degree Brix
^{0}C	degree Celsius
cm	centimetre
CO_2	carbon dioxide
et al.	and other people
etc.	etc etera
g	gram
h	hour
ha	hectare
KCAET	Kelappaji College of Agricultural Engineering and Technology
kg	kilogram
LDPE	Low Density Poly Ethylene
m	metre
mg	milligram
mm	millimetre
mm/s	millimetre per second

MT	Metric Ton
MT/ha	Metric Tons per hectare
N	Newton
NA	Not Applicable
NHB	National Horticultural Board
No.	Number
O_2	oxygen
PE	Poly Ethylene
PET	Poly Ethylene Tetra mine
PLW	Physiological Loss in Weight
ppm	parts per million
RH	Relative Humidity
Secs	seconds
SO2	Sulphur dioxide
TSS	Total Soluble Sugars
USDA	United States Department of Agriculture
VFPCK	Vegetable and Fruits Promotion Council Keralam

Introduction

CHAPTER 1

INTRODUCTION

Fruits are nature's most important gift to mankind as they are important supplements to the human diet such as essential minerals, nutrients including vitamin C, vitamin K, foliate, thiamine, carotene, dietary fibre, antioxidant phyto-compounds etc. Thus fruits help the human body to stay fit, free of diseases. Fruits account for substantial fraction of world's agricultural output and are of extensive cultural importance.

Banana (*Musa paradisica*) is an edible fruit produced by several kinds of large herbaceous flowering plants in the genus *Musa*. It is referred as "Kalpatharu" (Plant of Virtue) due to its multifaceted uses (Anon, 2011). It is grown in the tropics and is widely consumed in those regions. It is valued worldwide for its flavour, nutritional value, and availability throughout the year. A ripe fruit contains as much as 22% carbohydrate, mainly as sugar, and is high in dietary fibre, potassium, manganese, vitamin B6 and vitamin C. Hence banana is expected to have the potential to contribute to strengthening national food security and decreasing rural poverty.

Plate no. 1.1 Banana

Banana stands in the third position among the top 25 healthy fruits (Rosenbloom, 2008). India holds the first position in the world in banana production. Also, banana ranks first in production and third in area among fruit crops in India. It accounts for 13% of the total area and 33% of the production of fruits (NHB, 2011). Bananas have become a key source of revenue earner for farmers as they are traded not only within the region but also exported to other countries including Europe, earning lot of foreign exchange for the Country (Adejoro *et al.*, 2010).

Processed products, such as chips, banana puree, jam, jelly, juice, wine and halwa can be made from the fruit. The fruit is easy to digest, free from fat and cholesterol and hence banana powder is commonly used as the first baby food. It also helps in reducing risk of heart diseases when used regularly and is recommended for patients suffering from high blood pressure, arthritis, ulcer, gastroenteritis and kidney disorders (Anon, 2014).

Bananas are harvested green and begin ripening as soon as the banana stem is cut from the plant. This results in huge post-harvest losses. Ripening of fruits can be delayed if the fruits are kept in an anaerobic atmosphere which can be achieved by special packaging methods.

Loss during distribution is major problem banana encounters. In order to reduce this wastage, use of polyethylene film bags for wrapping whole bunches for transport is found to be most suitable. Different packaging methods can be adopted on the basis of product requirements, personnel preference, marketing systems etc. (Roy *et al*., 2000).

Food packaging is a system by which a fresh produce or processed product will reach from the production centre to the ultimate consumer in safe and sound condition at an affordable price. It works on the principle that if CO_2 in the atmosphere is augmented, the respiration rate and storage life can be extended (Khetarpaul and Punia, 2012). The major benefits of banana packaging includes reduced damage during distribution, reduction in space requirement during transportation, reduced shrink at supermarket level convenience and reduction in customer-induced fruit abuse (Mahinda,2008).

Banana can be protected and its shelf life increased by packing using vacuum. Vacuuming removes air from the containers which in turn retards spoilage. This principle is employed in case of vacuum packaging. Containers are usually bags made of polyethylene, aluminium, PET etc (Conie and Young, 2003).

Shrink packaging is the process in which sheets of transparent plastic film are wrapped around a product to form a solid, weather-resistant packaging layer. Plastic film are preheated, stretched and cooled prior to use. Shrink wrapping is now becoming one of the newest trends in packaging because it offers a versatile, cost effective packaging. Also the materials used are strong, flexible and provide effective protection, making the product tamper-proof. It is also considered as an ideal aid for general marketing purposes (Anon, 2014).

Market promotion is needed for better adaptability of the technology. In India, banana crop after harvest are traded by middlemen without adapting any preservation technique, causing wastage of large quantities. Size of the bunch and external fruit appearance determine the market price. Efforts are needed for better storage facility with assured marketing and trading. Research efforts are needed in developing better packaging and transportation techniques to avoid the losses and to fetch better price to farmers (Anon, 2011).

Taking the above points into consideration, this project is undertaken with the following objectives:

1) To study different packing methods for long term storage of banana (*Musa paradisica*).

2) To analyse the physical and bio chemical changes during storage of banana.

3) Cost Analysis of the various packaging practises.

The above project may be helpful to banana farmers to increase their profits by prolonging the storage time of banana and also in creating new business enterprises and jobs, and thus provide sustainability of farm families and communities that depend on banana cultivation.

Review of literature

CHAPTER 2

REVIEW OF LITERATURE

This chapter comprises of various reviews of research work related to the field of study; banana and its characteristics, vacuum and shrink packaging along with economics and marketing of packed bananas.

2.1 Banana (*Musa paradisica*)

2.1.1 History and Distribution

It is widely believed that banana originated in the rainforests of South East Asia with India as one of its centres of origin (NHB,2011). It is believed that the first domestication of this fruit took place in the highlands of Papua, New Guinea. The origin of the word banana is derived from the Arabic word 'banan', which means finger. This fruit has traversed a long way from jungle of South East Asia and Malaysia to become the most popular fruit of the world (Mararuai, 2010).

Banana is cultivated in more than 170 countries, India being the leading producer. Other major producers are Brazil, Eucador, China, Phillipines, Indonesia, Costarica, Mexico, Thailand and Colombia.

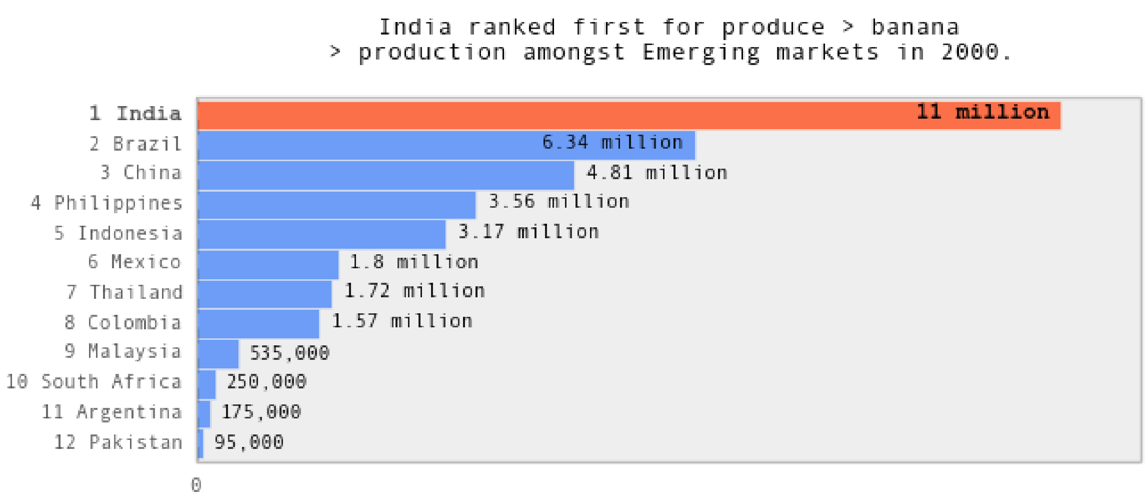

Figure 2.1 Global production of banana

Within India, Tamil Nadu covers the largest area of production (113700ha) whereas, Maharashtra has the highest productivity (65.70MT/ha). Other major banana producing states are Karnataka, Gujarat, Andhra Pradesh and Assam (Anon, 2014).

State	Banana 2010-11 Area (in '000 Hectare)	Banana 2010-11 Production (in '000 Tonne)
Andhra Pradesh	79.3	2774.8
Arunachal Pradesh	5.4	13.3
Assam	47.6	723.6
Bihar	31.9	1517.1
Chhattisgarh	14.8	351.4
Goa	2.3	25.1
Gujarat	64.7	3978.0
Haryana	NA	NA
Himachal Pradesh	0.1	0.4
Jammu & Kashmir	NA	NA
Jharkhand	3.2	64.3
Karnataka	111.8	2281.6
Kerala	58.7	483.7
Madhya Pradesh	38.1	1719.6
Maharashtra	82.0	4303.0
Manipur	33.7	34.9
Meghalaya	5.8	67.3
Mizoram	10.0	118.6
Nagaland	2.7	59.0
Orissa	26.9	488.7
Punjab	0.2	10.2
Rajasthan	0.1	0.8
Sikkim	1.7	3.4
Tamil Nadu	125.4	8253.0
Tripura	7.8	125.0
Uttarakhand	NA	NA
Uttar Pradesh	32.4	1346.1
West Bengal	42.0	1010.1

Table 2.1 Production of Banana in India

2.1.2 Botanical Aspects

Bananas are vegetatively parthenocarpic edible fruits. They may or may not be seed fertile, but they are effectively seed sterile, depending upon complex cytological factors (Simmonds, 1953). The edible pulp fills the fruit in parthenocarpic types and surrounds the seeds in seeded banana

(Ho, 1968). Bananas have been classified as climacteric fruit on the basis of the pattern of respiration and ethylene production during maturation and ripening.

Banana ripens slowly and irregularly. Initial ripening temperature should be maintained within 14-25 °C. If the bunch is fully mature ripening can be done at room temperature. In domestic market banana fruits are commercially ripened with calcium carbide covered with gunny bags. Banana is commercially ripened by treatment with exogenous ethylene (Golding *et al*., 1998).

2.1.3 Physiological and Morphological aspects

Banana plant is a tall, perennial monocotyledon with a circumference upto 2.5 m. All the above parts of a banana plant grow from a structure usually called a 'corm' and the ground trunk called 'pseudostem' which consists of concentric layers of leaf sheaths rolled into cylinder 20-50 cm in diameter (Pillay and Tripathi, 2007). The leaves of *Musa* plants composed of a stalk and blade emerge, tightly rolled, from the centre of the pseudostem in an anticlockwise spiral manner. The root system is adventitious spreading out laterally as far as 5.5 m and forming a dense mat mainly in the top 15 cm of soil.

Banana is botanically known as berry (finger). Each cluster of fruit at anode is known as a 'hand' and the entire collection of hands is known as a 'bunch'. Outer protective layer of each fruit, known as the 'skin' or 'peel' is a fusion of hypanthium and outer layer of the pericarp. This peel is easily removed from the fleshy pulp that originates mainly from the endocarp (Simmonds, 1953). Numerous long, thin strings of phloem bundles run lengthwise between the skin and the edible inner portion. The fruit is usually elongated and curved, with soft flesh rich in starch covered with a rind which may be green, yellow, red, purple, or brown when ripe. Colour, size, texture and flavour of common cultivated Musa fruits vary with cultivar. Fruit colour extends from yellow and green to red and orange (Ploetz*et al*., 2007).Edible Musa cultivars have fleshy, seedless fruits while wild bananas may have little flesh and be filled with black seeds 3-16 mm wide. Individual banana fruits average 125grams, of which approximately 75% is water and 25% dry matter (Morton, 1987).

2.1.4 Mechanical properties

Mechanical properties are explained on the basis of the internal structure of the fibre, namely, the number of cells, spiral angle and the number of defects (Preston, 1978). Properties such as the initial modulus, ultimate tensile strength, and percentage elongation are evaluated as a function of fibre diameter, test length and speed of testing.

It is found that there is no appreciable change in the mechanical properties of the fibres with an increase in the diameter of the fibre certain ranges. Usually the test length and breaking strength of fibre shows a linear relationship. However the effect of test speed on strength of fibres varies. The stress-strain curve for banana fibre is characterised by an initial linear stress-strain curve, the slope of which may be taken as the initial modulus, the linear portion is followed by a curve since the strain per unit stress is greater than that during the initial deformation (Kulkarny *et al*., 1983).

2.1.5 Varieties cultivated

Bananas are classified as dessert types and culinary types. A good variability of characters exists in both the dessert and culinary types. The varieties differ in shape, size, colour, quality and yield. Robusta, Dwarf Cavendish, Grand Naine**,** Rasthali, Vayalvazhai, Poovan, Nendran, Red Banana, Karpooravalli, Neypoovan are popular dessertvarieties in banana. Cavendish groups are generally prefered in export market.The culinary types have starchy fruits and are used in the mature unripe form as vegetables.Monthan, Vayalvazhai, Ash Monthan and Chakkia are cultivated for culinary purpose. Nendran is a dual purpose variety used for dessert and culinary.Almost all modern edible parthenocarpic (seedless) bananas come from two wild species – *Musa acuminate* and *Musabalbisiana* (Simmonds and Shepherd, 1955).

Plate 2.1 Banana varieties

Important banana varieties cultivated in Kerala are Nendran, Njalipoovan, Palayankodan (Poovan), Rasthali, Monthan, Red Banana and Robusta (Anon, 2014).

Nendran Bananas are a variety of banana popular in Kerala. They are much bigger in size than the regular Robusta bananas; flesh is firmer, silkier and sweeter. They have a distinct neck with thick green skin which turns buff yellow on ripening, and a pale yellow flesh. It is relished as a fruit, used as a staple food as well as used to make the famous Nendran Chips and processed into several other value added products. It is a nutritious diet for easy digestion, prevents diarrhea & worm trouble and is especially given to infants due to their high protein content.

2.1.6 Nutrient composition

Water is the major constituent in the pulp and peel of banana. Bananas are caloric dense fruits. It contains relatively high amounts of potassium and magnesium. They are also rich in soluble fibre pectin. Short chain fatty acids are constituted in bananas (Morton, 1987). The nutritional profile of banana also indicates that they are a very good source of vitamin B6, vitamin C, dietary fibre, biotin and copper. Banana peel contains beta sitosterol, stigmasterol, campesterol, cycloeucalenol, cycloartanol, and 24-methylenecycloartanol. The major constituents are 24-methylene cycloartanolpalmitate and an unidentified triterpene ketone.

Shown below is the tabular representation of the nutritional value of the banana fruit per 100 gram without peel (USDA National Nutrient data base)

Principle	Nutrient Value	Percentage
Energy	90 Kcal	-
Carbohydrates	22.84 g	18%
Protein	1.09g	2%
Total Fat	0.33 g	1%
Cholesterol	0 mg	0%
Dietary Fiber	2.60 g	7%
Vitamins		
Folates	20 µg	-

Niacin	0.665 mg	-
Pantothenic acid	0.334 mg	-
Pyridoxine	0.367 mg	-
Riboflavin	0.073 mg	-
Thiamin	0.031 mg	-
Vitamin A	64 IU	-
Vitamin C	8.7 mg	-
Vitamin E	0.10 mg	-
Vitamin K	0.5 µg	-
Electrolytes		
Sodium	1 mg	-
Potassium	358 mg	-
Minerals		
Calcium	5 mg	-
Copper	0.078 mg	-
Iron	0.26 mg	-
Magnesium	27 mg	-
Manganese	0.270 mg	-
Phosphorus	22 mg	-
Selenium	1.0 µg	-

Zinc	0.15 mg	-
Phyto-nutrients		-
Carotene-α	25 µg	-
Carotene-ß	26 µg	-
Lutein-zeaxanthin	22 µg	-

Table 2.2 Nutrient composition

2.1.7 Respiration rate

Respiration is the oxidative breakdown of complex substrates like carbohydrates to simpler molecules like CO_2 and H_2O (Mishra, 2012). Since banana is a climacteric fruit, respiration rate shows a decreasing trend to the lowest value termed as pre-climacteric minimum followed by a sharp rise in respiration rate to the climacteric peak. This sudden rise is called as respiratory climacteric followed by a decrease in respiration rate in the senescence period (Seymour, 1993). Banana shows a sudden increase of respiration rate and consequently a burst of ethylene production at the onset of climacteric peak. Enzymes play a key role in the climacteric rise in respiration rate (Ball et al., 1991).

2.2 Packaging

Postharvest shelf life extension has been a problem for years due to its climacteric respiration pattern and sensitivity to low temperature. Immediately after harvest, the sensorial, nutritional and organoleptic quality of fresh produce start to decline as a result of altered plant metabolism. This quality deterioration is the result of produce transpiration, senescence, ripening-associated processes and the development of postharvest disorders. Packing certain foods in sterile, sealed plastic is an excellent way to preserve them, and increase the value to the producer (Bazirake, 2010).

The packaging of dehydrated fruits requires the use of package which will prevent or at the very least minimise the ingress of moisture and, in certain instances, oxygen. The packaging material normally consists of one or more polymeric films having the desired barrier properties. This implies that the material must be a very good barrier to water vapour and, depending on the particular product, a good barrier to O_2 and may be SO_2 and certain volatiles (Khetharpaul and Punia, 2008).

2.4 Vacuum packaging

The most appropriate method of preservation is to vacuum pack bananas, which can be stored, refrigerated for up to four months. Vacuum packing became commercial in the 1960s. It made possible to present to consumers fresh and hygienic products and to export fresh products throughout the world.

Banana ripens in three to five days after harvesting. Ripening during the long distance transport and export, results in huge post-harvest losses. To delay ripening of fruits, vacuum packaging is one of the methods, where the matured banana hands are packaged and prevented from contact with air/ oxygen. Using a simple gadget for vacuum packaging, banana can be stored under vacuum. This delay ripening up to 21 days and further ripening is completed within one week after opening the package.

In 2003, Conie and Young conducted studies and concluded that vacuum packing lengthens the edibility quotient of food in all its varieties. Produce can be delivered to homes and export markets with guaranteed freshness and minimum waste and spoilage. Food is protected from air and moisture, as vacuum-packing locks in freshness and prevents freezer burn. Food remains fresh for three to five times longer. Peeled green bananas, which would normally loose freshness in minutes, stay fresh up to four months in the freezer.

Thompson (2000) reported that bananas stored at17°C had an extension of 4 to 6 weeks and they were kept in evacuated, collapsed PE bags by applying a vacuum not less than 300mg.

Vacuum packing has the following specific benefits:

1) Foods that are high in fats and oils won't become rancid, as there is no oxygen to cause rancid taste and smell.
2) Lack of oxygen prevents oxidation or discoloration, as is usually seen on green bananas being exposed to air.
3) Insects cannot grow, survive or hatch
4) Enjoyment or availability of favourite or special foods all throughout year, even out of season.

2.5 Shrink packaging

Shrink-wrap packaging is a new technique for post-harvest handling of fruits and vegetables. The technology delays physiological deterioration of fruits and also prevents condensation of droplets within the package. Individual shrink-wrapping of the produce provides optimum gas and humidity for maintaining quality of the produce during the transit and storage. As a result, it doubles or sometimes triples storage life of the fruits under proper storage conditions. Such unit packs also provide protection against abrasion and maintain attractive appearance of the product. It is easy, user-friendly, can be very well adopted by marginal farmers and/or entrepreneurs (Sharma and Pal, 2009).

Besides reducing moisture losses and changing the O_2 and CO_2 levels, shrink wrapping in film can also protect fruits from some damage. Thompson (1981) found that arracaaha roots deteriorated quickly after harvest but could be stored for 7 days if packed in shrink film. Samsoondear et al. (2000) found that the bread fruits that had been shrink wrapped with PE film had an extended storage life, lemons stored in PVC 100 shrink wrap retained a quality, with reduced loss of weight and rotting compared with those stored non wrapped or waxed (Neri et al., 2004).

This method was considered advantageous by Pal (2009) as:

- Year-round production of shrink-wrapped produce is possible.
- Shrink-wrapped produce looks attractive, hygienicand free from dust and dirt.
- It is easy to handle shrink-wrapped produce during storage or transportation.
- It avoids secondary infection, which is important for long-term storage.
- It delays deterioration of the produce, and thus enhances shelf-life.

The cost of the shrink-wrap packaging varies with the commodities to be wrapped films to be used for wrapping. In practice, it adds a packaging cost of about Rs 0.80 to 1.00 for 1kg fruits. This cost can be further reduced if tray-wrap packaging of 6-10 units per pack is done (Sharma and Pal, 2009).

2.6 Physico-chemical characteristics estimation

The physiochemical properties of foods (rheological, optical, stability, flavour) ultimately determine their perceived quality, sensory attributes and behaviour during production, storage and consumption.

According to the findings of Appiah et al. (2011) ripening is known to induce physico-chemical changes such as softening in fruits. Various investigators analysed the physico- chemical changes during storage life of fruits.

2.6.1 Physiological loss in weight

Weight loss depends on water loss mainly and it is important because it affects the visual appearance and texture of the fruits and causes a reduction in saleable weight. Generally, products must lose about 5 % of their fresh weight before visual appearance is affected (Kader, 2002).

Tourky et al. (2014) concluded that physiological loss of weight gradually increased as the shelf life period prolonged. Kulkurni et al. (2010) found that data on the cumulative loss in weight due to transpiration and respiration processes indicated that banana fruits kept in open condition without ethrel dip treatment lost weight up to 6.7% on 8th day of storage. Results showed that increase in PLW was directly proportional to increase in ethrel concentration. This increase in PLW of ethrel treated banana fruits during ripening could be due to upsurge in respiration rate leading to faster and uniform ripening compared to untreated fruits.

Similar results were reported by Singh et al. (1977) and Mahajan et al. (2008).

2.6.2 Total Soluble Solids (TSS)

Sugar is measured commonly as the total soluble solids (TSS) by refractrometry, giving a value in degrees brix**.** Among the physico-chemical determinants, TSS is a very good indicator of ripening (Camara et al., 1993). Increase of TSS is an important trait of hydrolysis of starch into soluble sugars such as glucose, sucrose and fructose. Kulkurny et al, and Marriot et al., Hossain et al. (2008) reported that there was high significant effect of maturirty stages of tomatoes on TSS.

Jha et al. (2006) observed that the TSS content of stored mangoes generally increased due to ripening, but at the end of storage period it decreased slightly and remained around 15° Brix. Decrease in TSS was concluded as due to excessive ripening and then rotting of mango during storage. The mangoes harvested at or above 8° Brix showed better shelf life and maintained the quality

Ibrahim et al. (1994) observed a gradual increase in TSS during ripening of banana. Similar findings were reported for Guava, Mango and Date fruit. Aravindakshan (1981) showed that packaging banana in LDPE bags considerably reduced the TSS as compared to control.

The TSS of ethylene treated banana was found to increase with ripening whereas for untreated fruit change in TSS content was slow and reached to a maximum of 7° Brix after 6 days of storage (Kudachikar *et al*., 2010).

2.6.3External Appearance

In bananas, ripeness and quality are evaluated by subjective visual examination based almost entirely upon the colour of the peel. This single subjective criterion is assumed to indicate both flavour and texture.

The colour of the peel goes from green to yellow. There is migration of water from the peel to the pulp and degradation of starch, which can soften the pulp. There is also production and accumulation of low molecular weight sugars. These changes contribute to the appearance, desirable sweetness and eating quality of the ripened banana (Marriot, 1980; Mota et al., 1997).

External skin colour changes during ripening often reflect changes in flesh colour .As the yellowing of the skin intensifies, the flesh colour changes from the typical 'opaque white' of a product with a high starch content to a 'very soft yellow'(Sanz et al.,2007).

Bananas are harvested green and begin ripening as soon as the banana stem is cut from the plant. Banana ripeness is classified into five peel colour stages: green, yellow with green tips, yellow, yellow with brown flecks and brown. As the banana ripens, its starch converts to sugar. The riper the banana, the creamier and sweeter it tastes (Alencar et al., 2012).

In banana postharvest, one of the principal problems encountered is related to fungal attack, which depreciates fruit quality making it inadequate for commercialization on the international level. Moraes*et al*. (2006) confirmed that pathogen establishment on the banana can occur in different forms: quiescent infection, bruising or during pre-harvest. Area affected by fungal pathogens on the surface of fruits was taken as percentage decay. Ocknokwo,(1990) cited by Sindhu,(2000) identified that the fungal pathogens which showed cellulosic activities were *Aspergillusniger*, *Rhizopus*sp, and *Boteyodiplodatheobromae.* Ndubizu(1976) suggested that matured green plantain dipped in fungicide and stored in PE bags remained green and hard for 3 to 4 weeks before ripening started. Fruits dipped in thiabendazole before storage remained virtually free of fungal attack even after they had completely ripened.

2.6.4 Total sugar

Sugar is often used as an indicator of maturity and is sometimes used as a basis for pricing. Garcia and Lajolo (1988) reported that a progressive increase in total sugar content and decrease in starch content was observed during ripening of banana. Bashir et al. (2002) concluded that the remarkable increase in total sugars in guava may be attributed to the increase in activity of enzymes responsible for starch hydrolysis and for decline in the rate of sugar break down by respiration.

The most striking chemical change which occurs during post-harvest ripening banana is the hydrolysis of starch and accumulation of sugars (Sindhu, 2000). Around 20-25% of the pulp of fresh green fruit is starch.

Total sugar in matured green banana reported by Kulkarney et.al. (2011) was 1.5% at the time of harvest. For the ripe pulp it increases up to 15-20%.

2.6.5Textural attributes

Food texture, in harmony with other sensory properties of food such as appearance, taste and flavour, is one of the most important factors in consumer appreciation and enjoyment of food products.

According to Konopacka and Plocharski (2004) texture perception is an important factor for quality evaluation of fruit and vegetable products and critical in determining the acceptability of fresh fruits.

For fresh foods such as fruits and vegetables, textural properties such as firmness and toughness are widely used as indices of maturity to meet requirements for long-term handling, storage and acceptability by the consumer (Chen et al., 2013). Firmness and toughness being important textural attributes are studied by most investigators.

2.6.5.1Toughness

Toughness of fruits and vegetables are complex. It is primarily due to cell wall components, pectins, hemicellulose and cellulose during maturation, storage and processing.

Adegoroye (2006) observed that preferential ripening of the uninjured portion of fruits increased toughness beyond expected values. The toughness of fruits were found to reduce with increase in time of boiling in the study. Goyal et al. (2007) concluded that fruits showed different values of toughness in different orientations the toughness of Chakaiya fruits was higher compared to other cultivar fruits. Pavithran et al. (1987) observed toughness of banana was lesser when compared to pineapple.

2.2.5.2Firmness

Firmness in fruits is sometimes evaluated as being the force necessary to attain a given deformation within the products. Firmness is defined as Young's modulus of elasticity of the flesh of fruits. Since modulus of elasticity is defined as the ratio of stress to strain within a material, it measures resistance to force, and has been reported to be a measure of the firmness of food products (Scott-Blair 1960).

The consumer preference to any fruit is driven primarily by its physical parameters like size, shape, colour, external defects/blemishes and firmness. One of the most significant quality aspects of mango for consumers is its firmness because it reflects the ripening stages of the fruit (Jha et al., 2010). Firmness relates to maturity of many agricultural products (Sirisomboon et al., 2008) and is an important attribute to have an idea of eating quality and remaining shelf life of mango fruit (Jha et al., 2006).

Fruit firmness, in general, decreases as fruits become more mature and decreases rapidly as they ripen. To ensure the supply of high quality fruit, it is important to select the fruit with proper degree of maturation (Schmilovitch et al., 2000), as physical appearance, taste and postharvest shelf life depends upon maturity level at harvest.

Chen (1996) reported that fruits when harvested before maturity do not ripen uniformly and may show excessive shrinkage and low levels of sweetness. Overripe or injured fruit is relatively soft and excessive softening leads to physical damages during handling, transportation and storage (Goulao and Oliveira 2008). Successful delivery of fruits therefore, requires care to have minimal textural changes during storage and transport (Varela et al.2008), for which knowledge and trend of textural properties are necessary.

Medlicott et al. (1988) reported that mature hard green mango fruit attain a superior eating quality when ripe while immature ones do not.In majority fleshy fruits like mango, textural characteristics are more important than other aromatic properties and fruit firmness is one of them (Johnson and Ridout 2000).

2.6.6 Sensory evaluation

Sensory rating of fruit by panellists and physical measurements of fruit properties are useful methods in the evaluation of fruit quality (Colaric et al., 2005). Sensory quality is a difficult concept to design; it should be comprehended as interaction between the consumer and the product. Taste, aroma, texture and appearance are generally considered to be among the most important sensory attribute.

Aroma of fruits improves during ripening because of which ripened products are preferred by the panellists. The characteristic aroma is usually derived by the production of different volatile compounds (Appiah et al., 2011).

According to Civille (2012) subjective measurement of texture, often referred to as “sensory perception” or “sensory evaluation”, encompasses all methods to measure, analyse and interpret human responses to the properties of foods and materials as perceived by the five senses: taste, smell, touch, sight and hearing

2.7 Economic Aspects

Bananas and plantains are highly perishable and, in the absence of modern technology and advanced harvesting practices, must be consumed within three weeks post-harvest, requiring rapid distribution and marketing (Fonsah and Chidebelu, 2011). Plantain distribution is carried out through a variety of interactions between farmers, collectors, wholesalers, and vendors. Bananas and plantains have the marketing characteristics specific to all perishable foodstuffs whose production is complex and distribution difficult to organize. The process involves a large number of producers and a few wholesalers who distribute plantains and bananas to consumers on a large scale (Fonsah and Chidebelu, 2011). Traders who want to sell their plantains at the ripe stage generally induce the ripening process by stocking them in baskets, drums or other containers covered with plastic bags or jute bags to maintain heat among fruits. These containers are ventilated by removing the covers after 2 to 4 days. Marketing potential of banana was discovered in 1870 by American and European industries emerged in Central and South America for plantation and its export. United Fruit Company was the first to start their commercial production. It plays in an important role in the economy of developing countries (Mararuai, 2010).

Vegetable and Fruit Promotion Counil Keralam (VFPCK) gives an insight on price schedule of banana which varies on a daily basis. As per price bulletin 2013, the price of banana green had a hike from Rs 27.91 to 40.89 with a yearly percentage variation of 46.51.

Vacuum-packing entrepreneurs could benefit from sales during the high demand periods. In the off-seasons however, farmers are unable to find adequate market for the third grade. During this period, the fruits are wasted and dumped, which explains the reason for farmers being reluctant to grow commercial-sized plantations of bananas solely for green fruit, in spite of the lower cost of production and minimal quality standards required, compared to ripe fruits. This problem can be solved to a larger extend by vacuum packing.

Materials and methods

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials and methodology adopted for satisfying the objectives of the study on vacuum and shrink packaging of banana.

3.1 Banana sample collection

Matured green banana belonging to Nendran variety was purchased from the local market near KCAET campus. The collected samples taken in clusters were washed with clear tap water to remove the extraneous matter and then wiped off with clean cloth to remove the external water. The fruits with external infections, deformities and damages were discarded.

3.2 Packaging materials

For vacuum packaging, LDPE films (150 gauges) which were found suitable from previous vacuum packaging studies were used. For shrink packaging, 90 micron polyethylene films were used.

3.3 Vacuum packaging

Vacuum packaging is another way to increase the shelf life of food products. Here the product is placed in an air-tight pack, the air sucked out and the package sealed. By removing air from around the product, the levels of oxygen in the packaging are reduced, impeding the ability of oxygen-breathing microorganisms to grow and spoil the product. The lack of oxygen also reduces the amount of spoilage due to oxidation – the process that causes apples and bananas to turn brown, for example.

For vacuum packing, the test samples were taken in suitable packing covers and sealed in vacuum packaging machine. The packaging operation includes removal of air in the packets loaded with the product. Air exclusion is attained and maintained by using vacuum pump and heat sealing. Sealing may take around 20-30secs.

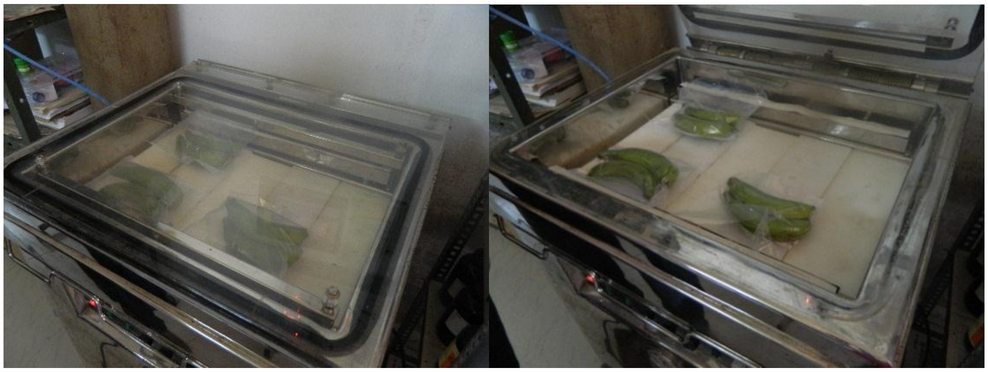

Plate 3.1 Vacuum packaging machine

3.4 Shrink packaging

In order to shrink pack the bananas, the cluster selected has to be sealed in a desirable heat-shrinkable film with the help of an impulse sealer. The produce is then then passed through a heated tunnel in the machine (Sevana DSTV) maintained at 120°C. A fan is then activated which circulates hot air around the produce, and the film shrinks tightly around the produce. Shrink-wrapped produce is immediately removed from the machine. The conveyor speed can be adjusted as per requirement of the product in the machine itself.

Plate 3.2 Shrink Packaging Machine

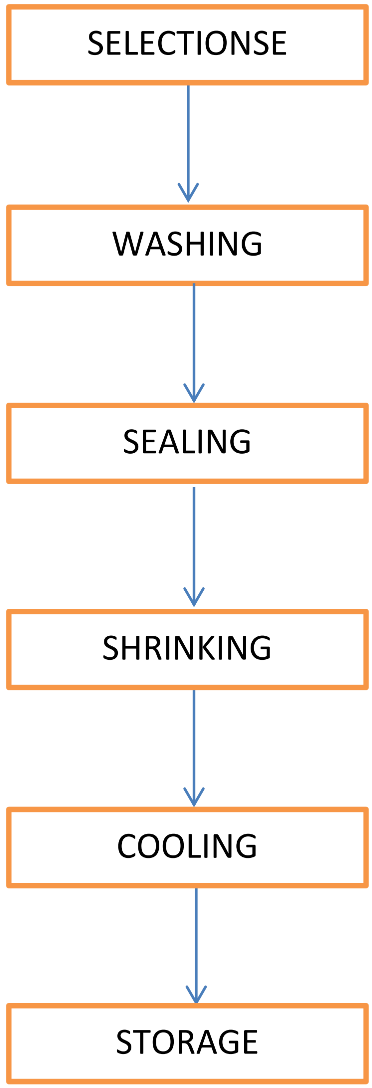

Figure 3.1 Flow chart for shrink packing of banana

The following were the test conditions:

1. Bananas kept under normal atmospheric conditions without any package (Control, C)
2. Bananas vacuum packed using LDPE 150 gauge film and stored in normal conditions(T1)
3. Bananas shrink packed with 90 micron polyethylene film and stored in normal conditions (T2)

Eight samples containing two bananas each were packed under the above test conditions. One of the samples stored under each test condition was opened in a periodic interval of 4 days and was left for further ripening. The various physic-chemical characteristics were determined on the day corresponding to unsealing.

3.5 Physico-chemical characteristics

The methods of estimating various quality attributes of banana for the study are briefly described below.

3.5.1 Physiological loss in weight

Fruits were weighed during storage daily with the help of an electronic balance. Percentage physiological loss in weight was calculated by the formulae given below.

$$\text{PLW (\%)} = \frac{\text{Loss of fresh weight x 100}}{\text{Initial weight}}$$

Loss of fresh weight = Initial weight-Final weight

3.5.2 Total soluble solids

Total soluble solid (TSS) was measured using a hand refractometer. Bananas were smashed well and filtered using muslin cloth. One or two drops of the clear sample were placed on the hand refractometer for TSS measurement. It was expressed in ° Brix.

Plate 3.3 Hand refractometer

3.5.3 External appearance

Colour was inspected visually as an index to the quality of banana.

The percentage of fruits spoilage due to fungal pathogens in different packaging methods of storage was calculated using the formulae

$$\text{Microbial spoilage (\%)} = \frac{\text{Area affected by fungal pathogens x100}}{\text{Total surface area}}$$

3.5.4 Total sugar

Total sugar was determined using Fehlings method (fssai, 2012).The reagents used were Fehling A, Fehling B, neutral lead acetate, Potassium oxalate solution and Methylene blue indicator. Weigh accurately 25gms of sample and transfer to 250ml volumetric flask. Add 10ml of neutral lead acetate solution and dilute to volume with water and filter. Transfer an aliquot of 25ml of clarified filterate to 500 ml volume flask containing about 100ml water. Add potassium oxalate in small amounts until there is no further precipitation. Make upto volume. Mix the solution well and filter through jatman No.1 filter paper. Transfer the filterate to a 50ml burette. Preliminary titration was performed by pipetting out 5ml each of fehling A and B into 250 ml conical flask. Mix and add about 10ml water. Heat the flask to boiling. Add 3 drops of methylene blue indicator. Continue the addition of solution drop wise until the blue colour disappears to a brick red end point. Note down the titre value.

Finally pipette 5ml each of Fehling A and B. Add sample solution about 2ml less than titre value of the preliminary titration. Heat the flasks to boiling within 3mins and complete the titration. Perform the titration duplicate and take the average. Calculate the reducing sugars as shown below.

$$\text{Reducing sugars (\%)} = \frac{\text{Dilution x Factor of Fehling (g) x 100}}{\text{Weight of sample x titre value}}$$

3.5.5 Textural attributes

These important textural parameters which affects the consumer acceptability of banana was determined using Texture Analyser (TAXT Plus, Stable Micro Systems). The instrument had a micro-processor regulated texture analysis system interfaced to a personal computer. The instrument consists of two separate modules; the test-bed and the control console (keyboard). Both are linked by a cable which route low voltage signal and power through it. The texture analyser measures force, distance and time and hence provide a three-dimensional product analysis. Forces may be measured to achieve set distances and distances may be measured to achieve set forces. The sample was kept on the flat platform of the instrument and was subjected to double compression by a cylindrical probe with 5 mm diameter. The test was conducted at a speed of 10 mm/s using 50 N load cell. The sample was allowed for a double compression of 40% with trigger force of 0.5 kg during which various textural parameters were determined. From the force deformation curve, the firmness or hardness (peak force), and toughness (area under the curve) were determined.

Plate 3.4Texture analyser

3.5.6 Sensory evaluation

Fruits were removed from storage after complete ripening and sensory evaluation was conducted on the corresponding day. A panel of 7 judges with good sensitivity and consistency were selected. The test involves individuals in isolated tasting condition under a standard light source. Descriptive sensory quality of ripe fruit viz., colour and appearance, texture (finger feel), taste flavour and overall quality were assessed by a panel of 7 judges. Judges were asked to access based on the 5 point scale as follows:

1 = poor

2= fair

3= good

4= very good

5=excellent

The scores marked by panellists were collected and an average was calculated for each parameter. These calculated averages were presented in the form of tables.

3.6 Cost Analysis

The cost of vacuum packaging and shrink packaging of banana were determined with suitable assumption using standard procedure. The cost analysis was undertaken in the month of January 2015 and the prevailing market rates of banana at that time were used for the study.

Results and discussions

CHAPTER 4

RESULTS AND DISCUSSIONS

The results obtained during the various observations made on the physico-chemical characteristics of banana during vacuum and shrink packaging studies are reported and discussions on the results obtained are given in this chapter.

4.1 External appearance

The external appearance is a major indicator of the ripening process. The change in colour and fungal infestation are the major changes in external appearance noted for banana. All the samples were inspected each day for any such change. Visual changes in colour were noted each day for the packaged samples and the control.

The ripening of banana kept as control was indicated by change in colour from green to yellow by the third day, and complete ripening was confirmed at the end of fourth day by the presence of black speckles over the bright yellowish peel. Vacuum packed banana retained the green colour even up to the 12th day after which they turned black. But the same was rejected due to fungal growth seen after 9th day. So, the packing was unsealed after the 9th day and ripening could be extended up to the12th day indicated by the yellow peels.

Shrink packed bananas shown prolonged freshness. They were more acceptable in terms of external appearance. There was no visible fungal growth throughout the period of study. The intensity of greenness in the peel was retained up to the 18th day and gradual change to greenish yellow was observed on the 19th day. Ripening was completed on 23rd day confirmed by the yellow peel with scattered black spots.

Plate 4.1 External appearance of C before and after ripening

Plate 4.2 External appearance of T1 before and after ripening

Plate 4.3 External appearance of T2 before and after ripening

Storage days	Control(C)	T1	T2
0	0	0	0
4	0	0	0
8	7.6	0	0
13	36.5	2.1	0
18	100	39.8	0
23	-	85.2	0
28	-	-	11.2

Table 4.1 Result of microbial spoilage on samples (%)

The change in colour took a prolonged period of time in case of shrink packages samples. This was expected to be due to the extended time obtained for the conversion of chlorophyll. Also physiological senescence is said to delay due to tight shrinking using heating and blowing. In case of extend of microbial spoilage, shrink packaged ones were more resistant as the degree of microbial spread was reduced as a result of heating.

4.2 Physiological loss in weight

Data on loss in weight due to transpiration and respiration processes indicated that banana fruits kept in open condition (without packaging) lost weight up to 7.5% on the 4th day of storage. Vacuum packaged and shrink packaged fruits showed an increase in PLW ranging from 5-6% and 7-9% respectively.

	0th	4th	8th	13th	18th	23rd
C	0	7.5				
T1	0	2.7	5			

T2	0	0.66	1.3	5.8	6.7	7

Table 4.2 Physiological loss of sample weights (%)

The higher weight loss (7.5%) in C after 4 days of storage at ambient conditions can be attributed to faster rate of respiration. Whereas shrink wrapped samples registered the lowest mean PLW (7%) even after 23 days of storage at ambient conditions. This was in conformity with the trend in weight loss obtained by Dhall et al, (2012)

4.3 Total soluble solids

The result exhibited that TSS content developed in continuous stream with the expansion of storage period. High significant variation as observed in TSS content between two different packages at different days after storage. The TSS of different samples for different storage period are shown below in table.

Mode of pack	0^{th}	4^{th}	5^{th}	12^{th}	18^{th}	23^{rd}	28^{th}
C	5.5	13.6					
T1	5.4	6.05	6.95	18.5			
T2	5	5.3	5.5	7.3	24.6	25.2	19

Table 4.3 TSS of samples (°Brix)

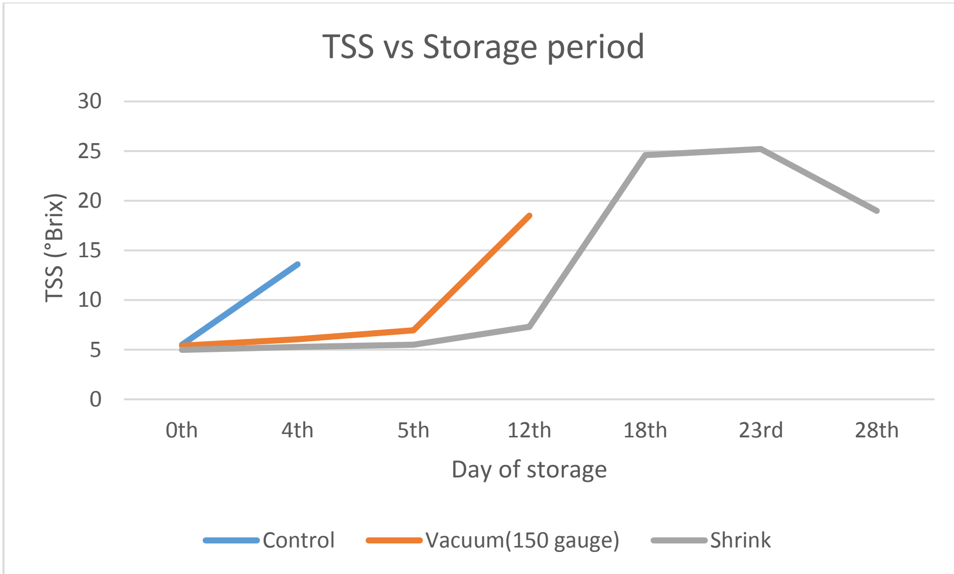

Figure 4.1 TSS of samples

From the initial to 4th day the TSS increased only to 16% for control. But in case of vacuum packaged samples there was a gradual increase up to 25% on the 12th day whereas tremendous increase in TSS up to 35% from the 0th to 23rd day was observed for shrink packaged samples.at different days of storage results showed that TSS accumulation increase with the increase of storage duration. It also explored that TSS content was hastily grown up from control to shrink.

It also revealed that TSS accumulation is strongly related to ripening and it caused falling off owing to decaying.TSS content was found to increase during advancing stages of ripening and storage for shrink packaged banana was possibly due to extended period of time obtained for hydrolysis of starch into sugar. However due to utilisation of sugars in respiration and degradation of total soluble substances because of prolonged storage are possible reasons for the decrease in TSS.

4.4 Textural attributes

In case of control, rapid decline in toughness and firmness (shear force) values were recorded up to 4.82 Kg Sec and 22.44 N respectively in 4 days.

Vacuum packaged samples showed an increased value of both toughness and firmness by 8th day which gradually decreased to 6.58Kg sec and 43.61 N on the 12th day after unsealing the package.

Gradual decrease was observed in case of shrink packaged samples as 2.74 Kg Sec and 10.97 N respectively for toughness and firmness. It was thus observed that softening of flesh occurs along with ripening of fruits.

Mode of packaging	Day	Toughness (Kg Sec)	Firmness (N)
C	1	13.59	49.58
	2	11.24	47.82
	3	6.54	33.81
	4	4.82	22.44
T1	4	17.35	53.8
	8	18.36	63.48
	12	6.58	43.61
T2	4	15.15	45.18
	8	11.36	43.8
	12	7.88	31.46
	18	5.45	35.77
	23	3.94	21.46
	28	2.74	10.97

Table 4.4 Result of textural analysis on samples

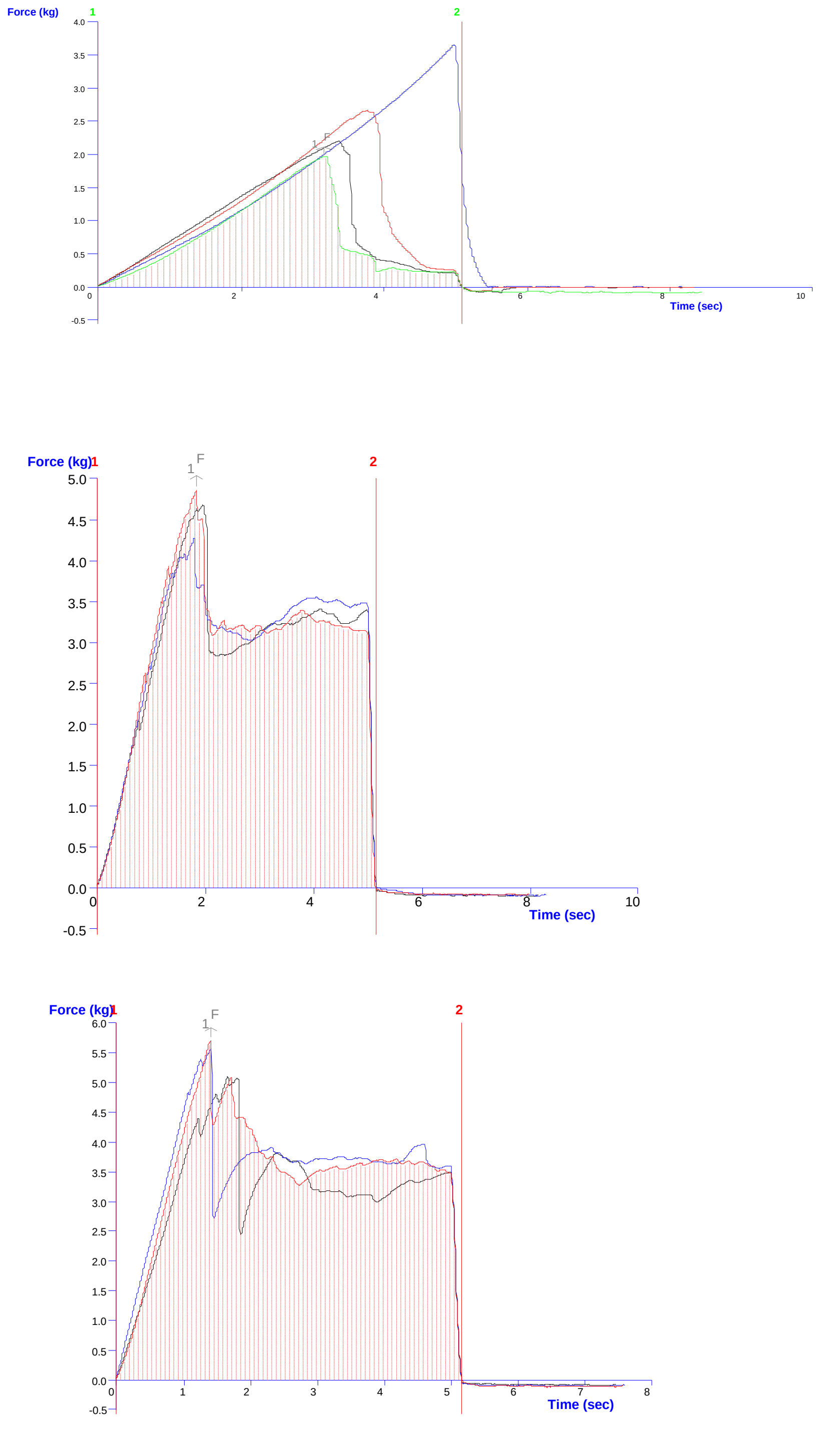

Figure 4.2 Result of texture analysis on C, T1 and T2 on 4th day

4.5 Total sugar

The calculated values of total sugars for the three different samples after ripening are given in table below.

Samples	Reducing Sugar (%)
C	4.5
T1	4.9
T2	5.1

Table 4.5 Percentage of reducing sugars of samples

Shrink wrapped bananas showed the highest percentage of reducing sugars (5.1%) when compared to the control and vacuum packed samples.

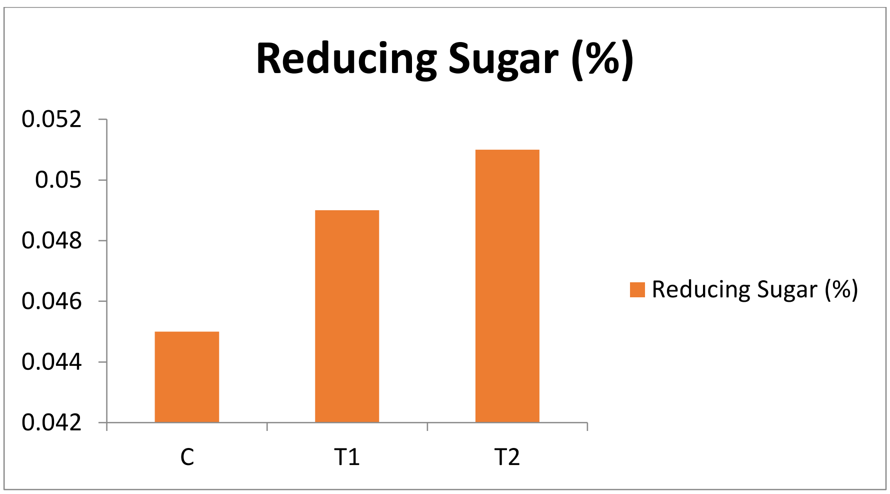

Figure 4.3 Reducing sugars (%) of samples after ripening

The increase in reducing sugars could be due to increased hydrolysis of starch into sugar with extended period during ripening. Similar were the results obtained by Adao et al. (2005) in changes during ripening of 'Prata' banana.

4.6 Sensory evaluation

Sensory evaluation indicated that bananas in normal air ripened normally without any significant difference in eating quality.

	Flavour and taste	Texture	Colour and Appearance	Overall quality	Total
C	3.8	3.9	4.3	4.2	16.2
T1	2.4	2.3	2.8	2.3	9.8
T2	4.2	4.9	4.5	4.5	**18.1**

Table 4.6 Result of sensory analysis on samples

The result of organoleptic evaluation from table 4.6 shows that the sample T2 is the best with total score of 18.1.

The best organoleptic results were obtained for shrink packaged samples may be because the flavour and taste were improved due to increased sweetness as a result of more conversion of starch into sugar. The vacuum packaged ones showed very less overall acceptance may be due to the loss of chewability developed due to rigid texture. The bright colour exhibited due to prolonged storage also made shrink packaged samples more acceptable in terms of colour.

4.7 Cost Analysis

The cost analysis was performed to determine the packaging costs of vacuum packaging and shrink packaging of banana and also the profitability of the project.The cost of vacuum packaging was Rs 3.12 per kg and a profit of 18.7% on investment could be expected by this method. For shrink packaged banana the cost of packaging per kg was Rs 2.31 and a profit of 22.48% on investment could be expected by this method. The results of cost analysis revealed that shrink packaging is a more economical packaging method when compared to vacuum packaging .The details are given in Appendix II.

Summary and conclusions

CHAPTER 5

SUMMARY AND CONCLUSIONS

Banana fruits are highly perishable and harvested banana crop ripen within 4-5 days after harvest under the ambient conditions in Kerala. The effect of vacuum and shrink packaging in extending the shelf life of green banana were studied under ambient conditions (35 ^{0}C and 80% RH). In general, banana samples shown extended shelf life when both vacuum and shrink packed.

It was found that the samples kept as control under ambient conditions did not last longer than 6 days and vacuum packaged did not last more than 15 days whereas that which was shrink wrapped showed a greater shelf life of 28 days (nearly one month). Ripening was analysed based on the visual changes in colour. The yellow colour which was ideal for consumption was achieved for shrink wrapped samples at 23rd day and, after 28days, brown specks started to appear on these samples. Hence the best results can be expected between 23rd day and 28th day of storage.

The total soluble solids in º Brix showed a gradual increase along with ripening and then decreased suddenly indicating spoilage .The increase in TSS was possibly due to extended period of time obtained for hydrolysis of starch into sugar. However due to utilisation of sugars in respiration and degradation of total soluble substances because of prolonged storage are possible reasons for the decrease in TSS. Analysis of total sugars and sensory evaluation were also carried out during texture analysis. Firmness and toughness showed a gradual decline with the increase in storage intervals. The softening of flesh during storage could be due to the degradation of soluble pectin as a result of various enzymatic activities in the sample. Sensory analysis and percentage of total sugars also proved that shrink packaged samples are the most acceptable ones.

The cost analysis was performed to determine the packaging costs of vacuum packaging and shrink packaging of banana and also to ascertain the profitability of the project on a commercial basis. It was found that the cost of vacuum packaging was Rs 3.12 per kg and a profit of 18.7% on investment could be expected by this method. For shrink packaged banana the cost of packaging per kg banana was Rs 2.31 and a profit of 22.48% on investment could be expected by this method.

Observing the results of various analyses conducted, it was concluded that the sample T2 (shrink packaged) proved to be the best in terms of PLW, microbial activity, TSS, total sugars, colour, texture and organoleptic characteristics. In the present study, owing to the physical injuries during harvesting and transportation, the shelf life extension was limited to one month. Hence further research work can be undertaken for asserting the shelf life of banana conclusively.

Hence it can be concluded that shrink packaging is more appropriate for packing banana for increasing its shelf life and also for earning more profit.

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CHAPTER 6

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Appendices

APPENDIX I

Sensory evaluation card

	Flavour and taste	**Texture**	**Colour and Appearance**	**Overall quality**	**Total**
C					
T1					
T2					

1 = poor; 2= fair; 3= good; 4= very good; 5=excellent

Name of examiner: Signature of the examiner:

Date:

APPENDIX II

Cost analysis

The cost of vacuum packaging 1 Kg of banana is worked out on the basis of following assumptions

1. The capacity of small scale unit is 250 Kg of raw banana per day of 6 hours.

2. The unit will work 1800 hours in a year.

3. Total annual packaging of the unit is 75000 Kg

4. Cost of packaging material per piece Rs. 1

5. Time taken for packing I Kg of banana is 1.5 minutes.

6. Life of the machinery is four years

7. One labour @ Rs 400 per day is employed.

8. Electricity consumption of the machinery is one unit per hour.

9. Transportation cost of banana@ Rs 1 per kg.

Calculations:

Cost of packaging setup	40000
Fixed cost	
Interest on capital cost at the rate of 15%	6000
Depreciation at 25%	10000
Repair and maintenance at 10%	4000
Total fixed cost	20000

Total cost/Kg = 20000/75000 = 0.266

≃ Rs.0.27/Kg

Operation cost

Cost of raw material = 250/(6*1800*35)

= 2625000

Total labour charge = 400 / 6 = Rs 66.7 per hour

Hourly packing = 60/1.5 =40 kg

Per Kg labour cost = 66.7/40 = Rs 1.67

Cost of packaging material for 1 kg of banana = Rs 1

Transportation cost per kg of banana = Rs 1

Cost of electricity @ Rs 7 per unit, electricity cost per kg is 7/40 =Rs 0.175

Total fixed cost = 0.27

Total variable cost = 1.67 +1 + 1+ 0.175 = Rs 3.85

Hence total packaging and transporting cost = Rs 4.12

Whole sale rate of banana @ 22 per kg

Retail rate of banana@ 30 per kg

Hence cost of shrink packaged banana = 22 + 4.12 = Rs 26.12

Selling price Rs 31 per kg for packaged banana to retailers (MRP Rs 35 per kg)

Profit per kg of banana = 31- 25.12/ 26.12 = Rs 4.88 or 18.7%

The cost of shrink packaging 1 Kg of banana is worked out on the basis of following assumptions

1. The capacity of small scale unit is 720 Kg of raw banana per day of 6 hours.

2. The unit will work1800 hours in a year.

3. Total annual packaging of the unit is 216000 Kg

4. Cost of packaging material per Kg is Rs.1.5

5. Time taken for packing I Kg of banana is 0.5 minutes.

6. Life of the machinery is four years

7. One labour @ Rs 400 per day is employed.

8. Electricity consumption of the machinery is one unit per hour.

9. Transportation cost of banana@ Rs 1 per kg

Calculations:

Cost of packaging setup	45000
Fixed cost	
Interest on capital cost at the rate of 15%	6750
Depreciation at 25%	11250
Repair and maintenance at 10%	4500
Total fixed cost	22500

Total cost/Kg = 22500/216000 = Rs 0.104 per kg

Operation cost

Cost of Raw material = 720/ (6*1800*35) = 7560000

Total labour charge = 400 / 6 = Rs 66.7 per hour

Hourly packing = 60/0.5 =120 kg

Per Kg labour cost = 66.7/120 = Rs 0.56

Cost of packaging material per kg banana = Rs 1.5

Cost of electricity @ Rs 7 per unit, electricity cost per kg is 7/120=Rs 0.175 Transportation cost per kg of banana = Rs 1

Total variable /operating cost = Rs 3.24 per kg

Total cost per kg of banana = 0.07 + 3.24 = Rs 3.31

Whole sale rate of banana @ 22 per kg

Retail rate of banana@ 30 per kg

Hence cost of shrink packaged banana = 22 + 2.31 = Rs 24.31

Selling price Rs 31 per kg

Profit per kg = 31- 25.31= Rs 5.69 or 22.48%

EFFECT OF VACUUM AND SHRINK PACKAGING ON SHELF LIFE OF BANANA (*Musa paradisica*)

By

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SUNISHA K.

ABSTRACT

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In

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ABSTRACT

Banana (*Musa paradisica*) is an edible fruit valued worldwide for its flavour, nutritional value, and availability throughout the year. They are harvested green and begin ripening as soon as the banana stem is cut from the plant. This results in huge post-harvest losses. Loss during distribution is also a major problem banana encounters.

In order to reduce these losses, use of a suitable packaging method for wrapping the fruit is found to be a solution. Food packaging is a system by which a fresh produce or processed product will reach from the production centre to the ultimate consumer in safe and sound condition at an affordable price. It works on the principle that if CO_2 in the atmosphere is augmented, the respiration rate and storage life can be extended

Here various samples of bananas were vacuum and shrink packaged and stored in ambient conditions to study their effect on shelf life extension. Various Physico chemical parameters were also analysed as a part of study. In general peel colour changed with time, fruit firmness and toughness decreased progressively and increase in total sugars and TSS were observed. Of these, the best results and a maximum shelf life of 28 days were obtained for shrink packaged samples. Evaluations of organoleptic properties were also performed by sensory analysis.