EVALUATION OF BANANA (*Musa* spp.) VARIETIES FOR THE DEVELOPMENT OF INTERMEDIATE MOISTURE FRUIT (IMF)

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KERALA, INDIA

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DEPARTMENT POST HARVEST TECHNOLOGY

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KERALA, INDIA

2022

DECLARATION

I, hereby declare that this thesis entitled **"Evaluation of banana (*Musa* spp.) varieties for the development of Intermediate Moisture Fruit (IMF)"** 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.

Vellanikkara
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CERTIFICATE

Certified that this thesis entitled **"Evaluation of banana (*Musa* spp.) varieties for the development of Intermediate Moisture Fruit (IMF)"** is a bonafide record of research work done independently by Ms. Thatayaone Malikongwa (2018-22-011) 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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LIST OF ABBREVIATIONS

^{o}C	: degree Celsius
µg	: microgram
mg	: milligram
g	: gram
kg	: kilogram
mM	: milli Molar
nm	: nanometre
ml	: millimetre
l	: Litre
ppm	: parts per million
h	: hour
%	: percentage
Eq.	: equivalent
et al.	: coworkers
CD	: critical difference
cfu	: colonies forming unit
FW	: Fresh weight
DW	: Dry weight
DM	: Dry matter

INTRODUCTION

1. INTRODUCTION

Banana (*Musa* spp.) is the second most important fruit crop in India, which belongs to the family *Musaceae* of the Zingiberales order. Bananas are cultivated in the tropical and subtropical regions of the world. India ranks first in terms of the area and production of bananas, contributing around 15 per cent of the global area under banana at 898 000 hectares and 29 per cent of the world's production at 31, 747, 000 metric tonnes (GOK, 2020; Nayak *et al.*, 2018). Kerala, a state in India, is blessed with a wide array of banana varieties which are grown in an area of 52, 898.61 hectares with a production of 424948.07 tonnes. The important varieties grown in Kerala are Nendran, Palayan Kodan (Poovan), Njali poovan, Rasthali, Red Banana, and Robusta, which are available for local and exportation needs (GOK, 2020).

Nearly 90 per cent of banana production is consumed primarily in banana producing areas, particularly in Asian, Latin American, and African countries (Edward *et al*., 2020).The food value of bananas has since been cherished due to their ample proportion of nutritive components. The banana is rich in caloric value, ranging from 67 to 137 calories per 100g. It is also rich in carbohydrates (27%), protein (1.2%), a significant amount of potassium (10%), phosphorus (290.0 parts per million) and calcium (80.0 parts per million). The fruit is free from fat and cholesterol and rich in fibre, so it is easily digested (KAU, 1996).

The banana pulp has several uses, such as being consumed as a table fruit and being substituted for vegetables like potatoes during meal preparations. The pulp (puree), smoothies, wine, jams, chips, fruit leathers, and powder are just a few of the value-added products that may be made from the fruit. Other than food production, bananas are used to treat high blood pressure, arthritis, gastroenteritis, and kidney problems (GOIN, 2015).

The majority of bananas in the wild are subjected to widespread exploitation and destruction, which has resulted in their extinction in their native habitat. Furthermore, the diversity of bananas (*Musa* spp.*)* in different places makes it difficult to identify and classify banana varieties correctly (Pachuau *et al*., 2014). To minimize confusion, some 30 banana species have been identified using scientific and local names, which contribute considerably to the commercial and nutritional value of bananas for millions of people throughout the world (FAO, 2003).

A characterization and nomenclature system have been developed by Simmonds and Shepherd (1955), which is based on ploidy level and morphological characters to describe the edible cultivated bananas. *Musa acuminata* and *Musa balbisiana* were designated as genotypes AA and BB, respectively, both being diploid species. These diploids species gave rise to the present edible and seedless banana varieties with different combinations of diploid, triploid, and tetraploid genomes such as AA, AB, AAA, BBB, AAB, ABB, and AAAB as a result of intra and inter-specific hybridization (Singh *et al*., 2016).

The genomic constitution of each variety imparts a distinctive trait such as colour, appearance, flavour, texture, and nutritional value, which can be used to determine its suitability for a specific purpose, especially during food processing. Although food processing is recognised as a 'sunrise industry' in India, accounting for a mere 3.6 per cent of GDP, a significant proportion of fresh bananas (5.8–18.10 %) has been reported going to waste. The processing, preservation, and value-addition of these wasted bananas have the potential to diversify into a variety of products that will appeal to a wide range of consumers (Srivastava and Kumar, 2002).

As a simple, affordable, and convenient technology used for processing, preservation, and value-addition, dehydration has the primary objective of lowering moisture levels and limiting microbial development as well as enzyme activities that can increase the rate of degradation. Dehydration causes a variety of quality deteriorations, including shrinkage owing to cell collapse, enzymatic browning, and loss of flavour, texture, and nutritional content, as well as rehydration difficulties.

To minimize limitations of conventional dehydration, drying by osmosis (osmodehydration) has gained attention due to its added advantages over other standard dehydration techniques because it preserves the sensory and nutritional characteristics of food. During osmodehydration of fruits, there is a partial removal of water from fruit tissues by osmosis when the fruit pieces are placed in a hypertonic solution. The fruit is reduced to about 50 per cent of its original weight, after which it is drained and either frozen or dried further into a product referred to as Intermediate Moisture (IM) fruit (Srilakshmi, 2018).

Intermediate Moisture Fruit (IMF) has a water activity (a_w) of 0.65-0.90 (15–40% moisture) as a result of slight thermal treatment, pH reduction, and the addition

of humectants and preservatives, all within the context of hurdle technology for food preservation (FAO, 2003). A thorough knowledge of banana varieties by evaluating and exploring their suitability in the development of IMF is a pre-requisite for prolonging the commodity's shelf life, reducing post-harvest losses as well as commercial utilization of the commodity.

Hence, a study was conducted which is expected to increase the income of farmers through preservation and value addition of banana fruits, improve the market efficiency of the banana industry, and strategize on the solution to reduce environmental pollution caused by the wasted produce. In this context, the present study was taken up with the following objectives:

1. Characterization of banana varieties for horticultural and biochemical traits.
2. Evaluation of osmotic agents on the quality of Intermediate Moisture (IM) banana.
3. Standardization of fruit to osmotic solution ratio and duration of immersion on quality of IM banana.
4. Study on packaging materials and storage temperature on quality of IM banana.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Bananas and plantains are monocotyledonous gigantic herbs in the Musaceae (Zingiberales) group that are widely dispersed throughout the tropical and subtropical continents. With an estimated production of 106 million tonnes, bananas are the world's fourth most significant crop after rice, wheat, and maize (Aurore *et al*., 2009; Bakry *et al*., 2009).

Bananas are grown in more than 120 countries, providing a vital food source and ensuring food security for over 400 million people (Voora *et al.,* 2020). Due to abundant vegetative reproduction and the natural occurrence of many hybrids, over a thousand banana cultivars or landraces are recognized globally, while over 50 species within the genus *Musa* remain unresolved (Heslop-Harrison and Shwarcher, 2007). Over a thousand banana cultivars or landraces worldwide are recognized and over 50 species within the genus *Musa* remain unresolved due to widespread vegetative reproduction and natural occurrence of many hybrids (Heslop-Harrison and Shwarcher, 2007). Over 30 banana species have been recognized, with scientific and native names given to avoid confusion (FAO, 2003). Simmonds and Shepherd (1955) devised the most widely used nomenclature scheme for edible cultivated bananas, which is based on ploidy level and morphological features.

2.1 Characterization of banana (*Musa* spp.*)* varieties

Ploidy and genomic constitution have been used to determine plant and fruit morphology since the 1940s. The International Network for the Improvement of Banana and Plantain (INIBAP) has created a collection of 119 agro-morphological descriptors based on morphological traits described by the Musa Information System (MGIS). Diagnostic genomic traits of two wild diploids, *Musa acuminata* (AA) and *Musa balbisiana* (BB) heavily influence these characteristics (KAU, 1996).

Several researchers have documented that interspecific and intraspecific hybridization between these two wild species resulted in seedless and parthenocarpic fruits of today's cultivated banana varieties of diploids (2n = 2x = 22), triploids (2n = 3x = 33), and tetraploids (2n = 4x = 44). These bananas have a diverse genomic constitution, with AA and AB being common for diploid kinds, AAA, AAB, and

ABB for triploids, and a genomic constitution of AAAA, AAAB, AABB, and ABBB for tetraploids. Despite the broad variety of banana varieties produced in India, the subcontinent is a centre of genetic diversity for AA, AB, AAA, AAB, and ABB clones (Hazarika *et al*., 2014).

2.1.1 AA genome

KAU (1996) claim that the AA genome is made up of diploid types with considerable morphological variability that are wild, semi-wild, or parthenocapic. They're not as hardy as triploid cultivars, but they produce high-quality fruit with a very sweet flavour. PisangLilin, Sikuzani, Namrai, Matti, Kadalli, Sannachenkadali, Tongat, and Pisang Seribu are important varieties of this dominating genome in South India, while Sannachenkadali's physicochemical qualities are similar to *Musa balbisiana*.

Perrier *et al.* (2019) conducted a study on the morphological variability of East African banana cultivars belonging to the same AA genetic group and discovered significant morphological variability among cultivars belonging to the same AA genetic group. Fruits from the same AA genetic group but divided into subgroups, namely Mchare and Sucrier, were discovered to be distinct. The Mchare subgroup was reported to be comparable to the plantain subgroup in the triploids, which are sub horizontal to pendulous bunches bearing fruits with marked ridges and a pronounced bottlenecked apex, forming tightly packed bunches, despite having small bearing fruits like other fruits of the AA genome.

Pisang Lilin is a well-known parthenocarpic cultivar from the AA genomic group that has been used for genetic improvement of banana varieties. According to Carvalho-Santos *et al.* (2019), the most preferred characteristics of Pisang Lilin are its morphological structures, particularly its short height and thick pseudostem. These morphological traits are used to improve the plant's vigour, productivity, and fruit sensory profile, all of which are in line with market demand.

Eighty-four morphological aspects of dessert bananas were described using Biodiversity International descriptors by Onyango *et al.* (2011). Muraru AA is reported to have a moderate, mildly tasty, or bland flavour, unlike the sweet fruits of

the AA subgroup. They also mentioned a thick peel and a firm texture, which matched the AAA genetic group.

2.1.2 AB genome

Neypoovan (AB) was described by Prem *et al.* (2019) as the best diploid cultivar under commercial production in South India, with dark green fruits that mature to golden yellow. They went on to characterize the fruit as fragrant, delicious, firm, and better keeping qualities compared to other varieties cultivated in Kerala.

Njalipoovan of the AB genome was described by Anu *et al.* (2019) as a South Indian banana variety having straight-shaped fruits with green-coloured peel that turns yellow when ripe. They also characterized the fruit pulp as yellow at maturity, with a soft, sweet flavour.

The nutritional composition of three banana cultivars in India, Njalipoovan (AB), Robusta (AAA), and Nendran (AAB), was examined by Kookal and Thimmaiah (2018). They discovered that among the selected cultivars cultivated, Njalipoovan of the AB group had the highest nutritional values. This came after biochemical composition examination of fruits, which revealed a range of values of 1.55-2.22 mg/100g total ash, 2.00–4.95 g/100g total protein, and 37.50–43.80 g/100g total sugars, with high values in Njalipoovan. They also found total fat levels ranging from 0.66 to 2.59 per cent, with Njalipoovan having the lowest fat content.

Nair *et al.* (2016) found that the Kunnan (AB) variety has high values for carbohydrates and proteins of 94.73 g/ml and 72.3 g/ml, respectively, compared to low values for carbohydrates (81.3 g/ml) and proteins (67.3 g/ml) in the variety Nendran (AAB). Kunnan was recommended for use as infant food due to its high nutritional value.

2.1.3 AAA genome

According to Hazarika *et al*. (2014), the AAA genomic group has some of the most productive clones, which are mostly represented by Cavendish, Gros Michel, and Red banana. Because of its exceptional tolerance to wind and diseases like

Sigatoka leaf spot and Fusarium wilt, Grand Naine and Robusta are key clones of the Cavendish subgroup that are replacing Gros Michel.

The AAA genome has two main subgroups: Gros Michel and Cavendish Gros Michel (AAA) subgroup is marked by heavy bunches with broad and thick skin that become dull yellow at maturity, while Cavendish (AAA) subgroup is distinguished by long, thin, short-pedicolate, bottlenecked and becoming yellow upon ripening. Both fruits have a delicious pulp with a sweet flavour (Hazarika *et al*., 2014).

Gilbert *et al*. (2009) investigated the morphological and compositional characteristics of 23 edible farmed cultivars. In comparison to the range of values indicated for starch content (74.2–88.2%) and pH (4.8–6.2), they reported intermediate nutritional values for the AAA genome. However, there was no difference in the nutritional composition of different varieties in terms of proteins, total soluble sugars, and crude fiber, where values of 3.2, 1.7, and 3 per cent were reported, respectively.

Vagas and Sandoval (2005) studied the horticultural and biochemical characteristics of AAA cultivar Yangambikm5 and concluded that its high bunch weight was due to a higher quantity of fruits. Although small in size, fruits of the Yangambi km5 variety were reported to have a slightly acidic flavour, with a soluble content of 18.50^{o}Brix and a fruit flesh firmness of 4.40N. They reported this variety as being hardy due to its total and functional roots as well as its resistance to insect pests such as nematodes and weevils.

2.1.4 AAB genome

The AAB genome comprises 12 internationally recognized subgroups, eight of which have been identified in India. Plantains are one of the most important subgroups of the AAB genetic group, accounting for 23% of global banana production (Hazarika *et al*., 2014). French plantain is a prominent subgroup of plantain, with Nendran being the most common variety, with its origin in South India.

According to Anu *et al.* (2019), red banana (AAB) has an asymmetrical bunch shape that is nearly straight, with fruits that are straight at the distal part. The fruits are said to have a pink peel that matures to a reddish-purplish colour, and the

fruit pulp is the colour of ivory, turning yellow with a sweet and acidic taste as it matures.

Kumar *et al*. (2019) measured the fruit weight, length, and circumference of the variety Nendran at 140 and 225 g, 19.00 and 25.00 cm, and 13.00 and 16.00 cm, respectively. Nendran is thought to be a good source of crude protein (6–9%), crude fat (3.8–11%), total dietary fibre (43.2–49.7%), and natural bioactive compounds (carotenoids, quercetin derivatives, phenolic acids, and saponins). They suggested processing the fruit into new nutraceutical products.

Leyva *et al.* (2012) described AAB bananas of varieties Africa 1 and Mbindi as industrial varieties of superior fruit lengths, fruit weight, fruit diameter, fruit lengths, and dry matter compared to other varieties of diverse genomic groups, viz., AB, BB, AAA, ABB, AAAB, and AAAA. The fruits were reported to have maximum viscosity, showing promising properties for processing industries which are searching to improve the stability of products such as sauces and soups.

Gilbert *et al.* (2009) used radar charts with a score between 0 and 1 to synthesize morphological, physical, and chemical characteristics of the AAB genome of the plantain subgroup. High scores were recorded for titratable acidity (0.8), starch (0.78), and sucrose (0.7), while mineral nutrients (K, Ca) and total ash both scored 0.5. Lower scores were given for physical characteristics such as the number of fingers per bunch (0.5), bunch weight (0.4) and finger length (0.3). They recommended new prospects for value addition for these plantain varieties, which they believed are neglected.

2.1.5 ABB genome

According to morphological research conducted by Hapsari and Lestari (2016) on bananas from the ABB genetic group, Raja Bandung and Kepok have a cream to yellow colour when fully matured. They also discovered a strong link between the ABB group and *Musa balbisiana* rather than *Musa acuminata* in the varieties Raja Bandung and Kepok, which they attribute to the existence of two "B" genomes.

According to Hazarika *et al*. (2014), Karpooravalli is the most common variety of ABB group, which is distributed all over Southern India. The fruit has an

ash-coated golden peel and is frequently seeded with a delicious, yellow pulp of good keeping quality.

Ravi and Mustafa (2013) investigated nine South Indian banana cultivars and found substantial differences in physical attributes at the 90 per cent maturity stage. They discovered that Karpooravalli (ABB) (1.60) had a lower pulp to peel ratio indicating thinner peel than both cooking (1.97) and plantain banana (1.70) from ABB genome. Although Karpooravalli was classified as a dessert banana, it was found to have reducing sugars (0.78mg/g) which were comparable to those found in plantain Nendran (AAB) (0.80 mg/g), implying that their sweetness was comparable.

2.2 Status of banana and dehydration preservation

India is the world's largest producer of banana (*Musa* spp.), accounting for 25 per cent of global production (31, 747, 000 metric tonnes) on an area of 898, 000 ha (GOK, 2020).This production is not fully utilized for a variety of reasons, with significant post-harvest losses of bananas estimated at 20 to 80 per cent (Srivastava and Kumar, 2002; Farooq *et al.,* 2018).To prevent post-harvest losses, simple and cost-effective preservation techniques are implemented to ensure that the fruits are sold at a profit.

Dehydration is one of the simplest methods of preservation, with the benefits of enhanced shelf life and reduced fruit weight, which lowers handling and packaging costs. Dehydration by osmosis (osmotic dehydration) involves partial removal of water from fruit pieces by immersing it in a concentrated solution of humectants such as sugars, low molecular weight polyols, protein derivatives as well as mineral and organic salts (Carnovas *et al*., 2007).

Pretreatment activities such as blanching, in combination with other agents such as sodium sulphite, citric acid, potassium metabisulphite etc, have been shown to be useful in maintaining the physical and chemical characteristics of dehydrated products (Ranjan *et al*., 2014). After all the pre-treatment activities are done, the solution is drained off and the fruit is either frozen or dried to produce a shelf-stable product containing low water activity in the range of 0.65-0.90 (15-40% moisture), which is referred to as the Intermediate Moisture (IM) fruit.

2.3. Intermediate Moisture Food (IMF) and its related mass transfer kinetics terminologies

According to Barrett and Cardello (2012), a comprehensive definition of Intermediate Moisture Food (IMF) was established by a committee at the National Center for Coordination of Research of Food and Nutrition in France as;

'Food products of soft texture, subjected to one or more technological treatments, consumable without further preparation and with a shelf stability of several months, assured without thermal sterilization, nor freezing or refrigeration, but an adequate adjustment of their formulation: composition, pH, additives etc. and mainly a_w *which must be between 0.6 -0.8 (measured at* 25^oC*)'*.

Tortoe (2010) defined osmotic dehydration as a three-part process in which solutes diffuse into paranchymatous cells: intercellular volume, extracellular volume, and the cell membrane between the two volumes. Solute penetration causes a chemical potential difference across the cell membrane, which draws water out of the extracellular volume.

The solute may or may not penetrate the cell membrane and enter the intracellular volume, depending on its molecular weight. The solid flow from concentrated solution into the tissue causes solid gain, and the water flow out of the tissue into the osmotic solution causes water losses. These are two major simultaneous countercurrent flows during the osmotic process (Ahmed *et al*., 2016).

The movement of countercurrent flows in an osmotic process is described by kinetics of mass transfer, and terms such as water loss, solid gain, and weight loss are used to evaluate osmodehydration (Tortoe, 2010).

Rahman *et al.* (1996) defined water loss as the net water loss on an initial mass basis and solid gain as net solids (both soluble and insoluble) transported into the sample on an initial mass basis, while weight loss was defined as the net mass loss of the sample on an initial mass basis.

2.4 Osmodehydration - its effect on the quality of Intermediate Moisture (IM) products

Food, nowadays is designed to not only satisfy hunger and give essential nutrients, but also to avoid nutritional diseases and improve physical and mental health (Betoret *et al*., 2011). Osmotic dehydration is one of the most efficient techniques to deliver desired solutes into the porous structure of foods, allowing for the production of Intermediate Moisture (IM) fruits and vegetables. This procedure results in moderate fruit and vegetable processing and is known to affect the physical, nutritional, and sensory qualities of fruits and vegetables.

2.4.1 Effect of osmodehydration on the physical quality of IM fruits

Hossain *et al.* (2021) investigated the effect of osmotic dehydration on the quality of garcinia fruit using various osmotic solutions such as sucrose (10%), fructose (10%), and brine (2%) solutions. They discovered that treated garcinia samples dried quickly, with equilibrium moisture reaching within 12 hours of dehydration in a 55°C oven drier. With untreated garcinia fruit samples, equilibrium moisture was extended to 20 hours. They also stated that sucrose solution treated samples had the best visual appeal, owing to the modest (14.95) colour value changes compared to fructose (16.02) and brine (16.04), but untreated samples had an undesirable colour value change (20.06).

According to Nowacka *et al.* (2021), after one hour of osmotic dehydration, there is a gradual disconnection and breakdown of tissues, a change in the shape of cellular walls, and a loss of turgor pressure on horticultural crops such as kiwi, apples, potatoes, and carrots. These changes in the microstructure of the plant tissue are attributed to the bidirectional exchange that occurs during osmodehydration.

Gutierrez *et al.* (2019) used sucrose, sucrose- hibiscus solution and piquinchilli oleoresin as osmotic agents to study the effects of osmotic agents on apples. After 120 minutes of osmotic treatment, the osmotic agents were shown to have a similar ability to remove water, with water losses ranging from 0.36 to 0.4 g water g^{-1} fresh weight. Osmodehydration with piquinchilli oleoresin, on the other hand, yielded smaller (0.4 g solids g^{-1} fresh fruit) solid gains than sucrose and sucrose-hibiscus solution yielded similar (0.8 g solids g^{-1} fresh fruit) solid gains. They explained this discrepancy to the size of the starch molecules used in the emulsion, which block the pores on the apple's surface, lowering the impregnated solids to

favour water loss by diffusion. When it came to colour alteration, apple slices osmodehydrated in sucrose-hibiscus solution and piquinchilli oleoresin solutions favoured a reddish shade, but apple slices treated with sucrose exhibited a yellow tone.

Fasogbon *et al.* (2013) investigated the influence of two osmotic conditions, viz. 50°Brix sugar and 47:3 per cent w/w sugar/salt solutions, on the osmotic dehydration of pineapple slices. Pineapple slices immersed in sugar/salt solution exhibited a significantly greater water loss (21.28 to 31.86%) up to the fourth hour of osmotic dehydration when compared to those samples immersed in sugar solution (15.23 to 24.36%). Sugar/salt solution increased solid gain recording values by 60 per cent compared to 55 per cent for sugar solution alone.

Cortellino *et al*. (2011) used two separate osmotic solutions, pineapple juice and sucrose solution, both at a concentration of 50ºBrix and air drying temperatures of 70-75-80°C, to study osmotic dehydration and air drying of pineapple rings. There were differences in solid gain between pineapple juice (2.05 g/100g fresh weight) and sucrose solution (1.10g/100g fresh weight), as well as water loss of 3.76g/100g fresh weight and 2.22g/100g fresh weight, respectively. As evidenced by the *a** values, which ranged from -3 to 6, the colour was protected throughout drying by the osmotic pre-treatment in the sucrose solution. However, even at lower drying temperatures of 70 °C, where *a** values ranged from 2 to 15, osmodehydration with pineapple juice did not have the same protective effect, resulting in an increase in the browning phenomena.

Ferrari *et al*. (2010) correlated textural changes to the kinetics of mass transfer in melon pieces. They observed a direct relationship between softening, chemical, and enzymatic factors, such as protopectin dissolution, loss of cell turgor pressure, and degradation of the middle lamella induced by the osmotic dehydration process. They recorded high stress values in fresh (78.37 kPa) melon fruit pieces compared to fruit slices treated with sucrose solutions at 40°Brix (61.68 kPa) and 60°Brix (65.68 kPa). Fruits processed with sucrose solutions at 60°Brix, on the other hand, showed less stress breakage and a more rigid structure at a greater osmotic concentration than fruits processed with sucrose solutions at 40°Brix.

Riva *et al.* (2005) studied osmotic dehydration and air-dehydrated apricot cubes treated with 60% (w/w) sucrose or sorbitol syrup and supplemented with antioxidants. After 30 minutes of osmotic immersion, the solid gain in both sucrose and sobitol syrup was in the range of 0.66 and 0.80 g/100g of initial fresh weight, which doubled with time to a range of 1.65 and 1.97 g/100g of initial fresh weight. Even when the osmodehydration immersion duration was extended from 30 to 60 minutes, values below 25% were reported in the case of water loss.

Krokida *et al*. (2000) observed maximum deformation for banana and apple slices osmotically pretreated with glucose syrup and then air dried at 70ºC compared to untreated air dried fruits. Osmotically treated fruits had the highest deformation values (0.6 and 0.95%), while air-dried fruits had the lowest (0.3 and 0.85%). The increased maximum stress of osmotic dehydration was reported to prevent sample breaking due to solids uptake by the fruits, which causes the structure to be plastic.

3.1.2 Effect of osmodehydration on nutritional quality of IM fruits

Hossain *et al.* (2021) investigated the effects of osmotic pretreatment on the nutritional quality of taikor (*Garcinia pendunculata*) using several osmotic syrup solutions, such as sucrose (10%), fructose (10%), and brine (2%). They discovered that fruits treated with a 10 per cent sucrose solution had higher vitamin C levels (115.25 mg/100g) than untreated (105.20 mg/100g) fruits. Carotenoids were identified in higher concentrations in fruits immersed in a 10 per cent fructose solution (31.2 mg/100g) than in untreated fruits (22.39 mg/100g). Furthermore, they discovered that when the temperature of the osmotic solution is between 45 and 55ºC, taikor fruits prepared with fructose syrup can retain their natural nutritional composition, including Vitamin B1, B2, B3, beta-carotene, and vitamin C.

Gutierrez *et al*. (2019) studied the antioxidant properties of osmodehydrated apples using different solutions, *viz*., sucrose, sucrose+hibiscus, and chillie oleoresin. They found that in fruits treated with oleoresin, the maximum values for soluble phenol and monomeric anthocyanins were 13.86 and 0.11 mg g^{-1}, respectively. When hibiscus was supplemented with sucrose solution, the antioxidant properties of osmodehydrated apple fruits were found to be affected, as evidenced by fruits treated with sucrose+hibiscus solution having higher soluble phenol (10.13 mg g^{-1}) and

monomeric anthocyanins (0.07 mg g^{-1}) than fruits treated with sucrose alone, which had only a soluble phenol content of 5.64 mg g^{-1}.

Nowacka *et al*. (2019) investigated non-thermal sonification technologies as well as high hydrostatic pressure to speed up osmodehydration kinetics. The chemical properties of dehydrated cranberry fruits were improved by osmodehydration combined with ultrasonic pretreatment, according to the researchers. This was after they discovered that treated cranberry fruit had higher nutritional compositions, such as dry matter (28.40%), total soluble solids (41.50%), and colour value lightness (51.70%) when compared to blanched cranberry fruits treated as control samples, which recorded the nutritional values of 9.3, 1.2, and 17.3 percent, respectively. When pre-treating cranberry fruits with osmodehydration and pressure, a low pressure of 300 mmHg (40 kPa) was recommended during osmodehydration, which was proven to have a preservation impact on bioactive components. They found a high amount of phenols (1802 mg GAE/100 g d.m.) at this low pressure, compared to blanched material processed in the same osmotic medium, which had lower values (1465 mg GAE/100 g d.m.).

Torres *et al*. (2018) evaluated the effects of Intermediate Moisture (IM) andean berry (*Vaccinium meridionale*) consumption on overweight adults. Andean berry was osmotically treated with 70 per cent sucrose solution (1 fruit: 3 sucrose solution) for 24 hours at 80 rpm was followed by heat dehydration for 14 hours at 60°C. They found a significant ($p \leq 0.05$) reduction in diastolic blood pressure (10.00%), systolic blood pressure (6.00%), body mass index (1.70%), weight (2.00%) and waist circumference (4.10%) were observed in the participants who completed the study. However, a significant (≤0.001) increase in glycemia (6.90%) was observed, while the lipid profile was unaffected.

Mahomud *et al.* (2015) studied the nutrient content of intermediate moisture (IM) bananas produced by blanching, sulphiting, and osmodehydration with three different osmotic agents, viz., honey (72.00%), sugar (72.00%), and sugar+honey (1:1 ratio). They discovered that honey-treated banana slices had high nutritional content in terms of protein (3.08%) and ascorbic acid (4.27%) compared to other IM bananas subjected to sucrose solution or sucrose+honey. Low nutritional content was recorded

in fruits immersed in sugar solution, where values of 2.10, and 2.31 per cent were recorded for protein and ascorbic acid, respectively.

2.4.3 Effect of osmodehydration on organoleptic quality of IM fruits

Keerthisree *et al.* (2017) investigated the sensory properties of osmo-air dried banana slices of the variety Nendran with varying thicknesses (5 to 15mm) and shapes (longitudinal, round, and ring). They gave the highest scores to slices with a minimum thickness of 5 mm and a ring shape, while slices with a maximum thickness of 15 mm and a longitudinal shape received the lowest scores. Based on sensory attributes such as appearance, taste, colour, flavour, texture, taste, and overall acceptability, this observation was made with over 80% of the panel of judges all in agreement with the assigned scores.

Rizzolo *et al*. (2013) evaluated the subsurface and microstructure of apple rings treated with sucrose (60% w/w) solution and air dried at 80ºC by using X-ray computed tomography (X-CT) and subsurface structure by optical coherence tomography (OCT). The features of osmo-dried fruits were crispier, which is the most acceptable attribute among consumers. The crispiness of osmo-air dried apple rings was attributed to the loose surface features that have a large inclusion of air, whereas the untreated air dried apple rings were reported to have a dense surface feature that makes the penetration depth limited.

Ribeiro *et al.* (2016) evaluated the sensory quality of osmotic dehydration followed by convectional dehydration in hot air at 60°C for pear slices. A high score on the sensory attributes such as colour, flavour, texture, sweetness, and overall acceptability was recorded in fruit slices that were treated with osmotic dehydration in combination with convectional dehydration compared to untreated fruits that were conventionally dried.

Shi *et al*. (1996) made jam using osmotically treated fruits in sugar solution (60 to 65°Brix) and compared it to untreated strawberries. They discovered that when strawberry fruits were osmotically treated prior to jam manufacture, the jam had a better natural colour, flavour, and general acceptability than when the fruits were used fresh.

2.5 Factors that affect the mass transfer kinetics during osmodehydration

Mass transfer kinetics during osmotic dehydration is not a smooth sailing process; several variables are responsible for its accomplishment. The success of osmodehydration depends on pretreatments, the raw material characteristics, type of osmotic agent, fruit pieces to osmotic solution ratio, process duration, as well as temperature and concentration of the osmotic solution (Ahmed *et al*., 2016; Sonia *et al.,* 2015).

2.5.1 Pretreatments

Garcia *et al.* (2021) studied the effects of hot (98.3°C) water blanching of papaya pieces before osmodehydration. Blanching resulted in a decrease of total solids (9.33 kg/100 kg) of papaya samples compared to the respective fresh fruits (12.12 kg/100 kg) due to losses of soluble solids during thermal treatment. However, after osmodehydration treatment, the blanched (34.14 kg/100 kg) papaya pieces had higher total solids compared to the unblanched (28.25 kg/100 kg), which was attributed to disruption to the cellular structure during blanching.

Removal of epidermal tissue, size reduction of material up to 10mm, blanching, immersion of materials in osmotic agents in combination with other agents such as calcium chloride, ascorbic acid and potassium metabisulphite are reported not only used with increasing permeability of plant tissue and facilitating the osmotic dehydration, but also to improve the quality of product in terms of its physical, biochemical, microbiological and sensory characters (Sonia *et al*., 2015).

The effects of ascorbic acid (AA), salt solution, lemon juice, and honey pre-treatment on the drying kinetics and sensory characteristics of mango slices were investigated by Abano *et al.* (2013). Uniform slices of dimension (6.0 × 3.0 cm) were subjected to pretreatment of ascorbic acid (4.17 mg/mL), salt solution (0.011 g/mL), lemon juice (0.5 v/v) and honey (0.3 v/v) for 10 minutes. They reported high moisture in honey pretreated samples (20.09%), followed by untreated control samples (17.27%), salt solution (16.95%), and finally AA pretreated samples (11.91%). They attributed the high moisture content retention of honey to its hygroscopic nature, which when exposed to hot air slows down mass transfer within mango tissues. Low moisture content in AA pretreated samples was credited to the

leaching effect of ascorbic acid during osmodehydration, which made it easier for water to diffuse out, resulting in moisture loss and dehydration.

Tortoe *et al*. (2009) studied effect of agitation during osmodehydration using hypertonic solution (40-55%sucrose+0.5%NaCl) on mass transfer of two apple varieties (Golden Delicious and Cox), potato and banana. They observed an improvement of mass transfer within the first 30 minutes of osmotic dehydration in the presence of agitation for all plant materials. Agitation was reported to impact mass transfer characters by securing a large gradient at the product/solution interface, thereby promoting turbulence, which leads to higher rate of diffusion during the process. Furthermore, increased water loss at the expense of solid gain was observed because of slow diffusion of solute into the natural tissue.

Xiao *et al.* (2009) found that blanching pretreatment with both hot water blanching and steam water could decrease the drying rate during the development of sweet potato bars. Sweet potato bars subjected to hot water blanching and steam water blanching were both reported to be softer, homogenous, and compact, with no starch granules found on the surface. However, the samples subjected to citric acid pretreatment and those not subjected to pretreatment had large and not uniform pores and lots of starch granules on their surface. Due to its drying kinetics and quality attributes, steam water blanching was considered more suitable than hot water blanching and citric acid pretreatment for drying sweet potatoes.

Pan *et al*. (2008) reported that dipping bananas in a solution containing 10g/L ascorbic acid and 10g/L citric acid reduced shrinkage. For the undipped banana slices, they reported a 40% weight reduction of banana slices, whereas when banana slices were dipped, a 20% weight reduction was reported. They further reported improved product colour with the ascorbic and citric acid dips.

Zhu *et al.* (2007) discovered that dipping apple cubes in antioxidant solutions containing ascorbic acid, citric acid, and calcium chloride at various concentrations (0.10-1.50 %) for up to 10 minutes is necessary to slow down the enzymatic browning rate and preserve the colour on the surface of apple cubes**.**A combination of the two, with either citric acid (0.20-0.40%), ascorbic acid (0.50-1.50%), or calcium chloride (0.10-1.50%), was recommended.

When hot steam was blasted for two minutes before dehydration, Krokida *et al.* (2000) found that enzymatic browning was minimized and the colour of banana, apple, potato, and carrot slices improved. In contrast to the benefits claimed for blanching, Dandamrongrak *et al.* (2002) found that hot water blanching failed to reduce the drying rates and drying times of banana slices.

2.5.2 Raw material characters

Variety, raw material maturity, and geometry (size, shape, and thickness) are the key factors that influence mass kinetics characters. To achieve optimal mass transfer kinetics, Ahmed *et al*. (2016), Sonia *et al*. (2015), and Tortoe (2010) recommended fully ripe and not over-mature fruits with a thickness of less than ten millimetres.

Archana and Lekshmi (2019) used sucrose solution as an osmotic solution to study the effects of process variables on mass transfer characteristics on a ripe Red Banana sliced into three shapes: ring, round, and pieces. They reported varying mass transfer characteristics depending on the shape. Osmodehydrated Red Banana chunks (0.80) had the highest water loss to solid gain ratio, followed by osmodehydrated round (0.52) shaped Red Banana, which were not substantially different from ring-shaped (0.49) shaped Red Banana slices. Therefore, among the different shapes under study, they recommended chunk-shaped pieces for optimum mass transfer characteristics.

Patil *et al.* (2013) tested the suitability of seven ripe banana cultivars for banana crisps made with a 70ºBrix sugar solution, including Grand Naine, Rajapuri, Yangambikm5, Monthan, Yalakkibale, Kothia, and Bluggoe. They suggested using Yalakkibale for banana crisps because of its superior quality qualities, including the highest crisp recovery (57.49%), lowest dehydration ratio (1.74), and lowest moisture content (2.83%). The other observed varieties recorded the physico-chemical characteristics of banana chips, such as crisp recovery (43.00 to 55.93%), rehydration ratio (1.87 to 2.23), and high moisture content (from 4.85 to 6.19%), which were inferior to the banana crisp of variety Yalakkibale. Despite the fact that Yalakkibale was said to have a healthy quality crisp because of its excellent physicochemical features, Grand Naine had a high total sugar content (64.79%), which was related to

its varietal sugar composition at the time of harvest, and the lowest (52.72%) sugar was recorded in the variety Kothia.

Moura *et al*. (2005) investigated the impact of initial tissue qualities on the mass transfer phenomena in Gala, Gold, and Fuji apple cultivars sliced into 10mm cubes and immersed in sucrose solution (50% w/w) at 30ºC. Variety Gala had the highest (0.90 g/g.gi.dm) value of solid gain and variety Gold had the lowest (0.74 g/dm/g.gi.dm). In the first hour of osmotic pretreatment, differences in weight loss were noticed, with variety Gold showing the highest (70%) total weight decrease, while Gala and Fuji both reported a weight reduction of roughly 50 percent. They attributed the discrepancies in mass transfer within the same species to variations in cell structural arrangement among apple varieties.

2.5.3 Types of osmotic agent used

Sethi and Kaur (2019) investigated the physicochemical parameters of osmodehydration followed by hot air (60°C) drying of pineapple cubes, using sucrose, honey, and honey-sucrose solutions as osmotic agents. They found that pineapple sample cubes treated with honey sucrose solution at an osmotic solution temperature of 50°C had better rehydration characteristics and the lowest moisture content. Organoleptic evaluation of all the samples revealed that the sample comprising both sucrose and honey (50ºC) had the highest sensory scores, whereas the sample with sucrose and honey had the highest ascorbic acid level. As a result, the sample with a sucrose and honey solution at 50ºC proved to be the best in terms of nutritional quality and shelf stability.

Kowalska *et al.* (2018) determined the impact of osmotic pre-dehydration and the rehydration properties of dried strawberry and apple fruit. The apples and partially defrosted strawberries were prior dehydrated in solutions of 60ºBrix sucrose solution and a mixture of 65ºBrixsucrose+chokeberry (1:4) juice concentrate at 50°C for two hours before final dehydration to a constant weight. Strawberries recorded three times greater dehydration effect than that of apples. Minimal damage to the product quality was observed in dried fruits with the use of the osmotic pre-treatment (69-88%) in comparison with dried fresh fruit. They further observed that chokeberry juice

concentrate generated a greater (7-8%) mass loss of fruit, compared to the osmotic solution without it.

According to Barman and Badwaik (2016), glycerol and sucrose proved to be the best osmotic agents compared to glucose and fructose at the same osmotic solution concentration (70°Brix) during osmotic dehydration of carambola and fruit: solution ratio fixed as 1:10 and 180 minutes, respectively. Their findings were based on the effects of these osmotic agents on the osmodried carambola slices' solid increase, water loss, and weight reduction percentage

Rodriguez *et al.* (2015) discovered that at the same osmotic solution concentration (60% w/w) , plum fruits osmotically treated with sorbitol solutions lost 4.52 per cent more water and gained 5.53 per cent more solids than plum fruits osmotically treated with glucose syrup. Although the osmotic agents had similar molecular weights, they were reported to be modified by other factors such as viscosity, water activity, and ionic behaviour arising from interactions between solutes and the water and solid matrix of the food.

Ferrari *et al.* (2010) used melon fruit pieces to study mass kinetics characters, utilizing a variation in sucrose concentration (40 to 60°Brix). Significant water loss (28%) was detected after two hours of immersion in a 60ºBrix syrup concentration, as was weight loss (19%) and modest solid gain (8.00%). Solid gain was reduced due to an increase in solution viscosity at 60°Brix, which hampered solid gain. However, solid gain rose by up to 11% with the addition of calcium lactate up to 10 g/kg^{-1}. The increased percent of solid gain with the addition of calcium lactate was attributed to its alterations in cell membrane permeability, which resulted in changes in the cellular structure of the fruit, allowing for better mass transfer.

Using different osmotic agents such as sucrose, fructo-oligosaccharide, concentrated apple juice, de-acidified and desalted concentrated apple juice, sorbitol, galactosorbitol, oligofructose, and inverted sugar, Konopacka *et al.* (2009) investigated the sensory perception and acceptability of osmo-dried and osmo-freeze-dried sour cherries. They discovered that dried fruits treated with sucrose, inverted sugar, or de-acidified fruit juice had a high acidity. The use of oligofructose in freeze-dried fruits results in a high level of crispness in the finished product. Galactosorbitol

and sorbitol were not recommended for osmotic impregnation of fruits since they increased the sensation of hardness, decreasing the acceptability of the product.

Riva *et al*. (2005) studied the effects of sucrose and sorbitol syrup (60% w/w) on the physical properties, structure collapse, and colour changes of osmo-air dried apricot cubes. Sorbitol showed the highest protective effect on colour attributes and ascorbic acid content compared to sucrose. When compared to sorbitol-treated fruits, apricot cubes pretreated in sucrose solution had less deformation and retained their original shape.

2.5.4 Fruit pieces to solution ratio

Ghellam *et al.* (2021) used Response Surface Methodology (RSM) to estimate the main effects of process variables on the physical quality of osmodehydrated olive berries. They discovered that, among other independent variables such as concentration and temperature, the fruit-osmotic solution ratio has no impact on the physical characteristics of osmodehydrated olive berries, except in water loss, where the least (p = 0.049) impact was recorded. The best process parameters for the osmodehydration of olive berries were found to be a 1.8:10 fruit to osmotic solution ratio, a 70 per cent osmotic solution concentration, and a 70ºC osmotic solution temperature. Water loss (59.21%), solid gain (19.21%), weight loss (32.34%), water activity (0.85), density (1.22 g/cm^3), and colour change value (3.65) were all predicted under these conditions.

Ramakrishnan (2014) compared the effect of the fruit: osmotic solution ratio during osmotic dehydration of mango fruit slices.They discovered that increasing the fruit osmotic solution resulted in more weight loss (19.91%), water loss (31.02%), and solid gain (11.11%). Furthermore, this treatment's total soluble solids (63.10ºBrix) and overall acceptance (82.00%) were both high. Beyond the fruit: osmotic solution of 1:2, it was discovered that the treatment of 1:4 resulted in lower weight loss (16.68%), water loss (25.70%), solid gain (8.92%), total soluble solids (59ºBrix), and overall acceptance (76.00%).

Campos *et al*. (2012) reported a decrease in moisture content with an increase in fruit osmotic solution when star fruit slices were treated in sucrose (45%) syrup and dried to constant weight in a vacuum oven at 60ºC. When the fruit-osmotic solution

ratio was 1:2, they found moisture content of 75 per cent, which dropped to 62 per cent at fruit: osmotic solution ratio of 1:7. Furthermore, as the fruit: osmotic solution ratio increased, lower values of colour in relation to the fresh fruit were found, as demonstrated by the high colour values of ΔE (15.9) in untreated dried fruits, which reduced to ΔE (6.9) at a fruit: osmotic solution ratio of 1:7.

Kumari and Samsher (2015) investigated the optimum conditions for osmotic (50% sugar syrup) pretreatment of 8mm thick banana slices prior to final dehydration in a mechanical hot (60^{o}C) air oven using different fruits: osmotic solutions of 1:2, 1:4, and 1:6. Banana slices of the 1:4 treatment expressed the highest drying rates during the three-hour osmotic period, followed by 1:2 and then 1:6. The moisture content of the samples varies from 19 to 21 per cent dry basis against an initial moisture content of 27 per cent dry basis after osmotic treatment. The final moisture content of the fruit slices after eight hours of hot air dehydration was 40, 32, and 38 per cent dry basis of samples, respectively. Therefore, fruit: osmotic solution ratio of 1:4 was considered ideal for osmodehydration pretreatment of banana slices.

In apple varieties, Chauhan *et al*. (2011) reported a standardized fruit-osmotic solution ratio of 1:2 when the fruit slices were blanched for 2 minutes at 95°C in 60^{o}Brix solutions containing various sugars (glucose, fructose, sucrose, maltose, sorbitol, and honey) and then dipped in the same for 2 hours at 40°C for osmotic dehydration, ideal to meet the requirements of processors and consumers.

Chavan *et al*. (2010) established standardized procedures for optimal osmotic dehydration of bananas as 8mm thick banana fruit slices with or without sulphuring at 2 g/kg of slices for 2 hours, followed by immersion in 60°Brix sugar syrup containing antioxidants at a 1:2 w/v ratio of fruit slices to syrup for 16 hours.

2.5.5 Process duration

Rastogi and Raghavarao (1994) observed mass transfer kinetics over a six hour immersion time on mature coconut of 8mm thickness. A gradual decline in weight was recorded up to four hour duration after which it came to a constant rate as the equilibrium period reached.

Archana and Lekshmi (2019) observed an increase in solid gain, water loss, and weight reduction with an increase in immersion time of osmodehydrated red banana, regardless of fruit shape. They recommended the immersion time for osmodehydration of red banana as 180 minutes, which had a high (8.47%) weight reduction and a water loss to solid gain ratio of 0.60. When banana slices were immersed for less than 180 minutes, a lower (0.49) water loss to solid gain ratio was reported at 120 minutes, while the least (5.61%) weight reduction was observed at 60 minutes.

Gurumeenakshi and Varadharaju (2019) evaluated the quality characteristics of osmodried mango by soaking the fruit slices in sugar syrup (60ºBrix) and osmotic immersion duration of 18 hours before 60ºC cabinet drying for six hours. Similar studies by Ramakrishnan (2014) recorded the highest quality of physicochemical quality of osmo-dried mango slices when fruit slices were immersed in 70ºBrix sugar solution for 12 hours.

Keerthisree *et al.* (2017) reported the maximum texture, as described by cutting force and cutting energy, of the osmodehydrated banana variety "Nendran" to be attained within 60.99 and 65.55 minutes of immersion time. The low browning index was found when the osmotic solution concentration and the immersion time were in the range of 53 and 57.7ºBrix, as well as 44.68 and 49.08 minutes, respectively, which intensified beyond these points.

Phisut *et al*. (2013) investigated the sensory qualities of melon slices that have been osmotically treated in sucrose solution (30 to 50ºBrix) and hot air dried at 60ºC. Cantaloupe osmodehydration was done in two ways: fast osmodehydration and slow osmodehydration, with immersion times of 24 and 72 hours, respectively. Fruits kept in slow osmodehydration reported to have a soft texture and retain their physical structure, scoring higher than those kept in quick osmodehydration. Furthermore, high loss of phenolic compounds and increment for both reducing sugars and total sugar content was observed in fast osmodehydration compared to slow osmodehydration

Lewicki and Pawlak (2005) reported a rapid increase in dry matter of apple within the first 30 minutes of osmodehydration treatment, which was equated to 70

per cent, and beyond this time, a slow increase in dry matter was observed.After three hours of osmodehydration, there was a two-fold increase in dry matter.

Rahman *et al*. (1996) recorded high (0.92-1.00) regression coefficients for the water loss and solid gain over time of pineapple wedges treated in a hypertonic solution of palm sugar, indicating a linear relationship among these variables. Based on these findings, they concluded that during osmodehydration treatment, there was an increase in water loss and a solid gain of pineapple wedges over time.

2.5.7 Temperature of osmotic solution

Hossain *et al*. (2021) observed that with the rise of temperatures from 45 to 55ºC of dehydration temperature when developing osmodried garcinia fruit slices, there was an increase in the pH of the sample from 1.91 in the fresh sample to 2.9 in the samples treated in hypertonic solution of sucrose (10%) as well as for the untreated sample. However, a reduction of other biochemical parameters such as total acidity and vitamins (B and C) was recorded for osmodried garcinia slices.

Pavkov *et al.* (2021) observed an increase in water loss and solid gain with increased temperature during drying of apricot slices in a sucrose solution at temperatures ranging from 30 to 60 °C and 50 to 65% (w/w) solution concentration in apricot halves. They observed reductions in drying times with higher temperatures with a lower value of effective diffusivity of water recorded from 3.00×10^{-10} m/s to 1.97×10^{-9} m^2/s and a high values for the coefficient of determination which ranged from 0.89 to 0.99, indicating a high dependence of mass transfer characteristics on temperature.

The effect of osmotic temperature on mass transfer of pineapple cubes was studied by Sethi and Kaur (2019), using different osmotic agents, viz., honey (80ºBrix), sucrose, and honey-sucrose (72ºBrix) temperatures of 30 and 50ºC. Sensory evaluation of all the samples revealed that the highest scores were obtained by the sample containing both sucrose and honey when the osmotic solution temperature was 50ºC. Increased osmotic temperature also enhanced physico-chemical parameters such as total ash, rehydration ratio, moisture content, and water activity. However, the ascorbic acid levels were found to be higher in osmodehydration at 30ºC compared to that at 50ºC.

Zahoor and Khan (2017) studied the kinetics and mathematical models of osmotic dehydration of pineapple slices using three levels of temperature: 40°C, 50°C, and 60°C. They found that when the osmotic solution temperature was increased, moisture loss and solid gain increased. This was demonstrated when temperature was raised from 40°C to 60°C, with water loss ranging from 42 to 45 per cent and solid gain ranging from 8 to 9 per cent.

The effects of osmotic dehydration (OD) pre-treatment on the drying durations of apple slices immersed in hypertonic (HD) sucrose or sorbitol solutions were investigated by Assis *et al.* (2017). Without osmotic pre-treatment, apple slices dried in ten and three hours at 25 and 80ºC, respectively. At 25ºC, osmodehydration pretreatment was found to reduce subsequent air drying periods by 20 per cent with sucrose and 30 per cent with sorbitol. Using sucrose and sorbitol as osmotic agents, the reduction was 22 and 39 per cent at 80ºC, respectively.

Shanmugasundaram and Haripriya (2014) found that as the temperature of the osmotic solution increased, the time required for dewatering decreased. They found that when fruits of the banana cultivars "Poovan" and "Cavendish" were immersed in sugar syrup (40 to 60 °Brix) at osmotic solution temperatures of 30, 50, and 75ºC, respectively, more than half of the dewatering occurred during the fourth, second, and first hours of osmosis. Extensive water loss was reported at 50 and 75ºC, and the least was at 30ºC among all syrup concentrations.

Temperatures of osmotic solutions should be kept between 30 and 60ºC, according to Tortoe (2010), because temperatures over this range can kill plant tissues. During osmodehydration, the high temperature, short time procedure has been proposed as suitable for inactivating enzymes, eliminating air from intercellular gaps, and enhancing osmotic agent penetration into the tissue.

2.5.8 Concentration of osmotic solution

Islam *et al.* (2019) found a reduction in moisture content as the osmotic solution concentration increased during osmodehydration of papaya fruit slices. The average moisture content at 40ºBrix, 50ºBrix, and 60ºBrix was found to be 72.35 per cent, 67.35 per cent, and 57.59 per cent, respectively, when the osmotic solution temperature was adjusted to 55ºC.

Archana and Lekshmi (2019) reported high water loss and solid gain with an increase in osmotic solution concentration during osmodehydration of banana fruit slices. Water loss to solid gain ratios of 0.82, 0.58, and 0.42 were recorded when banana fruit slices were immersed in osmotic solution concentrations of 80, 60, and 40°Brix, respectively.

Singh and Gangwar (2020) reported an increase in moisture loss and solid gain with an increase in osmotic solution concentration. They evaluated carrot slices treated using two different concentrations of sucrose+ salt solution (40 to 60°Brix and 1.00 to 3.00% NaCl) and found high (13.32-56.93%) values for carrot slices treated with 60°Brix and 3 per cent salt solution and lower (9.01-41.83%) values for carrot slices treated with 40°Brix and 3 per cent salt solution. At lower concentrations, values between 0.80 and 3.45 percent were reported, but as the concentration of osmotic solution increased to 60°Brix, these values doubled to ranges between 2.34 and 5.86 percent.

On several nutritional parameters of osmotically dehydrated chestnut slices, the influence of sucrose concentrations (60, 70, and 80%, w/v) was investigated by Delgado *et al.* (2017). They discovered that varying sucrose syrup concentrations have a smaller impact on the preservation of bioactive substances such starch, free sugars, fatty acids, and tocopherol profiles in chestnut slices. However, the largest amounts of fumaric acid were obtained at the highest sugar concentrations (70 and 80%), implying that sucrose concentration impacts the organic acids in chestnut slices.

Ramakrishnan *et al.* (2014) investigated four different osmotic concentrations of sugar *viz.* 40, 50, 60 and 70°Brix on mango variety 'Muvandaan' and recorded high values for weight loss (17.84%), water loss (25.86%), solid gain (10.26%), total soluble solids (68.5°Brix) and sensory attributes in 70°Brix sugar solution. Subjecting mango slices to lower concentration of 40°Brix was reported to display lower values in terms of weight loss (14.62%), solid gain (8.99%), total soluble solids (58.10 %) and sensory attributes.

Ferrari *et al.* (2010) studied the effects of cellular and mechanical structure of osmodehydrated melons using hypertonic sucrose solutions (40 and 60°Brix)

incorporated with salt and calcium lactate (5 to 20 g kg^{-1}). Structural preservation was observed when salt was used at a concentration of up to 10 g kg^{-1}, while cytoplasm plasmolysis and cell damage occurred beyond 15 g kg^{-1}. Because low syrup concentrations (40°Brix) have been shown to inhibit calcium incorporation, a concentration of 60°Brix is recommended for osmotic pretreatment of melon cubes.

2.6 Improvements in osmotic dehydration during the development of Intermediate Moisture (IM) fruits

Fan *et al*. (2020) and his co-workers investigated a novel method for enhanced osmotic dehydration using ultrasound (20 kHz) treatment performed at different powers (0–300 W) for 30 minutes. Ultrasound application in osmodehydration was reported to accelerate water loss and solid gain in kiwi fruit due to a rapid series of alternative expansions and compressions. Microscopic image analysis showed the preserved cell structure of kiwifruit subjected to conventional osmodehydration and ultrasound assisted osmodehydration (120W), which were similar to fresh kiwi fruit. Thus, ultrasound (20kHz and 120W) application in osmodehydration was found to be suitable for improving the physicochemical quality of kiwifruit without causing a severe distortion of its original texture.

Sharif (2018) studied dehydration kinetics using combined techniques of microwave (800 Watts for 60 seconds) assisted osmodehydration and subsequent hot air conventional dehydration on wild berry fruits. A significant ($p = 0.05$) reduction in the drying time of wild berry fruits was recorded compared with the control by five hours. Microwave application is reported to raise temperatures of both food products and osmotic solutions, resulting in accelerated evaporation for dehydration of food materials.

Shen (2017) compared the effects of vacuum impregnation and high pressure during osmodehydration of mango fruit slices immersed in sucrose solution (60°Brix) with 0.48% of pectin methylesterase. Vacuum pre-treatment showed a high (0.27 g solid/g) solid gain after 4 hours compared to the high-pressure treated sample (0.20 g solid/g) and the sample without pre-treatment (0.11 g solid/g). They attributed this gain to the high degree of changes that vacuum causes in the tissue structure of mango, which favours hydrodynamic gain.

Gamma irradiation during osmodehydration improved the mass transfer kinetics of guava slices in sucrose solutions, according to Srijava and Priya (2017). Over a 45-day period, the fruit slices were reported to be nutrition stable and microbial-safe. However, with a fixed concentration of 40ºBrix, non-enzymatic browning values increased from 0.40 to 0.80 with increasing radiation from 0.25 to 1.0 kGY, respectively.

Rastogi (2005) recommended the application of force between 200 and 2800 rpm on fruits for increased contact of the fruit pieces with the osmotic solution. Low stirring speed was reported as not sufficient to reduce the cell membrane resistance to mass transfer, but high stirring speed was observed to cause excessive damage to the cell membrane. High agitation was observed to increase water loss by 15% while decreasing solid uptake by 80%.

2.7 Subsequent dehydration of osmodehydrated fruits for increased product stability

Ade-Omowaye *et al*. (2002) reported that moderate thermal (25–55ºC) osmodehydration using sucrose and sodium chloride as osmotic agents reduces the vitamin C content and carotenoids of bell peppers compared to high electric field (0.5–2.5 kV/cm) osmodehydration. This was after they recorded decreasing values of 20 to 4 percent and 13 to 7 percent for thermal and high electric field osmodehydration, respectively. After hot (70°C) air drying of bell pepper discs for product stability, both treatments showed a further decrease of vitamin C, which was recorded as a 5 per cent reduction, whilst carotenoids were reduced from 80 to 55 per cent of their initial weight.

When subsequent air dehydration temperatures were kept constant at 70°C, Jariyawaranugoon (2015) observed increased hardness and loss of ascorbic acid on osmodehydrofrozen banana slices with time. At four and six hours of tray drying, an average of 21.08 and 23.43N was measured, indicating that moisture removal during tray drying improves hardening. In addition, tray drying lowered ascorbic acid concentrations from 1.9 mg/100g to 1.67 mg/100g, which was attributed to ascorbic acid oxidation to dehydroascorbic acid.

Pavkov *et al*. (2021) reported a shortened drying time of osmodehydrated

apricot halves with an increase in temperature from 40 to 60ºC in a tray drier. Osmodehydration pre-treatment was reported to reduce moisture content by 3.15 to 4.12 kg H_2O/kg d.m within 180 minutes, while the untreated sample achieved this moisture level between 220 and 315 minutes. In both osmotically treated and untreated apricot halves, air drying between the temperatures of 40ºC and 60ºC accelerated the drying process by 11.72 to 17.70 per cent.

Kumar and Sagar (2014) found that osmodried mango, guava, and aonla retained maximum nutrients like acidity, ascorbic acid, sugar, water removal, and moisture ratio when subsequently dried in a vacuum oven dryer followed by cabinet drying. The solar drier produced more non-enzymatic browning, which is an undesirable characteristic for dried products. The set temperatures for optimum dehydration using both the vacuum oven drier and the cabinet drier were 40 and 58 ±2 ºC, respectively.

Mitra *et al*. (2015) compared vacuum oven drying to hot air drying and microwave drying of pre-treated (5% NaCl + 0.2 % KMS) onion slices. They discovered that vacuum oven-dried onion slices had superior colour, flavour, and microstructure. The density of vacuum oven dried onions was lower than that of hot air dried onions, but the thermal conductivity was the same. Vacuum drying was found to be the best method for onions, followed by hot air drying and microwave drying.

Using a vacuum oven drier, Amiripour *et al*. (2015) investigated the best conditions for osmodehydrated pear slices. They employed response surface methodology to estimate these ideal circumstances by varying pressure (10–30 kPa), temperature (50, 60, and 70ºC), and time (180-300 minutes). The ideal vacuum drying conditions for pear were determined to be 10 kPa vacuum pressure, 55°C temperature, and 250 minute drying duration. Moisture content (23.26 %), rehydration ratio (1.46), and shrinkage (67.45 %) were all reported at this optimum stage.

Junlakan *et al*. (2017) investigated the structural changes of banana slices over a ten-hour period using vacuum drying temperatures of 70, 80, and 90ºCand a chamber pressure of 30 mmHg. The high dehydration temperatures of 90ºC resulted in short drying times (1.67 hours), a high degree of yellowness (0.10), low shrinkage

(31.44%), and low hardness (33.56N).Lower temperatures of 70ºC, on the other hand, resulted in long drying times (9.17 hours), low yellowness, shrinkage, and hardness values of 0.02, 40.41 percent, and 53.16 N, respectively. For improved quality, they recommended a temperature of 90ºC and a pressure of 30 mmHg for the dehydration of banana fruit slices.

Falade *et al.* (2003) reported optimum sensory attributes in terms of colour, taste, flavour, chewiness, and overall acceptability of cashew apples treated with high (60-68ºBrix) sucrose compared to the same osmotic solution with a low (52ºBrix) osmotic concentration. However, no significant difference in the organoleptic quality of osmodehydrated cashew apple was observed when the fruits were eventually dried in an air oven drier and a vacuum oven at 50ºC for six hours.

2.8 Storage stability of Intermediate Moisture (IM) products

Hui *et al.* (2017) found that the microbial load of intermediate moisture pineapple in sucrose treated samples was high (4.33 to 6.26 log cfu g^{-1}) but low in sorbitol (1.85 to 6.55 log cfu g^{-1}) and sucrose sorbitol (1.85 to 5.31 log cfu g^{-1}). Sucrose-treated samples may be kept for up to 14 days, whereas sucrose-sorbitol mixes could be kept for up to 35 days with no coliform contamination. The ability of sorbitol to further diminish the water activity of pineapple fruit tissue when compared to sucrose alone was responsible for the extended shelf life of sucrose-sorbitol treated pineapple slices.

Gomez *et al.* (2013) investigated the microbial community of intermediate moisture strawberry jam when combined with pomegranate, rosemary, lemon, and balsamic lemon plant extracts. Pomegranate (0.04 to 0.1 g/mL) and lemon extract (0.14 g/mL) were the most efficient natural extracts against the bacterial flora of the jam. In comparison to the untreated sample, which had a storage life of just 18 days at room temperature, adding extract to intermediate moisture jam increased the product's shelf life and improved the consistency of the jam over a 24-day period at room temperature.

Subhajit (2019) investigated the microbiological stability of dried fruits that had been pretreated in a hypertonic (65-70%) sugar solution. An increase in osmotic solution concentration increased the product stability, as evidenced by the reduced

growth of yeast and moulds. Furthermore, osmodehydrated fruits produced with a finite concentration of sugar syrup were reported to have improved nutritional and sensory value in addition to being shelf stable.

Mondhe *et al.* (2016) evaluated the package materials on the sensory attributes of intermediate moisture papaya. They reported a better retention of colour, flavour, texture, appearance, and overall acceptability for samples packed in high density polythene (HDPE) at a refrigerated temperature compared to samples stored in laminated aluminum foil at the same temperature regime.

Mahomud *et al.* (2015) studied the quality of intermediate moisture (IM) bananas subjected to various packaging materials, *viz.* single layer high density polythene, double layer high density polythene, and single layer high density polythene plus kept in tin can be stored at different (75%, 80%, and 90%) relative humidity at room temperature. They reported that keeping banana slices in single-layer polythene and then keeping this package in a tin can gave the best result for storing the dried banana slices. Among the different storage conditions of dried banana slices, 75 per cent relative humidity was reported as the most suitable condition for storing IM banana slices. For a longer shelf life, low humidity and moisture-proof packaging were recommended to maintain the quality of slices of IM banana.

Ramakrishnan (2014) observed that storage package material impacts the shelf life of intermediate moisture (IM) mango. The highest population of microbes throughout the storage period was in the polyethylene (200 gauge) package and the least was in the polyethylene aluminium foil laminated cover. Furthermore, IM mango stored in a polyethylene aluminium foil laminated cover was observed to have maintained the highest values of biochemical constituents such as titratable acidity, ascorbic acid, and total soluble solids, as well as the highest sensory attributes. Vacuum packaging in aluminium foil laminated cover was recommended due to less moisture and the absence of air in the package, which may otherwise invite microbial spoilage.

Microbiological experiments on osmo-dried intermediate moisture bananas by Chavan *et al*. (2010) show that fruit slices can be stored in polypropylene bags (200

gauge) for up to six months under ambient temperature (27ºC) and are microbiologically safe. They claimed that these kinds of storage conditions are good for nutrition and colour retention.

2.9 Economies of Intermediate Moisture (IM) products

The effects of osmotic dehydration on the kinetics of hot air drying of apricot halves were investigated by Pavkov *et al*. (2021). They discovered that increasing the temperature from 40 to 60ºC and the air velocity from 1 to 1.5 m/s reduced the length of subsequent dehydration. They found that dehydrated fruits that got osmotic treatment consumed less energy (35.216–46.469 kJ/mol) than untreated fruits, which consumed more energy (46.38 and 51.51 kJ/mol), demonstrating the efficiency of osmodehydration pretreatment in reducing energy consumption.

Edward *et al*. (2020) reported that due to a change in the global business landscape from oligopoly to monopsony trading of bananas, an annual increase of 1.36 per cent in the consumption of bananas has been reported between the periods of 2008 to 2017 with increased prices from €0.61/kg in 2011 to €0.77/kg in 2017. To minimize losses encountered throughout the value chain of bananas, research and development for minimal processing of bananas on a commercial scale was recommended.

Kumar *et al*. (2016) discovered no waste during the production of osmo-air bitter gourd chips, as evidenced by a 100 per cent recovery rate. The cost of production for osmo-air dried bittergourd chips was calculated to be Rs. 138 per kilogram, with an 11.00 per cent product yield.

The product output of osmo-dried banana slices of the variety Grand Naine was reported at a 20% recovery rate by Chavan *et al*. (2010), and the cost of production was approximated at Rs. 65 per kilogram.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The research work 'Evaluation of banana varieties *(Musa* spp.) for the development of Intermediate Moisture Fruit (IMF)' was conducted at the Department of Post Harvest Technology, College of Agriculture, Vellanikkara in Thrissur district of Kerala Vellanikkara, Thrissur, Kerala during August 2018-March2022. Vellannikkara lies between 10^{o} 32' N latitude and 76^{o} 17' E longitude at an altitute of 23 m above sea level and the climate is warm and humid. The whole study was divided into four different experiments which are;

Experiment I: Characterisation of banana varieties for horticultural and biochemical traits

Experiment II: Evaluation of osmotic agents on quality of Intermediate Moisture (IM) banana

Experiment III: Standardisation of fruit to osmotic solution ratio and duration of immersion on quality of IM banana

Experiment IV: study of packaging and storage temperature on quality of IM banana

3.1. Characterisation of banana varieties for horticultural and biochemical traits

The study was carried out in the Department of Post Harvest Technology, College of Agriculture, Vellanikkara, Thrissur, Kerala between the periods of December 2020 and March 2021 using the six banana varieties of different genomic groups, *viz*., Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA). Nendunendran of the variety Nendran was used in the present study. The fruits of the respective varieties were collected from the Banana Research Station, Kannara, Kerala, where they were grown under uniform conditions as per the Package of Practice recommendations of the Kerala Agricultural University (KAU, 1996).

3.1.1. Morphological fruit characterization

Morphological fruit characterization was done according to 'Descriptors for banana (*Musa* spp.) by International Plant Genetic Resources Institute (IPGRI, 1996). Twenty five morphological traits were classified as given below.

3.1.1.1. Fruit position

The symmetrical arrangement of the fruit around the stalk was observed and recorded according to the following positions: curved towards the stalk, parallel to the stalk, curved upwards (obliquely, at 45^{o} angle upward), perpendicular to the stalk, and pendant.

3.1.1.2. Number of fruits per hand

The actual number of fruits on the mid-hand of the bunch was physically counted on each plant at maturity.

3.1.1.3. Fruit length (cm)

The fruit from the mid-hand of the bunch was selected and distance between the pedicel length and apex was measured, and expressed in cm.

3.1.1.4. Fruit shape (longitudinal curvature)

The fruit from the mid-hand of the bunch was selected and the fruit shape observed. In the case of an asymmetric fruit bunch, the dominant fruit shape appearing in the bunch was selected and categorised as straight, slightly curved, straight in the distal part, curved (sharp curve), curved in a slight "S" shape (double curvature) or other shape not stipulated as per IPGRI guidelines.

3.1.1.5. Transverse section of fruit

Banana fruits were randomly selected from the bunch's mid-hand, and observations were made on the transverse section of the mature fruit (ready to eat-ripe but not over ripe yellow stage). The transverse section of the fruit was categorised as either pronounced ridges or slightly ridged and rounded.

3.1.1.6. Fruit apex

The fruit from the mid-hand of the bunch was randomly selected at harvest time and observed at the distal end of the fruit, which was categorised as either pointed, lengthily pointed, blunt-tipped, bottle-necked, or rounded.

3.1.1.7. Remains of flower relicts at fruit apex

The remains of the flower relicts were observed at harvest before cutting the bunch to avoid them from falling off. The observations were classified as having fewer flower relicts (20% of the fruit with relicts) or having persistent flower relicts (20% of the fruit with relicts), or with only the base of the style persisting.

3.1.1.8. Fruit pedicel length (mm)

The length of the pedicel of the fruit from the mid-hand of the bunch was measured to scale with the help of the thread, and the average length of the pedicel was expressed in mm.

3.1.1.9. Fruit pedicel width (mm)

The width of the pedicel of the inner fruit in the middle of the mid-hand of the bunch was measured on scale with the help of thread, and the average width of the fruit pedicel was expressed in mm.

3.1.1.10. Pedicel surface

The pedicel surface of bananas was observed using a hand-held magnifier and recorded according to the presence or absence of hair on the pedicel surface.

3.1.1.11. Fusion of pedicels

The fusion of the fruit pedicels in the mid-hand of the bunch was observed as to whether there was a very partial or no visible sign of fusion, partial fusion, or total fusion of pedicels before joining the crown.

3.1.1.12. Immature fruit peel colour

The immature peel colour of the inner fruit in the mid-hand of the bunch was visually marched against the Royal Horticultural Society (RHS) colour chart before the maturity of the fruit.

3.1.1.13. Mature fruit peel colour

The mature peel colour of the inner fruit at the mid-hand of the bunch was visually marched against the Royal Horticultural Society (RHS) colour chart at fruit maturity (ready to eat-ripe but not over ripe yellow stage).

3.1.1.14. Fruit peel thickness (mm)

A mature banana fruit (ready to eat-ripe but not over ripe yellow stage) was transversely cut at the midpoint, hand peeled, and the peel thickness was measured using a digital veneer calliper and expressed in mm.

3.1.1.15. Adherence of the fruit peel

A mature banana (ready to eat-ripe but not over ripe yellow stage) was recorded based on its ease of fruit peeling or the fruit not easily peeled at maturity.

3.1.1.16. Cracks in fruit peel

The cracks on mature fruit peel were recorded to observe if the peel splits with or without cracks at maturity.

3.1.1.17. Pulp in fruit

The pulp and peel were recorded separately using a balance scale, and the relative proportion of pulp and peel was worked out.

3.1.1.18. Pulp colour before maturity

The immature fruit pulp colour on the youngest hand of the bunch was visually marched against the Royal Horticultural Society (RHS) colour chart before maturity of the fruit.

3.1.1.19. Pulp colour at maturity

The pulp colour of the inner fruit of the mid-hand of the bunch was visually marched against the Royal Horticultural Society (RHS) colour chart at fruit maturity (ready to eat-ripe but not over ripe yellow stage).

3.1.1.20. Fruit fall from hands

The fruit fall from the hand was observed from the bunch and recorded as persistent or deciduous at maturity.

3.1.1.21. Flesh texture

The flesh texture was recorded as either firm or soft per the IPGRI (1996) guidelines.

3.1.1.22. Predominant taste

The predominant taste of banana was evaluated by 15 panellists as per banana descriptors using score scales provided as astringent (like cooking banana), mild, slightly tasty or tasteless, sweet (like Cavendish), sugary (like Pisang Mas), sweet and acidic (apple-like), and other.

3.1.1.23. Presence of seed with source of pollen

The number of seeds existing was recorded among banana varieties.

3.1.1.24. Seed surface

The surface of the seed with source of pollen was observed and recorded as either smooth or wrinkled.

3.1.1.25. Seed shape

The seed shape was observed and recorded as either flat, angular (more or less pyramidal), globular (spherical) or rounded (but not completely spherical).

3.1.2. Horticultural characters

The horticultural characters of the fruit were evaluated for the number of fruits per hand, fruit length, fruit pedicel length, fruit pedicel width, fruit peel thickness, fruit pulp weight, fruit peel weight, fruit to peel ratio and fruit flesh firmness.

3.1.2.1. Number of fruits per hand

The number of fruits of each banana variety was physically counted on five plants during harvest, and the average number of fruits per bunch was recorded.

3.1.2.2. Fruit length (cm), fruit pedicel length (mm), fruit pedicel width (mm) and fruit peel thickness (mm)

The fruit length, fruit pedicel length, fruit pedicel width and fruit peel thickness were recorded using a digital vernier caliper and the values were expressed in mm.

3.1.2.3. Fruit pulp weight (g) and fruit peel (g)

The fruit pulp weight and fruit peel weight were measured using a balance scale and the values were expressed in g.

3.1.2.4. Fruit to peel ratio

Fruit to peel ratio was calculated by dividing the values of fruit pulp weight and fruit peel.

3.1.2.5. Fruit flesh firmness (kg cm^{-2})

The flesh texture of the pulp mature banana was determined by using a hand-held pressure tester (Model F 001 and F 327, Effigy, Italy) fitted with an 8mm probe and the measurements were expressed in kg cm^{-2}.

3.1.3. Biochemical traits

Firm ripe banana fruits were further analysed for different biochemical parameters which included titratable acidity (TA), total soluble solid (TSS) content, total protein, total carbohydrates, total fat, total ash, vitamin C, calcium (Ca), iron (Fe), potassium (K) , antioxidant activity (DPPH, FRAP and ABTS), total phenol,

Spectrophotometer

Flame photometer

Refractometer

Water activity meter

Plate 1. The instruments used for determination of fruit quality

crude fibre and total carotenoid content. Some of the equipment used for the determination of biochemical characteristics are displayed in Plate 1.

3.1.3.1. Titratable Acidity (%)

Titratable acidity was estimated by titrating known volume of sample against standard 0.1 N NaOH using phenolphthalein as an indicator and expressed as per cent of malic acid (Ranganna, 2019).

3.1.3.2. Total Soluble Solids (^{o}Brix)

The total soluble solid (TSS) content of fresh banana fruits was determined using a Erma hand refractometer (range 0-32^{o}Brix) and expressed in degree Brix.

3.1.3.3. Total protein (g/100g)

The Lowry method as described by (Ranganna 2019) was used to estimate total protein, in which 500 mg of the fruit sample was ground with a pestle and mortar, 5-10 ml of buffer was added, centrifuged, and the supernatant was collected. A series of test tubes of working standards were pipette out at volumes of 0.2, 0.4, 0.8, and 1 ml, while the sample extracts of 0.1 and 0.2 ml were pipette into other test tubes. Both of the tubes containing sample extract and the working standard were made up to 1 mL volume with distilled water.

A volume of 5 ml of mixture containing 0.5% copper sulphate solution, 1% potassium sodium tartarate and 0.1 N sodium hydroxide in 2% sodium carbonate solution was added to the test tubes containing the samples and a series of working standards as well as 1ml of distilled water was made as a blank.

The resulting mixture was shaken and allowed to stand for 10 minutes. Then, 0.5 ml of Folin-Ciocalteus reagent (half diluted in distilled water) was added. The mixture was shaken once again and allowed to rest in the dark for 30 minutes to allow a blue colour development, and the absorbance reading was taken at 660 nm using a spectrophotometer. The quantification of total protein was done using a calibration curve prepared and results were expressed as g per 100g of sample.

3.1.3.4. Total carbohydrates (g/100g)

The total carbohydrates were estimated using the Anthrone method as suggested by Ranganna (2019). A 100g banana sample was weighed into a boiling tube. The sample was hydrolysed by keeping it in a boiling water bath for 3 hours with 5 ml of 2.5 N HCL. It was then allowed to cool at room temperature. Solid sodium carbonate was added to neutralise it and the volume was made up to 100 ml. The solution was centrifuged, the supernatant collected and volumes of 0.5 mL and 1 mL aliquots were collected for analysis.

Meanwhile, the standards containing 0, 0.2, 0.4, 0.6, 0.8, and 1 mL were prepared from the working standard. The sample and standard aliquots were made up to 1 mL in all test tubes by adding distilled water. Four millilitres of anthrone reagent were added to all tubes and then heated in a boiling water bath for eight minutes. A colour of green to dark green developed, which was read at 630 nm. A standard graph was drawn by plotting the concentration of the standard on the X-axis versus its absorbance on the Y-axis. From the graph, the amount of carbohydrate present in the sample was expressed as g of glucose per 100g fruit

3.1.3.5. Total fat (%)

A 5 g sample was folded in filter paper to hold it, placed in the tubes of the soxhlet apparatus, and extracted with petroleum ether for 6 hours at temperatures ranging from 60 to 80^{o}C. The extract was allowed to cool, the extraction flask was dismantled, and the petroleum ether was allowed to evaporate. The obtained extract was allowed to cool, evaporate and the weight recorded to a constant value in percentage

3.1.3.6. Total ash (%)

The weight of the silica crucible along with the 5 g of sample was noted, and this was then decarbonised on a heater until the smoke was no longer emitted. The decarbonised sample was then transferred into a muffle furnace and ignited at 550-660^{o}C for 2-3 hours until there were no black particles left. The crucible was filled with ash as it cooled in a desiccator, and the weight was quickly noted. The total ash was calculated by the difference in weight and expressed in per cent.

3.1.3.7. Vitamin C (mg/100g)

The vitamin C content was determined by removing 5 g of the sample and extracting it with 4 % oxalic acid. The vitamin C content of the pulp was estimated by titration using standard indicator dye 2,6, dichlorophenol indophenols, and the end point was determined when excess unreduced dye is rose pink in acid solution. The amount of vitamin C content was expressed as mg/100g of fruit.

3.1.3.8. Calcium (mg/100g)

Ash solution was prepared by placing a 5 g of the fruit sample into the crucible which was then ignited at 550-660^{o}C for 2-3 hours until there were no black particles left. The crucible with ash was allowed to cool, transferred into a 100 ml beaker and a volume of 50 ml diluted hydrochloric acid (1 mole HCL) added to make the ash solution. This solution was then heated in a water bath for a period of an hour, filtered and the volume made up to 100 ml with distilled water.

Calcium standard solution was prepared by dissolving 0.624 g of calcium carbonate in 10 ml hydrochloric acid (10% v/v). The volume was made up to 250 ml using distilled water, different aliquots of standards and sample were pipette out and volume made up to 100 ml. The readings were taken using flame photometer photometer and the results were expressed in mg/100g.

3.1.3.9. Iron (mg/100g)

The iron content was determined by following the method adopted by Ranganna (2019), where iron in banana ash solution was converted to ferric form using potassium persulfate and thereafter treated with potassium thiocyanate to form the used ferric thiocyanate, which is calometrically measured at 780 nm with spectrophotometer (UV-Visible 1800 spectrophotometer, Shimadzhu, Kyoto, Japan) and the results expressed as mg/100g.

3.1.3.10. Potassium (mg/100g)

An ash solution was prepared by placing 5 g of fruit sample into the crucible, which was then ignited at 550-660^{o}C for 2-3 hours until there were no black particles left. The crucible with ash was allowed to cool, transferred into a 100 ml beaker, and

a volume of 50 ml of diluted hydrochloric acid (1 mole HCL) was added to make the ash solution. This solution was then heated in a water bath for a period of an hour, filtered, and the volume made up to 100 ml with distilled water.

Potassium standard solution was prepared by dissolving 0.477 g potassium chloride in 250 ml of distilled water. The different aliquots of standards and sample were pipette out and volume made up to 100 ml. The readings were taken using flame photometer and the results were expressed in mg/100g.

3.1.3.11. Antioxidant activity (DPPH, FRAP, ABTS) (µg/ml)

3.1.3.11.1. Antioxidant by DPPH assay

The DPPH (2, 2-diphenyl-1-picrylhydrazyl) free radical scavenging activity of banana samples was determined according to Schmidt *et al. (*2015) and Marjoni and Zulfisa (2017). An oven-dried banana sample was extracted in 80 per cent alcohol using the Soxhlet apparatus, and the extract was collected in a beaker. The extract was evaporated in a water bath and then dissolved in methanol at a 1:1 ratio.

Different aliquots of standards and samples were pipette out and 2.8 ml of methanol was added with 0.2 ml of DPPH (50 µM) reagent. The mixture was homogenized and left for 20 minutes in the darkness, and the absorbance was measured at 517 nm with a spectrophotometer (UV-Visible 1800 spectrophotometer, Shimadzhu, Kyoto, Japan). The antioxidant activity of the samples was determined by the amount of DPPH radical absorption resistance. The percentage of DPPH absorption inhibition was calculated using the formula;

$$\text{Per cent of DPPH quenched} = \frac{\text{OD of blank} - \text{OD of sample}}{\text{OD of blank}} \times 100$$

The IC50 values of each extract and fractions concentrations were calculated using the linear regression formula and the results expressed as µg/ml.

3.1.3.11.2. Antioxidant by FRAP assay

The ferric reducing antioxidant power (FRAP) assay on banana pulp was estimated by the following method adopted by Bashmil *et al.* (2021). The FRAP

reagent was prepared by adding 10 volumes of 300 mM sodium acetic buffer (3.1 g of sodium acetate plus 16 ml of glacial acetic acid/L) to 1 volume of 10 mM TPTZ prepared in 40 mM HCL and 1 volume of 20 mmM of ferric chloride. The mixture was pre-warmed to 37ºC and 3ml was added to 0.1ml of 80% (v/v) methanolic extract of each sample and held at 37ºC for 8 minutes. **S**tandard curves for each assay were prepared using ascorbic acid, and the results were expressed as mg of ascorbic acid equivalents/g.

3.1.3.11.3. Antioxidant by ABTS assay

The 2, 2'-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) on banana pulp was estimated by following the method adopted by Badhani *et al.* (2015) with some modifications. In 10ml of 7.0 µM ABT salt and 10ml of 2.45 µM potassium persulfate, they were combined to produce ABTS radical cations ($ABTS^{+}$) and kept in the dark at 221ºC for 16 hours. The ABTS radical solution was diluted to an absorbance of 0.70±0.05 at 734 nm using 80 per cent ethanol.

To make the sample extract, an oven-dried banana sample was extracted in 80 percent alcohol using a soxhlet apparatus and collected in a beaker. The extract was evaporated in a water bath and then dissolved in methanol at a 1:1 ratio. Different aliquots of samples were pipette out and standards made up to 0.10 ml with 80 per cent (v/v) methanol. Then 3.90 ml of the diluted $ABTS^{+}$ was added and mixed thoroughly.

The reaction mixture was allowed to stand for 6 minutes at 221ºC in the dark before its absorbance at 734 nm was measured using a spectrophotometer (UV-Visible 1800 spectrophotometer, Shimadzhu, Kyoto, Japan) in comparison to a blank prepared with 80 per cent (v/v) methanol. The amount of ABTS radical absorption resistance in the samples was used to determine their antioxidant activity. The formula was used to calculate the percentage of ABTS absorption inhibition. The amount of ABTS radical absorption resistance in the samples was determined by calculating the percentage of ABTS absorption inhibition using the formula;

$$\text{Per cent of ABTS quenched} = \frac{\text{OD of blank} - \text{OD of sample}}{\text{OD of blank}} \times 100$$

The IC50 values of each extract and fractions concentrations were calculated using the linear regression formula and the results expressed as µg/ml.

3.1.3.12. Total phenols (mg/100g)

Phenols were determined using the Sadasivam and Manickam (2008) method with some modifications, in which 1 g of ground sample was centrifuged in 10 ml of ethanol (80%) at 10,000 rpm for 20 minutes. The supernatant was re-extracted with five times the volume of 80 per cent ethanol, centrifuged, and the pool of supernatants was collected and evaporated to dryness using a water bath.

The residue remaining was dissolved in 5 ml of distilled water and different aliquots of standard and sample were pipetted out. The pipette aliquots were made up to 5 ml with distilled water and 0.5 ml of Folin-Ciocalteau reagent added. After 3 minutes, 2 mL of sodium carbonate (20%) sodium carbonate was added to each of the different aliquots, thoroughly mixed, and kept at room temperature for 60 minutes.

Thereafter, the absorbance was measured against a blank using a reagent blank at 650 nm using a spectrophotometer (UV-Visible 1800 spectrophotometer, Shimadzhu, Kyoto, Japan). The quantification of total phenolic contents was carried out using a calibration curve prepared and the results were expressed as mg of catechol equivalent per 100 g of sample.

3.1.3.13. Crude fibre (%)

The crude fiber was determined using an acid-base extraction approach described by Ranganna (2019). A dried sample of 2 g which had been extracted with petroleum ether was boiled in 200 ml of sulphuric acid for 30 minutes with bumping chips. It was then filtered through muslin cloth and washed with boiling water until the washings were no longer acidic.

The residue collected was boiled in a 200 ml sodium hydroxide (NaOH) solution for 30 minutes. The residue was filtered again through a muslin cloth and washed with 25 ml of sulphuric acid, 150 ml of water, and 25 ml of alcohol. The residue was removed, transferred to an ashing dish and dried for 2 hours at 130±2°C. The dish was cooled in a desiccator and weighed (W_2). Preheat the oven to for 30

minutes at 600±15ºC. It was then cooled in a dessicator and weighed (W3). The following formula was used to calculate crude fiber:

$$\text{Per cent crude fiber} = \frac{(W2-W1)\,(W3-W1)}{\text{Weight of the sample}} \times 100$$

Where:

W1= Weight of empty crusible

W2= Weight of crucible with residue

W3= Weight of ignited sample and crusible

3.1.3.14. Total carotenoids (µg/100g)

Total carotenoids were extracted with acetone and petroleum ether in a separating funnel, the anhydrous sodium sulphate was used to absorb excess moisture during extraction. Acetone (3%) was used as blank and optical density of the collected extract was measured at 452 nm (UV-Visible 1800 spectrophotometer, Shimadzhu, Kyoto, Japan) and results expressed as µg/100g material.

3.2. Experiment II: Evaluation of osmotic agents on quality of Intermediate Moisture (IM) banana

Longitudinal slices of ripe banana fruit from the six varieties were evaluated for the development of IM bananas using different osmotic agents in combination with ascorbic acid (AA) (antioxidant) and potassium metabisulphite (KMS) (antimicrobial) (Plate 3). Fruit slices were immersed in various osmotic agents for 8 hours before being dehydrated to constant moisture in a cabinet drier or a vacuum drier at 55–60ºC.

3.2.1. Collection of materials required for the development of IM banana

The study was carried out at the Department of Post Harvest Technology, College of Agriculture, Vellanikkara in the Thrissur district of Kerala using ripe fruits of banana varieties of different genomic groups, *viz*., Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) collected from Banana Research Station, Kannara. Nedunendran of

variety Nendran was used in the present study. The fruits of the respective varieties were used when the fruits were ripe but not over ripe fully yellow stage (Stage 6 of Plate 2).

Osmotic agents such as sucrose, glucose, sorbitol, palm sugar (a concentrated product of sap from the palm, *Borassus* spp.), honey, sodium chloride (NaCl), potassium meta-bisulphite, ascorbic acid lime (*Citrus aurantiifolia*) were purchased from the local market. Treatment combinations of osmotic agents used in the experiment were used as given below (Plate 3).

T1-sucrose solution (60^{o}Brix sucrose + 0.5% ascorbic acid + 0.25% potassium metabisulphite)

T2-glucose solution (60^{o}Brix glucose + 0.5% ascorbic acid + 0.25% potassium metabisulphite)

T3-sucrose + sorbitol solution (60^{o}Brix (50:50) sucrose: sorbitol + 0.5% ascorbic acid + 0.25 % potassium metabisulphite)

T4- glucose + sorbitol solution (60^{o}Brix (50:50) glucose: sorbitol + 0.5% ascorbic acid + 0.25% potassium metabisulphite)

T5-palm sugar solution (concentrated product of sap from the palm, *Borassus* sp) (60 ^{o}Brix + 0.5% ascorbic acid + 0.25% potassium metabisulphite)

T6- honey (pure honey + 0.5% ascorbic acid + 0.25% potassium metabisulphite)

T7-sucrose+NaCl solution (60^{o}Brix sucrose + 0.5% sodium chloride + 0.25% potassium metabisulphite).

3.2.2. The preparation steps adopted for development of intermediate moisture (IM) banana

The following procedure was adopted for intermediate moisture banana development

1. Banana fruits from the six banana varieties were cut into 8 mm longitudinal slices using a banana fruit slicer (Plate 3), followed by steam blanching for 2 minutes.

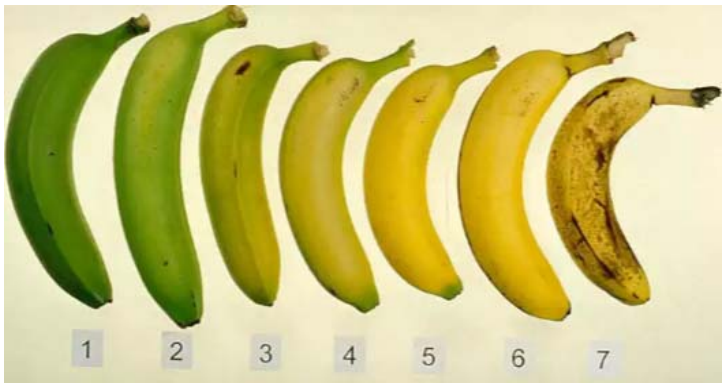
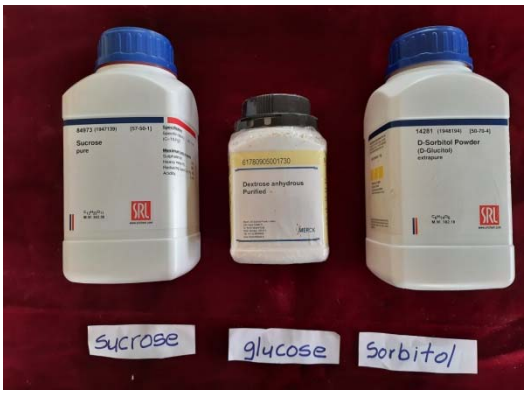


Plate 2. The colour chart for banana fruit to describe various stages of ripeness



Banana fruit slicer

Plate 3. Osmotic agents and banana fruit slicer used for the development of Intermediate Moisture (IM) banana

Cabinet drier

Vacuum drier

Water bath

Package material

Plate 4. The equipments and material used for the development of intermediate moisture banana

2. The blanched fruits were then immersed in ice cold water for 10 minutes followed by dipped in acid lime (*Citrus aurantiifolia*) juice for 30 minutes.

3. The banana fruit slices were subsequently immersed separately in seven different osmotic agents in combination with ascorbic acid (0.5%) and potassium metabisulphite (0.25%) at fruit to osmotic solution ratio of 1:2 for 8 hours.

4. The osmotic solution was then drained from the fruit slices and blotted using an absorbent paper and subsequently dried at 60ºC for two hours in a cabinet drier or vacuum drier to constant moisture (Plate 4).

3.2.3. Physical characteristics

The physical characteristics of intermediate moisture (IM) banana studied include the moisture content (%), weight loss (%), solid gain (%), water loss (%), water activity, colour values (*L*,a*,b**) and the equilibrium relative humidity (%).

3.2.3.1. Moisture content (%)

Moisture content of IM banana was determined using an infra-red moisture analyser (Hallmark Mechatronics, Model-Sartorius, MA 150C, Germany) which records moisture in percentage.

3.2.3.2. Weight loss (%)

Weight reduction per cent of IM banana was calculated by the method described by Sridevi and Genitha (2012) which is as follows:

$$\text{Weight reduction \% (WR)} = \frac{M_o - M}{M_o} \times 100$$

Where:

M_o = initial mass of sample (g)

M = mass of sample after dehydration (g)

3.2.3.3. Solid gain (%)

The solid gain per cent was calculated using the method adopted by Panagiotou *et al*. (1999) which is as follows;

Solid Gain % (SG) = $\frac{m-m_o}{M_o} \times 100$

Where:

m = dry mass (g) of fruit after time‘t’ of osmotic treatment

m_o = dry mass (g) of fresh fruit

M_o = initial mass (g) of fresh fruit prior to the osmotic treatment

3.2.3.4. Water loss (%)

The water loss percentage was calculated using the method described by Chavan *et al*. (2010) where per cent weight reduction (WR) and solid gain (SG) were summed WR+SG.

3.2.3.5. Water activity

Water activity was estimated using water activity meter (Aqua lab, Model- Pre 40412, Decagon Devices, USA) in which a digital output value was directly observed after filling the cup with a sample to about half of its capacity.

3.2.3.6. Equilibrium relative humidity (%)

Equilibrium relative humidity was obtained converting water activity value into a percentage.

3.2.3.7. Colour values (*L,* a** and *b**)

Colour values were determined by reflectance measurement, with a Minolta CM-3600D spectrophotometer (Konica Minolta Sensing, Inc., Osaka, Japan). D_{65} lamp was used as reference light source. The colour values L^*, a^* and b^* were analysed using JAYPAK 4808 software (Quality Control System, Version1.2). For the colour values L^* represent lightness, a^* for redness/browning and while b^* represent yellowness.

3.2.4. Biochemical parameters

The biochemical characteristics of intermediate moisture (IM) banana studied include total soluble solids (^{o} Brix), titratable acidity (%), total ash (%), pH, reducing

sugars (%), non- reducing sugars (%), total sugars (%),vitamin C (mg/100g),total carotenoids (µg/100g),total phenols (mg/100g) and non- enzymatic browning (NEB)

3.2.4.1. Total soluble solids (°Brix)

Total soluble solids was estimated as in 3.1.3.2.

3.2.4.2. Titratable acidity (%)

Titratable acidity was estimated as in 3.1.3.1.

3.2.4.3. Total ash (%)

Total ash was estimated as in 3.1.3.6.

3.2.4.4. pH

A 1:3 fruit-to-distilled-water ratio was homogenized and filtered through Whatman No. 1 filter paper. The electrodes of the pH meter were immersed in the sample, and the pH value was taken after the sample filtrate had stabilized.

3.2.4.5. Reducing sugars (%)

A known weight of sample was ground in a pestle and mortar and transferred into a 250 ml volumetric flask. A volume of about 100 ml distilled water was added followed by 2 ml pre-standardised 45 per cent neutral lead acetate for clarification. Excess lead acetate was neutralised by adding 2 ml of pre-standardised 22 per cent potassium oxalate solution.

The clarified solution was made up to the mark with distilled water and then filtered through Whatman No.1 filter paper**.** The reducing sugar was determined by titrating against Fehling's solution using methylene blue as an indicator. The reducing sugars were calculated by the formula as given below:

$$\text{Reducing sugars (\%)} = \frac{\text{Fehling's factor} \times \text{dilution}}{\text{Titre value} \times \text{weight of sample}} \times 100$$

3.2.4.6. Non reducing sugars (%)

Non-reducing sugar was calculated as a percentage by subtracting reducing sugar content from total sugar content (Ranganna, 2019).

Non-reducing sugars (%) = Total sugars (%) – reducing sugars (%)

3.2.4.7. Total sugars (%)

Total sugars were determined using the titration method mentioned by Ranganna (2019). A known weight of sample was ground in a pestle and mortar and transferred into a 250 ml volumetric flask. A volume of about 100 ml distilled water was added followed by 2 ml pre-standardised 45 per cent neutral lead acetate for clarification.

Excess lead acetate was neutralised by adding 2 ml of pre-standardised 22 per cent potassium oxalate solution. The clarified solution was made up to the mark with distilled water. The solution was then filtered through Whatman No.1 filter paper. Filtrate (50 ml) was taken into a 100 ml volumetric flask and 5 ml concentrated HCL was added for hydrolysing the sample.

The hydrolysed solution was then neutralised with 20 per cent NaOH by using one or two drops of phenolphthalein. Diluted HCL was added until the hydrolysed solution became colourless. Finally, the volume was made up to 100 ml and it was titrated against Fehlings solution using methylene blue as an indicator and the total sugars calculated as given below:

$$\text{Total sugars (\%)} = \frac{\text{Fehling's factor} \times 250 \times \text{dilution}}{\text{Titre value} \times 50 \times \text{weight of sample}} \times 100$$

Non-reducing sugars (%) = Total sugars (%) – reducing sugars (%)

3.2.4.8. Vitamin C (mg/100g)

Vitamin C was estimated as in 3.1.3.7.

3.2.4.9. Total carotenoids (µg/100g)

Total carotenoids were estimated as in 3.1.3.14.

3.2.4.10. Total phenols (mg/100g)

Total phenols were estimated as in 3.1.3.12.

3.2.4.11. Non-enzymatic browning (optical density value)

Non-enzymatic browning was determined using standard methods suggested by Zhu *et al.* (2009). 5 g of IM banana was homogenized with 5 ml of 95% ethyl alcohol and the sample was centrifuged at 5000 rpm for 10 minutes. The supernatant of the centrifuged sample was measured using a spectrophotometer at 420 nm using 95% ethanol as a blank, and the absorbance (optical density value) obtained was considered the non-enzymatic browning index**.**

3.2.5. Microbial analysis

The microbial analysis was conducted using the serial dilution plating technique for the isolation and enumeration of bacteria, *Escherichia coli*, fungi, and yeast. One-gram samples were added to 9 mL of sterile distilled water and the mixture was allowed to blend for five minutes. A 1ml sample from a 10^{-1} dilution was then transferred into a test tube containing 9 ml of sterile distilled water so as to get a dilution of 10^{-2}. Similarly, 10^{-3}, 10^{-4}, and 10^{-5} dilutions were prepared from these serial dilutions.

3.2.5.1. Estimation of bacterial population (cfu/g)

The bacterial population was estimated using a dilution of 10^{-5} on nutrient agar medium. One ml of 10^{-5} dilution was pipetted into a sterile petri dish using a micropipette. About 20 ml of the melted and cooled nutrient agar media was poured into the petri dish and swirled. After solidification, it was taken for incubation at room temperature. Three petri dishes were kept as replicates for each sample. The petri dishes were incubated at room temperature for 48 hours. The bacterial colonies were counted and expressed as cfu/g of sample.

3.2.5.2. Estimation of *Escherichia coli* (*E.coli*) population (cfu/g)

One mL of 10^{-5} dilution aliquot was pipetted into a sterile petridish using a micropipette. About 20 ml of the melted and cooled Eosin methylene blue (EMB

agar) media was poured into the petridish and it was swirled. After solidification, it was kept for incubation at room temperature. Three petridishes were kept as replicates for each sample. The petriplates were incubated at room temperature for 48 hours. The appearance of a metallic green sheen indicates the presence of *E. coli.*

3.2.5.3. Estimation of fungal population (cfu/g)

One ml of 10^{-3} dilution aliquot was pipetted into a sterile petri dish using a micropipette. About 20 ml of melted and cooled Potato Dextrose Agar (PDA) media was poured into the petri dish and it was swirled. After solidification, it was kept for incubation at room temperature. Three petri dishes were kept as replicates for each sample and incubated at room temperature for 48 hours. The fungal colonies developed at the end of five days were counted and expressed as cfu/g of the sample.

3.2.5.4. Estimation of yeast population (cfu/g)

One ml of 10^{-4} dilution aliquot was transferred into a sterile petri plate in triplicate, and a fourth plate was kept as a control sample. About 20 ml of Sabouraud Dextrose Agar (SDA) was poured into these plates and swirled in a clockwise and anticlockwise direction. All the plates were incubated at 37ºC for 48 hours. The yeast colonies developed at the end of 48 hours were counted and expressed as cfu/g of the sample.

3.2.6. Organoleptic evaluation

A panel of judges of different age groups was selected with care to evaluate the Intermediate Moisture (IM) banana for various sensory parameters such as appearance, colour, flavour, texture, odour, taste and overall acceptability, based on the 9 point hedonic scale rating. The samples were coded and presented to the judges the way they are normally consumed and no discussion during sensory evaluation was allowed. Plain water was given to the judges to rinse their mouth in between the evaluation of samples. A score of 5.5 and above was considered acceptable.

3.2.7. Cost of production

The cost of producing intermediate moisture bananas was calculated by deducting the costs of raw materials and labour charges incurred during the preparation process.

3.3. Standardisation of fruit to osmotic solution ratio and duration of immersion on quality of IM banana

Based on the physicochemical, organoleptic, and microbial stability of the IM banana, the fruit slices from the six banana varieties were immersed in the best osmotic solution from Experiment II at different ratios of fruit to solution (1:1, 1:2, 1:3, and 1:4) for varying periods of immersion (4, 8, and 12 hours). The osmotic solution temperature was placed at 40^{o}C by placing it in a water bath (Plate 4), and osmotic solution concentration of 60^{o}Brix. Liquid glucose was incorporated as one of the osmotic agents in the best final selected treatment. The osmodehydydrated fruits were then dehydrated using the best technique from Experiment II to constant moisture.

3.3.1. Physical characteristics

The physical characteristics of intermediate moisture (IM) banana studied include the moisture content (%), weight loss (%), solid gain (%), water loss (%), water activity, colour values (L^*,a^*,b^*) and the equilibrium relative humidity (%).

3.3.1.1. Moisture content (%)

The moisture content was estimated as in 3.2.3.1.

3.3.1.2. Weight loss (%)

The weight loss was estimated as in 3.2.3.2.

3.3.1.3. Solid gain (%)

The solid gain was estimated as in 3.2.3.3.

3.3.1.4. Water loss (%)

The water loss was estimated as in 3.2.3.4.

3.3.1.5. Water activity

Water activity was estimated as in 3.2.3.5.

3.3.1.6. Colour values (*L*,a*,b**)

The colour values (*L*,a*,b**) were estimated as in 3.2.3.7.

3.3.1.6. Equilibrium relative humidity (ERH) (%)

The equilibrium relative humidity was estimated as in 3.2.3.6.

3.3.2. Biochemical characteristics

The biochemical characteristics of intermediate moisture (IM) banana studied include total soluble solids (° Brix), titratable acidity (%), total ash (%), pH, reducing sugars (%), non- reducing sugars (%), total sugars (%),vitamin C (mg/100g),total carotenoids (µg/100g),total phenols (mg/100g) and non- enzymatic browning (NEB)

3.3.2.1 Total soluble solids (°Brix)

Total soluble solids was estimated as in 3.1.3.2.

3.3.2.2. Titratable acidity (%)

Titratable acidity was estimated as in 3.1.3.1.

3.3.2.3. Total ash (%)

Total ash was estimated as in 3.1.3.6.

3.3.2.4. pH

pH was estimated as in 3.2.4.4.

3.3.2.5. Reducing sugar (%)

Reducing sugars were estimated as in 3.2.4.5.

3.3.2.6. Non reducing sugars (%)

Non reducing sugars were estimated as in 3.2.4.6.

3.3.2.7. Total sugar (%)

Total sugars were estimated as in 3.2.4.7.

3.3.2.8. Vitamin C

Vitamin C was estimated as in 3.1.3.7.

3.3.2.9. Total carotenoids (µg/100g)

Total carotenoids were estimated as in 3.1.3.14.

3.4.2.10. Total phenols

Total phenols was estimated as in 3.1.3.12.

3.3.2.11. Non enzymatic browning

Non enzymatic browning index was estimated as in 3.2.4.11.

3.3.3. Microbial observations

3.3.3.1. Bacterial population (cfu/g)

Bacterial population was estimated as in 3.2.5.1.

3.3.3.2. Escherichia coli population (cfu/g)

Escherichia coli population was estimated as in 3.2.5.2.

3.3.3.3. Fungal population (cfu/g)

Fungal population was estimated as in 3.2.5.3.

3.3.3.4. Yeast population (cfu/g)

Yeast population was estimated as in 3.2.5.4

3.3.4. Organoleptic evaluation

Organoleptic evaluation was conducted as in 3.2.6.

3.3.5. Cost of production

Cost of production was estimated as in 3.2.7.

3.4. Study on packaging materials and storage temperature on quality of IM banana

Based on the physicochemical, organoleptic and microbial stability of the IM banana, 250g of IM banana of the best treatment from Experiment III was selected. IM banana was vacuum packaged in different packaging materials viz. LDPE (200 gauge) and polyethylene laminated aluminium pouches (Plate 4). The product was kept under ambient (32-34^{o}C) and low (5-7^{o}C) temperature to evaluate changes in the quality of the product during storage.

3.4.1. Physical characteristics

The physical characteristics of intermediate moisture (IM) banana studied include the moisture content (%), water activity, colour values (*L*,a*,b**), equilibrium relative humidity (%) and critical moisture point

3.4.1.1. Moisture content (%)

The moisture content was estimated as in 3.2.3.1.

3.4.1.2. Water activity

Water activity was estimated as in 3.2.3.5.

3.4.1.3. Colour values (*L*,a*,b**)

The colour values (*L*,a*,b**) were estimated as in 3.2.3.7.

3.4.1.4. Equilibrium relative humidity (ERH) (%)

The equilibrium relative humidity was estimated as in 3.2.3.6.

3.4.1.5. Critical moisture content

The weight equilibrium method proposed by Wink (1946) and Rai *et al.* (2004) was used to calculate the critical moisture content of intermediate moisture (IM) bananas. Two grams of IM banana were weighed and subjected to relative humidity levels ranging from 0 to 100 per cent of the ambient temperature. At a 24-

hour interval, the weight gain or loss of IM bananas was determined for each humidity level. The observations for product appearance and the presence of mould growth were made in order to determine critical moisture content.

3.4.2. Biochemical characteristics

The biochemical characteristics of intermediate moisture (IM) banana studied include total soluble solids (° Brix), titratable acidity (%), total ash (%), pH, reducing sugars (%), non- reducing sugars (%), total sugars (%),vitamin C (mg/100g),total carotenoids (µg/100g),total phenols (mg/100g), non- enzymatic browning (NEB) and shelf life.

3.4.2.1. Total soluble solids (°Brix)

Total soluble solids were estimated as in 3.1.3.2.

3.4.2.2. Titratable acidity (%)

Titratable acidity was estimated as in 3.1.3.1.

3.4.2.3. Total ash (%)

Total ash was estimated as in 3.1.3.6.

3.4.2.4. pH

pH was estimated as in 3.2.4.4.

3.4.2.5. Reducing sugar (%)

Reducing sugars were estimated as in 3.2.4.5.

3.4.2.6. Non reducing sugars (%)

Non reducing sugars were estimated as in 3.2.4.6.

3.4.2.7. Total sugar (%)

Total sugars were estimated as in 3.2.4.7.

3.4.2.8. Vitamin C

Vitamin C was estimated as in 3.1.3.7.

3.4.2.9. Total carotenoids (µg/100g)

Total carotenoids were estimated as in 3.2.4.9.

3.4.2.10. Total phenols

Total phenols were estimated as in 3.1.3.12.

3.4.2.11. Non enzymatic browning

Non enzymatic browning index was estimated as in 3.2.4.11.

3.4.2.12. Shelf life (days)

The shelf life of intermediate moisture banana was determined by direct method as implicated by New Zealand Food Safety Authority (2005) which is based on sensory evaluation, microbiological tests, chemical and physical tests.

3.4.3. Microbial observations

3.4.3.1. Bacterial population (cfu/g)

Bacterial population was estimated as in 3.2.5.1.

3.4.3.2. *Escherichia coli* population (cfu/g)

Escherichia coli population was estimated as in 3.2.5.2.

3.4.3.3. Fungal population (cfu/g)

Fungal population was estimated as in 3.2.5.3.

3.4.3.4. Yeast population (cfu/g)

Yeast population was estimated as in 3.2.5.4.

3.4.4. Organoleptic evaluation

Organoleptic evaluation was conducted as in 3.2.6.

3.4.5. Cost of production

Cost of production was estimated as in 3.2.7.

3.5. Analysis of data

The experiment was laid out in a completely randomised design with three replications and presented as means in one way ANOVA to examine the significant differences using Web Based Agricultural Statistics Software Package (WASP) for analysis. Duncan's multiple range test was used for the comparison of means at 95% confidence level (p=.05). Qualitative analysis of fruit characters were quantified using unweighed scoring method and subsequently subjected to clustering analysis using SPSS version 20 windows (IBM SPSS Inc.,Chicago,IL) software, using Euclidean distances and presented as a two dimensional dendrogram.

RESULTS

4. RESULTS

The results of the present study conducted in the Department of Post Harvest Technology, College of Agriculture under the project 'Evaluation of banana (*Musa* spp.) varieties for the development of Intermediate Moisture Fruit (IMF)' are presented in this chapter under the following headings;

4.1. Characterization of banana varieties for horticultural and biochemical traits

4.2 Evaluation of osmotic agents on quality of Intermediate Moisture (IM) banana

4.3 Standardization of fruit to osmotic solution ratio and duration of immersion on the quality of IM banana

4.4 Study on packaging materials and storage temperature on quality of IM banana

EXPERIMENT -1

4.1 Characterization of banana varieties for horticultural and biochemical traits

The present study was conducted with the objective of characterizing banana varieties of Kerala *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) for their suitability in the development of Intermediate Moisture (IM) fruit. Nendunendran of the variety Nendran was used in the present study. The genomic groups were determined using Simmonds and Shepherd (1955) nomenclature scheme for edible cultivated bananas, which is based on ploidy level and morphological characteristics. The fruits of the respective cultivars were collected from the Banana Research Station in Kannara, Kerala's Thrissur district, where they were grown under uniform conditions in accordance with the Kerala Agricultural University's Package of Practices recommendations.

4.1.1 Evaluation of banana varieties for morphological characteristics

The fruit morphological characteristics of six banana varieties, namely Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA), were investigated and are presented in Table 1 and Plates 5-7. Fruit samples were taken from the bunch's mid-hand and

youngest hand, and the 25 morphological descriptors used were fruit position, number of fruits, fruit length, fruit shape, transverse section of fruit, fruit apex, remains of flower relicts at fruit apex, fruit pedicel length, fruit pedicel width, pedicel surface, fusion of pedicels, immature fruit peel colour, mature fruit peel colour, fruit peel thickness, adherence of the fruit to the peel, cracks in fruit peel, pulp in fruit, pulp colour before maturity, pulp colour at maturity, fruit fall from hands, flesh texture, predominant taste, presence of seed with source of pollen, seed surface and seed shape. The varieties were found to exhibit considerable variability for fruit characters.

4.1.1.1 Fruit position

Table 1 and Plate 5 show the symmetrical position of the fruit around the stalk. Nendran (AAB) and Pisang Lilin (AA) varieties had fruit positions that were perpendicular to the stalk, whilst Njalipoovan (AB) and Yangambi km5 (AAA) varieties had fruit positions that were curved towards the stalk. The fruit positions of the varieties Karpooravalli (ABB) and Grand Naine (AAA) were both curved upwards and parallel to the stalk, respectively.

4.1.1.2 Number of fruits per hand

Table 1 reveals the number of fruits observed on the mid-hand of the bunch. Variety Nendran (AAB) had a number of fruits of ≤12, while other observed varieties, *viz.* Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) recorded 13-16 fruits on the mid-hand of the bunch.

Table 1: Evaluation of banana (*Musa* spp.) varieties for morphological characteristics

Sl. No.	Character	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	GrandNaine (AAA)	Yangambi km5 (AAA)
1	Fruit position	Perpendicular to the stalk	Perpendicular to the stalk	Curved upward	Curved towards the stalk	Parallel to the stalk	Curved towards the stalk
2	Number of fruits on the mid-hand	≤12	13-16	13-16	13-16	13-16	13-16
3	Fruit length (cm)	21-25	≤15	≤15	≤15	16-20	≤15
4	Fruit shape	Straight at the distal end	Straight at the distal end	Slightly curved	Slightly curved	Slightly curved	Slightly curved
5	Transverse section of fruit	Pronounced ridges	Rounded	Rounded	Slightly ridged	Slightly ridged	Rounded
6	Fruit apex	Lengthily pointed	Lengthily pointed	Bottlenecked	Bottle necked	Blunt tipped	Bottlenecked
7	Remains of flower relicts at fruit apex	Base of the style prominent	Without any floral relicts	Base of style prominent	Base of the style prominent	Persistent style	Persistent style
8	Fruit pedicel length (mm)	≥21	≤10	11-20	≥21	11-20	11-20
9	Fruit pedicel width (mm)	>10	>10	5-10	5-10	>10	>10
10	Pedicel surface	Hairless	Hairless	Hairless	Hairless	Hairless	Hairless
11	Fusion of pedicels	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion	No visible sign of fusion
12	Immature fruit peel colour	149C Medium green	149A Medium green	149A Ashy green	149A Light green	149A Medium green	144D Light yellowish

							green
13	Mature fruit peel colour	7B Yellow	7D Yellow	2C Yellow with ashy tint	7C Yellow	12C Bright yellow	1B Yellow
14	Fruit peel thickness (mm)	Three or more	Two or less	Two or less	Two or less	Three or more	Two or less
15	Adherence of the fruit to the peel	Fruit peels easily	Fruit peels easily	Fruit peels easily	Fruit peels easily	Fruit peels easily	Fruit peels easily
16	Cracks in fruit peel	Without cracks	Without cracks	Without cracks	Without cracks	Without cracks	Without cracks
17	Pulp in fruit	With pulp	With pulp	With pulp	With pulp	With pulp	With pulp
18	Pulp colour before maturity	Light orange yellow	Cream	Cream	White	Cream	Cream
19	Pulp colour at maturity	Orange yellow	Cream	Cream	White	Cream	Cream
20	Fruit fall from hands	Persistent	Deciduous	Persistent	Persistent	Deciduous	Persistent
21	Flesh texture	Firm	Firm	Firm	Firm	Soft	Soft
22	Predominant taste	Sweet (like Cavendish)	Sweet and acidic	Mild, slightly tasty or tasteless	Sweet (like Cavendish)	Sweet (like Cavendish)	Sweet(like Cavendish)
23	Presence of seed with source of pollen	ND	ND	ND	ND	ND	ND
24	Seed surface	ND	ND	ND	ND	ND	ND
25	Seed shape	ND	ND	ND	ND	ND	ND

ND= Not detected

Nendran (AAB)

Pisang Lilin (AA)

Karpooravalli (ABB)

Njalipoovan (AB)

Grand Naine (AAA)

Yangambi km5 (AAA)

Plate 5: Arrangement of fruit around the stalk of the six selected banana (*Musa* spp.*)* varieties

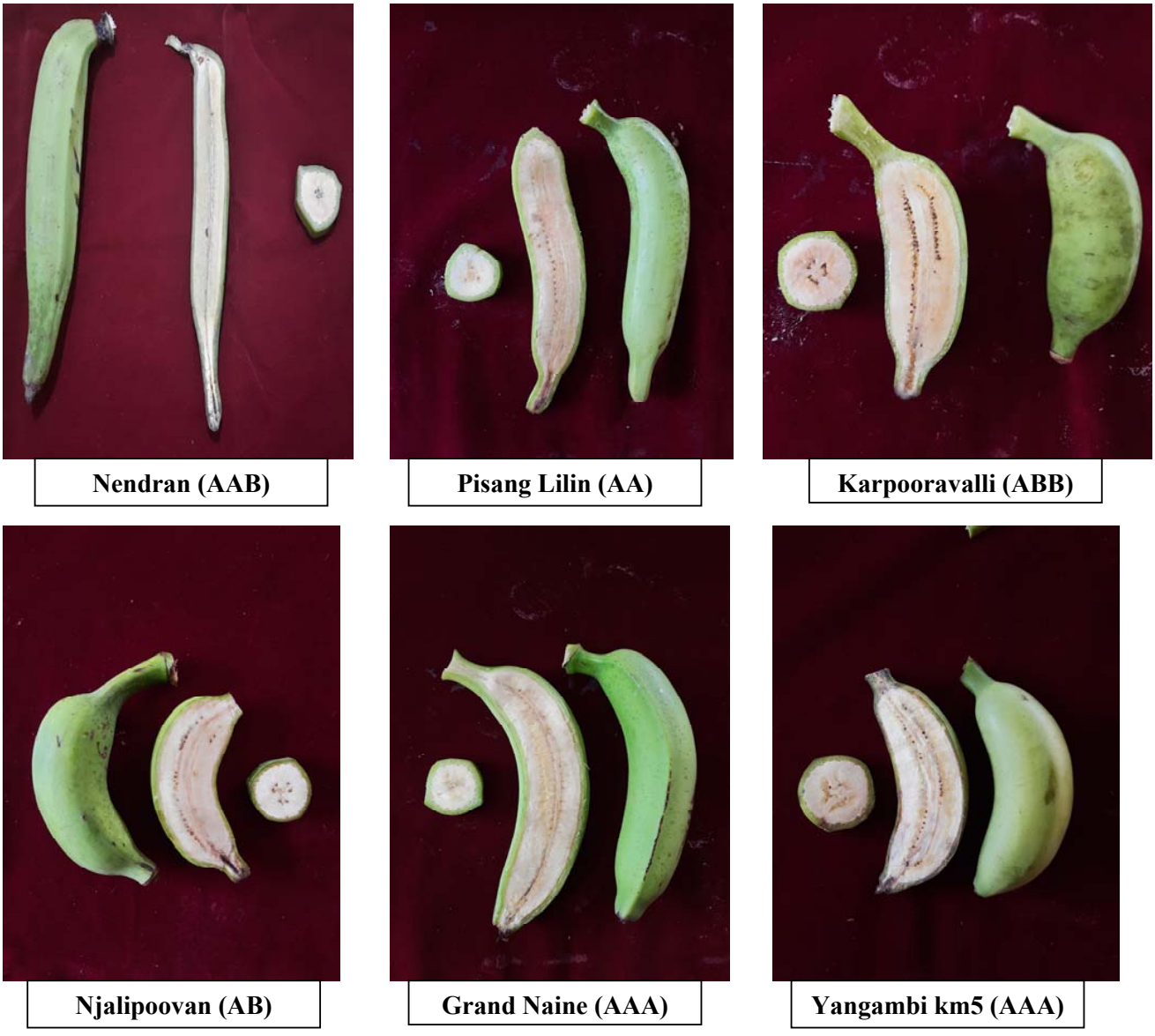


Plate 6: Unripe fruits of the six selected banana (*Musa* spp.) varieties

Nendran (AAB)

Pisang Lilin (AA)

Karpooravalli (ABB)

Njalipoovan (AB)

Grand Naine (AAA)

Yangambi km5 (AAA)

Plate 7: Ripe fruits of the six selected banana (*Musa* spp.) varieties

4.1.1.3 Fruit length (cm)

The fruit length (cm) of the internal arc of banana fruit without a pedicel at maturity is revealed in Table 1. The longest fruit length was recorded in the variety Nendran (AAB) in a range of 21–25 cm, followed by Grand Naine (AAA) with a fruit length range of 16–20 cm. Shorter fruit lengths were recorded for varieties of Pisang Lilin (AA), Karpooravalli (AB), Njalipoovan (AB) and Yangambi km5 (AAA), where fruit lengths varied from 13 to 16 cm.

4.1.1.4 Fruit shape (longitudinal curvature)

The fruit shape of banana varieties observed in the mid-hand of the bunch is given in Table 1. The fruit shape of Nendran (AAB) and Pisang Lilin (AA) was recorded as straight at the distal end, while varieties of Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) were observed to have a fruit shape that was slightly curved.

4.1.1.5 Transverse section of the fruit

A transverse section of the six mature banana fruits is provided in Table 1. Variety Nendran (AAB) had a transverse section with pronounced ridges, whereas Pisang Lilin (AA), Karpooravalli (ABB), and Yangambi km5 (AAA) had round transverse sections. Njalipoovan (AB) and Grand Naine (AAA) both had transverse sections that were slightly ridged.

4.1.1.6 Fruit apex

Table 1 shows the fruit apex observed at the distal end of fruit among the six banana varieties. Variety Nendran (AAB) and Pisang Lilin (AA) had long, pointed fruit apices, whereas Karpooravalli (ABB), Njalipoovan (AB), and Yangambi km5 (AAA) had bottleneck fruit apices. Grand Naine (AAA) was recorded as the only fruit among the six selected varieties of the present study to have a fruit apex that is blunt.

4.1.1.7 Remains of the flower relics at fruit apex

Remains of flower relics at the fruit apex among the six banana varieties are presented in Table 1. The varieties Nendran (AAB), Karpooravalli (ABB) and

Njalipoovan (AB) recorded a prominent base of style, while varieties Grand Naine (AAA) and Yangambi km5 (AAA) had a persistent style. The Pisang Lilin variety had no floral relics at the fruit apex.

4.1.1.8 Fruit pedicel length (mm)

The fruit pedicel length of the six selected banana varieties under study is presented in Table 1. Nendran (AAB) and Njalipoovan (AB) had long pedicel lengths (≥21 mm), while Karpooravalli (ABB), Grand Naine, and Yangambi km5 (AAA) had pedicel lengths ranging from 11 to 20 mm, and Pisang Lilin (AA) had a fruit pedicel length of ≤10 mm.

4.1.1.9 Fruit pedicel width (mm)

Table 1 presents the fruit pedicel length of banana varieties under investigation. Nendran (AAB), Pisang Lilin (AA), Grand Naine (AAA), and Yangambi km5 (AAA) banana varieties had long (>10 mm) fruit pedicel widths, whereas Karpooravalli (ABB) and Njalipoovan (AB) banana varieties had fruit pedicel widths ranging from 5 to 10 mm.

4.1.1.10 Pedicel surface

Table 1 reveals the pedicel surface among the six banana varieties under evaluation, *viz.,* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) as hairless.

4.1.1.11 Fusion of pedicels (before joining the crown)

In Table 1, no visible signs of fusion of the fruit pedicels to the crown among the six banana varieties evaluated, *viz.,* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) were observed.

4.1.1.12 Immature fruit peel colour

Immature fruit peel colour among the six banana varieties under study is recorded in Table 1 and Plate 6. The immature fruit peel colour of the varieties Nendran (AAB), Pisang Lilin (AA), and Grand Naine (AAA) was medium green,

whereas the Karpooravalli (ABB) variety had an ashy green fruit peel colour. The immature fruit peel colour for varieties, Njalipoovan (AB) and Yangambi km5 (AAA), was observed to be light green and light yellowish green, respectively.

4.1.1.13 Mature fruit peel colour

The mature fruit peel colour of banana varieties under study is presented in Table 1 and Plate 7. More than half of the investigated varieties had yellow fruit peel at maturity, *viz.,* Nendran (AAB), Pisang Lilin (AA), Njalipoovan (AB) and Yangambi km5 (AAA). Mature fruit peel of ashy yellow and bright yellow was observed in the varieties Karpooravalli (ABB) and Grand Naine (AAA), respectively.

4.1.1.14 Fruit peel thickness

Table 1 of the results reveals a thick (≥3 mm) fruit peel thickness in varieties Nendran (AAB) and Grand Naine (AAA), while other varieties, *viz.* Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB) and Yangambi km5 (AAA), were observed to possess thin (≤ 2mm) fruit peels.

4.1.1.15 Adherence of the fruit peel

Table 1 reveals that the fruit peels among all banana varieties investigated in the present study, *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) could be easily separated from the fruit.

4.1.1.16 Cracks in fruit peel

Table 1 of results reveals no cracks in the fruit peels of banana varieties selected in the present study, *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA).

4.1.1.17 Pulp in fruit

Table 1 reveals content of fruit pulp among all banana varieties investigated, *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA).

4.1.1.18 Pulp colour before maturity

The immature pulp colour of the banana varieties selected for the present study is revealed in Table 1. Pisang Lilin (AA), Karpooravalli (ABB), Grand Naine (AAA), and Yangambi km5 (AAA) had a cream immature pulp colour, whereas Nendran (AAB) and Njalipoovan (AB) immature pulp colour of light orange yellow and cream pulp, respectively.

4.1.1.19 Pulp colour at maturity

The mature pulp colour of the six selected banana varieties is presented in Table 1. A significant number of banana varieties under study, *viz.* Pisang Lilin (AA), Karpooravalli (ABB), Grand Naine (AAA) and Yangambi km5 (AAA) had a cream-coloured pulp at maturity, whilst varieties of Nendran (AAB) and Njalipoovan (AB) had orange-yellow and cream pulp, respectively.

4.1.1.20 Fruits fall from hands

Table 1 reveals varieties Nendran (AAB), Karpooravalli (ABB), Njalipoovan (AB) and Yangambi km5 (AAA) as having persistent fruit fall from their hands at maturity, while varieties Pisang Lilin (AA) and Grand Naine (AAA) had deciduous fruit fall from their hands.

4.1.1.21 Flesh texture

Table 1 reveals a significant proportion of banana varieties in the present study, *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), and Njalipoovan (AB) with a firm textured pulp at maturity, while varieties Grand Naine (AAA) and Yangambi km5 (AAA) recorded soft textured fruit pulp at maturity.

4.1.1.22 Predominant taste

The predominant tastes of the banana varieties in the present study are presented in Table 1. Nendran (AAB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA) banana varieties were discovered to have a sweet flavour similar to Cavendish. Pisang Lilin (AA) had a predominant taste that was noted as sweet and acidic, whereas Karpooravalli (ABB) was recorded as having a mild,

slightly tasty, and tasteless taste, as per the banana descriptors of *Musa* spp. described by IPIGRI (1996).

4.1.1.23 Presence of seed with pollen

Table 1 shows that there was no seed detected among all the banana varieties that were under study, *viz*. Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA).

4.1.1.24 Seed surface

Table 1 of the results shows that no seed surface was identified because no seed was detected in any of the banana varieties studied, namely Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA).

4.1.1.25 Seed shape

Table 1 of the results shows that no seed shape was identified because no seed was detected in any of the banana varieties studied, namely Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA).

Table 2: Evaluation of banana (*Musa* spp.) varieties for horticultural characteristics

Banana varieties	Average number of fruits per hand	Fruit length(cm)	Fruit pedicel length (mm)	Fruit pedicel width (mm)	Fruit peel thickness (mm)	Fruit pulp weight (g)	Fruit peel weight (g)	Fruit to peel ratio	Fruit flesh firmness (cm^2kg^{-1})
Nendran	12.33	22.07^{a}	28.54^{a}	11.56^{a}	3.10^{a}	89.20^{a}	49.30^{a}	1.81^{d}	0.08^{a}
Pisang Lilin	11.67	14.03^{bc}	9.82^{c}	10.23^{ab}	1.45^{cd}	43.87^{de}	18.97^{c}	2.32^{c}	0.06^{b}
Karpoorvalli	15.67	10.67^{c}	16.41^{b}	7.97^{c}	1.17^{d}	46.50^{cd}	9.65^{d}	4.81^{a}	0.06^{b}
Njalipoovan	15.67	12.17^{bc}	26.00^{a}	9.57^{bc}	1.74^{cd}	33.03^{e}	9.60^{d}	3.41^{b}	0.09^{a}
Grand Naine	15.67	19.01^{a}	17.30^{b}	10.15^{ab}	2.56^{ab}	62.30^{b}	23.20^{b}	2.69^{c}	0.04^{c}
Yangambi km5	13.67	14.67^{bc}	17.58^{b}	10.90^{ab}	2.02^{bc}	55.89^{bc}	17.39^{c}	3.20^{b}	0.04^{c}
CD (0.05)	NS	3.96	5.53	1.70	0.61	11.16	3.57	0.45	0.02

4.1.2 Evaluation of banana varieties for horticultural characteristics

The horticultural characteristics of the fruit such as the number of fruits per hand, fruit length, fruit pedicel length, fruit pedicel width, fruit peel thickness, fruit pulp weight, fruit peel weight, fruit to peel ratio and fruit flesh firmness were evaluated.

4.1.2.1 The average number of fruits per hand

The average number of fruits per hand for the varieties Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA) is shown in Table 2. The average number of fruits per hand was not significantly different amongst the six banana varieties studied, which ranged from 11.67 to 15.67.

4.1.2.2 Fruit length (cm)

Table 2 shows the fruit length of the six banana varieties selected for this study. Fruit length varied significantly amongst varieties, with Nendran (ABB) and Grand Naine (AAA) having the highest fruit lengths of 22.07 and 19.01 cm, respectively. Banana varieties Pisang Lilin (AA), Njalipoovan (AB), and Yangambi km5 (AAA) had fruit lengths ranging from 12.17 to 14.67 cm with no variation. The shortest fruit length was recorded at 10.67cm in Karpooravalli (ABB).

4.1.2.3 Fruit pedicel length (mm)

Table 2 shows the fruit pedicel length of the six banana cultivars under study. A significant difference in the fruit pedicel length among banana varieties was observed, with Nendran (AAB) and Njalipoovan (AB) recording the longest fruit pedicel lengths of 28.54 mm and 26.00 mm, respectively. A range of 16.41 and 17.58 mm was recorded among varieties of Karpooravalli (ABB), Grand Naine (AAA), and Yangambi km5 (AAA), with no variation. The variety Njalipoovan has the shortest fruit pedicel length of 9.82 mm.

4.1.2.4 Fruit peel thickness (mm)

Table 2 reveals that the thickness of the fruit peel varies significantly between banana varieties, ranging from 1.17 to 3.10 mm. Nendran (AAB) had the thickest peel at 3.10 mm, followed by Grand Naine (AAA) and Yangambi km5 (AAA) at 2.56 and 2.02 mm, respectively. Among all the banana varieties under observation, variety Karpooravalli (ABB) had the lowest fruit peel thickness of 1.17 mm.

4.1.2.5 Fruit pulp weight (g)

A significant variation among the fruit pulp weights of different banana varieties was observed (Table 2). A significantly high pulp weight of 89.20 g was recorded in the variety Nendran (AAB), followed by 62.30 and 55.89 g in Grand Naine and Yangambi km5 (AAA), respectively. Lowest pulp weight value of 33.03 g was recorded in the variety Njalipoovan (AB).

4.1.2.6 Fruit peel weight (g)

A significant difference in fruit peel weight was observed among different banana varieties under study (Table 2). Variety Nendran (AAB) had the highest fruit peel weight of 49.30 g, followed by Grand Naine (AAA) with a fruit peel weight of 23.20 g. No significant difference in fruit peel weight was observed between varieties of Pisang Lilin (AA) and Yangambi km5 (AAA), where values of 18.97 and 17.39 g were observed, respectively. Njalipoovan (AB) and Karpooravalli (ABB) had lower fruit peel weights of 9.60 and 9.65 g, respectively.

4.1.2.6 Fruit to peel ratio

The fruit-to-peel ratio of the various banana varieties studied differed significantly (Table 2). Variety Karpooravalli (ABB) had the highest fruit to peel ratio of 4.81, followed by varieties Njalipoovan (AB) and Yangambi km5 (AAA) with 3.41 and 3.20,

respectively, with no difference. The variety Nendran (AAB) had the lowest fruit to peel ratio of 1.81.

4.1.2.7 Fruit flesh firmness (cm^2kg^{-1})

Table 2 reveals a significant difference in the firmness of the fruit flesh between the different banana varieties under study. Fruit flesh firmness was highest in the varieties Njalipoovan (AB) and Nendran (ABB), with 0.09 cm^2kg^{-1} and 0.08 cm^2kg^{-1}, respectively, which were followed by Pisang Lilin (AA) and Karpooravalli (ABB), both with 0.06 cm^2kg^{-1}. Lowest fruit flesh firmness of 0.04 cm^2kg^{-1} was recorded in the varieties Grand Naine (AAA) and Yangambi km5 (AAA).

4.1.3 Biochemical traits

Different banana varieties, namely Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA) were collected at firm, ripe but not over ripe full yellow stage. The fruits were analyzed for the biochemical traits like titratable acidity (%), total soluble solids(^{o}Brix), total protein (g/100g), total carbohydrates (g/100g), total fat (%), total ash (%), vitamin C (mg/100g), calcium (mg/100g), iron (mg/100g), potassium (mg/100g), antioxidant activity (DPPH, FRAP, ABTS), total phenols (mg/100g), crude fibre (%) and total carotenoids (µg/100g) were evaluated and presented in Table 3.

4.1.3.1 Titratable acidity (%)

There were no significant differences in the titratable acidity of the various banana varieties used in this study (Table 3). The titratable acidity range for banana varieties was 0.18 to 0.34 per cent, with Pisang Lilin (AA) having the lowest and Nendran (AAB) having the highest.

4.1.3.2 Total soluble solids (^{o}Brix)

There was a significant difference in the total soluble solids (TSS) content of banana varieties (Table 3). Nendran (ABB) had the highest TSS value of 23.90 ^{o}Brix,

followed by Pisang Lilin (AA), Grand Naine (AAA), and Karpooravalli (ABB) varieties, which both had total soluble solids of more than 20°Brix. The lowest TSS (16.43°Brix) was recorded in the variety Njalipoovan (AB).

4.1.3.3 Total protein (g/100g)

The protein content of the banana varieties chosen for this investigation did not differ significantly (Table 3). Protein content ranged from 1.67 to 2.72 g/100 g, with the Pisang Lilin (AA) and Grand Naine (AAA) varieties having the lowest and highest protein content, respectively.

4.1.3.4 Total carbohydrates (g/100g)

There was no significant difference in the carbohydrate content of the six banana varieties studied, which ranged from 24.70 to 37.51 g/100 g. (Table 3). Variety Nendran (AAB) had the highest carbohydrate content of 37.51 g/100g, followed by variety Karpooravalli (ABB) with 33.87 g/100g. The variety Grand Naine (AAA) had the lowest carbohydrate content, with 24.70 g/100g.

4.1.3.5 Total fat (%)

There was no significant variation in total fat content between the six varieties of banana studied, which ranged from 0.13 to 0.41 per cent (Table 3). Njalipoovan (AB) had the highest total fat content of 0.41 per cent, while Karpooravalli (ABB) had the lowest fat content of 0.13 per cent.

4.1.3.6 Total ash (%)

The total ash content was significantly varied between the six banana varieties under evaluation, with ranges of 1.16 and 14.89 per cent. The highest ash content of 14.89 per cent was recorded in the variety Nendran (AAB), followed by Karpooravalli (ABB) at 9.30 per cent. The variety Grand Naine (AAA) was found to have a low ash percentage of 1.16 per cent.

4.1.3.7 Vitamin C (mg/100g)

Table 3 shows no variation in vitamin C content between varieties in the present study, where a range of between 8.00 and 17.33 mg/100g was observed. The variety Karpooravalli (ABB) had a high vitamin C level of 17.33 mg/100g, followed by Pisang Lilin (AB) and Karpooravalli (ABB), which both had a vitamin C value of 13.33 mg/100g. The variety Yangambi km5 (AAA) has the lowest vitamin C concentration, with 8.00 mg/100g.

4.1.3.8 Calcium (mg/100g)

Table 3 reveals a significant difference in the calcium content among the six banana varieties under observation, which ranged from 69.90 to 168.90 mg/100g. The variety Yangambi showed the highest calcium content of 168.90 mg/100g, which was significantly different from other varieties such as Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA), where no variation in calcium content was observed among these varieties.

4.1.3.9 Iron (mg/100g)

There was no significant variation in iron content among banana varieties, which ranged from 0.40 to 0.89 mg/100g (Table 3). The variety Njalipoovan (AB) had the highest iron concentration, with 0.89 mg/100 g, followed by 0.84 mg/100 g in the variety Pisang Lilin (AB). The variety Yangambi km5 (AAA) had the lowest iron concentration, with 0.40 mg/100g.

4.1.3.10 Potassium content (mg/100g)

The potassium content of the six banana varieties selected in this study differed significantly (Table 3). Yangambi km5 (AAA) had the highest potassium content at 406.60 mg/100g, followed by the Pisang Lilin (AA) and Karpooravalli (ABB) varieties,

which had 346.80 and 335.33 mg/100g, respectively. Lowest potassium content of 187.27mg/100g was found in the variety Grand Naine (AAA).

4.1.3.11 Antioxidants (DPPH, FRAP and ABTS)

There was a significant difference in DPPH scavenging activity among banana varieties in this investigation (Table 3). Yangambi km5 (AAA) had the highest DPPH scavenging capacity, followed by Karpooravalli (ABB) and Nendran (AAB), with values of 134.00, 167.79, and 205.61 µg/mL. Pisang Lilin (AA) had the lowest (271.27 µg/mL) DPPH scavenging capacity.

In FRAP antioxidant assay, significant variation was found among the banana varieties in the present study, where radical scavenging activity ranged from 0.29 to 0.39 mg/AAE/g (Table 3). Njalipoovan (AB) and Yangambi km5 (AAA) varieties had the highest FRAP scavenging activity of 0.29 and 0.33 mg/AAE/g, respectively, while Nendran (AAB), Grand Naine (AAA), and Pisang Lilin (AA) varieties had the lowest at 0.39, 0.38, and 0.37 mg/AAE/g, respectively.

There was no significant difference in ABTS scavenging activity among banana varieties in this investigation (Table 3). However, the highest (0.02 µg/mL) ABTS scavenging capacity was recorded in the variety Pisang Lilin (AA), followed by Karpooravalli (ABB) and Yangambi km5 (AAA), which both recorded an ABTS scavenging capacity of 0.03 µg/mL. The lowest (0.03 µg/mL) ABTS scavenging capacity was recorded in the varieties Nendran (AAB), Njalipoovan (AB) and Grand Naine (AAA).

4.1.3.12 Total phenols (mg/100g)

A considerable variation was found in total phenol values between the six varieties under study (Table 3). Variety Grand Naine (AAA) had the highest total phenol content at 57.50 mg/100 g, followed by 39.12 mg/100 g for Njalipoovan (AAA) and

28.33 mg/100 g for Yangambi km5 (AAA). The lowest phenol content among the banana varieties under study was recorded at 13.23 mg/100g for the variety Pisang Lilin (AA).

4.1.3.13 Total crude fibre (%)

The total crude fibre content did not significantly vary among the selected banana varieties in the present study (Table 3). The total crude fibre was in the range between 0.17 and 0.90 per cent, with the highest value being in the variety Nendran (AAB), and the lowest crude fibre content being in the variety Pisang Lilin (AA).

4.1.3.14Total carotenoid content (µg/100 g)

The variance in total carotenoids content of the six banana varieties adopted in this study is shown in Table 3. Variety Nendran (AAB) had the highest carotenoids content, with 533.55 µg/100 g, followed by Yangambi km5 (AAA) with 433.27 µg/100 g. Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), and Grand Naine (AAA) were not statistically different, although Grand Naine (AAA) had the lowest (151.50 µg/100 g) value for total carotenoids among all varieties under observation.

Table 3: Biochemical characteristics of banana (*Musa spp*.) varieties

Varieties	TA (%)	TSS (^{o}Brix)	Total protein (g/100g)	Total carbohydrate (g/100g)	Total fat (%)	Total ash (%)	Vit. C (mg/100g)	Ca (mg/100g)	Fe (mg/100g)	K (mg/100g)	Antioxidants			Total phenols (mg/100g)	Crude fibre (%)	Total carotenoids (µg/100g)
											DPPH (µg/mL)	FRAP (mg/AAE /g)	ABTS (µg/mL)			
Nendran	0.34	23.90^{a}	2.31	37.51	0.31	14.89^{a}	12.57^{a}	82.50^{b}	0.67	237.67^{bc}	205.61^{c}	0.39^{a}	0.04	20.00^{de}	0.90	533.55^{a}
Pisang Lilin	0.18	21.67^{ab}	1.67	26.00	0.38	6.01^{c}	13.33^{a}	92.50^{b}	0.84	346.80^{ab}	271.27^{a}	0.37^{a}	0.02	13.23^{e}	0.17	168.83^{c}
Karpooravalli	0.27	21.33^{ab}	2.32	33.87	0.13	9.30^{b}	17.33^{a}	101.10^{b}	0.54	335.33^{ab}	167.79^{d}	0.34^{b}	0.03	27.50^{cd}	0.69	226.28^{c}
Njalipoovan	0.22	16.43^{c}	2.09	25.67	0.41	3.67^{d}	13.33^{a}	90.30^{b}	0.89	260.73^{bc}	230.19^{b}	0.29^{c}	0.04	39.12^{b}	0.49	204.42^{c}
Grand Naine	0.29	21.53^{ab}	2.72	24.70	0.36	1.16^{e}	10.67^{a}	69.90^{b}	0.53	187.27^{c}	232.60^{b}	0.38^{a}	0.04	57.50^{a}	0.36	151.50^{c}
Yangambi km5	0.31	18.33^{bc}	1.84	31.33	0.26	2.68^{de}	8.00^{a}	168.90^{a}	0.40	406.60^{a}	134.00^{e}	0.33^{c}	0.03	28.33^{bc}	0.48	433.27^{b}
CD	NS	4.34	NS	NS	NS	2.15	NS	43.04	NS	132.55	17.85	0.03	NS	35.14	NS	92.92

TA= Titratable acidity; TSS=Total soluble solids; Vit. C=Vitamin C; Ca=Calcium; K=Potassium; Fe=Iron

EXPERIMENT 2

4.2 Evaluation of osmotic agents on quality of Intermediate Moisture (IM) banana

Different osmotic agents, namely sucrose, glucose, sucrose and sorbitol, glucose and sorbitol, palm sugar, honey, and sucrose and sodium chloride in combination with ascorbic acid (AA) (antioxidant) and potassium metabisulphite (KMS) (antimicrobial) were evaluated for the development of IM banana. The firm, ripe but not overripe fruits at full yellow stage of the selected banana varieties, namely Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) were collected and processed into IM bananas. The results of the experiment on the evaluation of osmotic agents on the quality of intermediate moisture (IM) bananas are presented here.

4.2.1 Physical characteristics

The physical parameters *viz.* moisture content (%),weight loss (%), solid gain(%), water loss(%), equilibrium relative humidity(%) and colour values (*L*, a*, b**) were recorded.

4.2.1.1 Moisture content (%)

Table 4 shows the effect of osmotic agents on the moisture content of IM bananas, with a significant difference observed in varieties Njalipoovan, Grand Naine, and Yangambi km5. The highest (27.46 %) moisture content was recorded in the variety Njalipoovan in fruit slices immersed in palm sugar solution (T5) and the lowest (13.53 %) was recorded for Nendran in fruit slices immersed in sucrose+NaCl solution (T7).

4.2.1.2. Weight loss (%)

Table 5 shows the effect of osmotic agents on IM banana weight loss, with a significant difference in the variety Pisang Lilin. The IM banana from Njalipoovan had the highest (45.40 %) weight reduction in fruit slices immersed in honey (T6), while the

variety Pisang Lilin had the lowest (19.13 %) in fruit slices immersed in glucose+sorbitol solution (T4).

Table 4: Effect of osmotic agents on the moisture content (%) of IM banana

Treatments	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	16.68	17.44	19.03	25.28^{ab}	16.22^{b}	14.39^{b}
T2	18.46	18.05	15.20	16.93^{d}	15.29^{b}	14.49^{b}
T3	16.50	17.10	17.50	21.85^{bc}	18.65^{a}	20.36^{a}
T4	18.12	18.38	16.99	25.36^{ab}	15.31^{b}	15.19^{b}
T5	15.10	16.37	20.00	27.46^{a}	15.12^{b}	16.60^{b}
T6	19.48	17.52	18.53	19.72^{cd}	15.01^{b}	15.45^{b}
T7	13.53	19.33	20.01	23.24^{abc}	16.64^{b}	15.97^{b}
Mean	16.84	17.74	18.18	22.83	16.03	16.06
CD (0.05)	NS	NS	NS	4.90	1.68	3.18

Table 5: Effect of osmotic agents on the weight loss (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	39.90	31.78^{ab}	21.23	36.70	32.58	33.98
T2	36.75	34.61^{a}	22.50	36.68	34.80	33.73
T3	38.15	35.18^{a}	19.57	38.35	33.30	40.25
T4	36.90	19.13^{c}	19.83	37.43	31.08	33.64
T5	40.40	25.43^{bc}	20.80	41.85	33.53	41.53
T6	39.90	37.50^{a}	34.70	45.40	39.43	40.25
T7	38.45	30.95^{ab}	20.93	41.60	34.38	36.44
Mean	38.60	30.65	22.79	39.72	34.12	37.12
CD (0.05)	NS	9.02	NS	NS	NS	NS

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite(KMS)(0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

4.2.1.3 Solid gain (%)

The effect of osmotic agents on the solid gain of IM banana is given in Table 6, with a significant difference observed in varieties of Pisang Lilin and Karpooravalli. The highest (23.55 %) solid gain was recorded in the variety Grand Naine in fruit slices immersed in glucose solution (T2) and the lowest (5.83 %) solid gain was in fruit slices immersed in honey (T6) for the variety Karpooravalli.

4.2.1.4 Water loss (%)

Table 7 shows the effect of osmotic agents on the water loss of IM bananas, with a significant difference observed in the variety Grand Naine. The IM banana from variety Grand Naine had the highest (62.12 %) water loss in fruit slices immersed in honey (T6) and Karpooravalli had the lowest (29.77 %) water loss in fruit slices immersed in sucrose+ NaCl solution (T7).

Table 6: Effect of osmotic agents on the solid gain (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	12.28	12.59^{bcd}	13.63^{ab}	11.57	19.50	16.33
T2	15.40	9.04^{d}	10.90^{cd}	14.72	23.55	18.55
T3	14.03	19.53^{a}	16.00^{a}	12.07	21.08	13.13
T4	15.28	18.64^{ab}	11.80^{bc}	13.00	23.44	17.11
T5	11.75	15.98^{abc}	14.80^{a}	9.88	20.10	11.76
T6	12.25	10.00^{cd}	5.83^{e}	11.79	22.69	16.43
T7	13.70	15.50^{abcd}	8.83^{d}	9.63	18.35	13.98
Mean	13.50	14.47	11.68	11.81	21.24	15.53
CD (0.05)	NS	6.67	2.51	NS	NS	NS

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite(KMS)(0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)

Table 7: Effect of osmotic agents on the water loss (%) of IM banana

Treatments	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	52.18	41.64	34.71	48.27	52.09^{c}	50.36
T2	52.15	45.00	33.40	51.15	58.35^{ab}	52.28
T3	52.18	55.94	35.57	50.42	54.38^{bc}	53.38
T4	52.18	41.24	31.63	50.43	54.52^{bc}	50.75
T5	52.15	41.409	30.60	51.73	53.64^{bc}	53.28
T6	52.15	42.18	40.53	57.20	62.12^{a}	56.68
T7	52.15	47.49	29.77	51.33	52.74^{bc}	50.42
Mean	52.20	45.00	33.74	51.50	55.41	52.45
CD (0.05)	NS	NS	NS	NS	5.89	NS

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite(KMS)(0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

4.2.1.5 Water activity

Table 8 shows the effect of osmotic agents on the water activity of IM bananas, with a significant difference among the varieties Nendran, Njalipoovan, Grand Naine, and Yangambi km5. The IM banana from variety Nendran had the highest (0.87) water activity values in fruit slices treated with palm sugar solution (T5) and the lowest (0.74) water activity values were IM bananas treated with glucose+sorbitol (T4) of variety Nendran. Among all the six banana varieties in the present study, IM banana slices immersed in honey (T6) had a water activity that did not exceed 0.80.

4.2.1.6 Equilibrium Relative Humidity (ERH) (%)

The ERH values of IM bananas subjected to different osmotic agents are presented in Table 9, which ranged from 74.13 to 87.20 per cent. A significant difference in ERH values of IM banana among different osmotic treatments was recorded in varieties Nendran, Njalipoovan, Grand Naine, and Yangambi km5, whilst no variation among osmotic agent treatments on varieties of Pisang Lilin and Karpooravalli was

observed. Highest ERH of 87.20 per cent was recorded in Nendran slices treated with palm sugar solution (T5) and the lowest (74.13 %) ERH values were of variety Nendran fruit slices immersed in glucose+sorbitol (T4). Among the six banana varieties in the present study, IM banana slices immersed in honey (T6) had an ERH that did not exceed 80 per cent.

Table 8: Effect of osmotic agents on the water activity (a_w) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	0.79^{bc}	0.86	0.85	0.83^{a}	0.80^{a}	0.82^{ab}
T2	0.79^{bc}	0.85	0.81	0.80^{ab}	0.78^{ab}	0.81^{abc}
T3	0.79^{bc}	0.82	0.82	0.79^{abc}	0.78^{ab}	0.80^{bc}
T4	0.74^{d}	0.80	0.80	0.78^{bc}	0.78^{ab}	0.78^{cd}
T5	0.87^{a}	0.82	0.82	0.82^{ab}	0.80^{a}	0.84^{ab}
T6	0.75^{cd}	0.78	0.75	0.75^{c}	0.75^{b}	0.75^{d}
T7	0.80^{b}	0.81	0.84	0.81^{ab}	0.80^{a}	0.84^{a}
Mean	0.79	0.82	0.81	0.80	0.79	0.80
CD (0.05)	0.04	NS	NS	0.04	0.04	0.04

Table 9: Effect of osmotic agents on the equilibrium relative humidity (ERH) (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	79.33^{bc}	86.30	85.10	82.67^{a}	80.67^{a}	81.80^{ab}
T2	78.70^{bc}	85.33	81.33	80.66^{ab}	77.87^{ab}	80.50^{abc}
T3	79.17^{bc}	81.56	81.70	78.50^{abc}	78.28^{ab}	79.83^{bc}
T4	74.13^{d}	80.00	80.13	77.18^{c}	78.07^{ab}	77.53^{cd}
T5	87.20^{a}	82.36	82.33	81.83^{ab}	80.50^{a}	83.57^{ab}
T6	75.23^{cd}	77.87	75.33	75.27^{c}	74.70^{b}	74.30^{d}
T7	80.00^{b}	81.00	84.03	81.07^{ab}	80.13^{a}	84.17^{a}
Mean	79.10	82.10	81.40	79.60	78.60	80.20
CD (0.05)	4.54	NS	NS	3.34	3.68	4.08

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

4.2.1.7 Colour values (*L*, a*, b**)

Table 10 denotes the colour values (*L*, a*, b**) of IM bananas prepared using different osmotic agents. Highest (94.69) values of *L** were recorded for the variety Njalipoovan in fruit slices immersed in glucose+sorbitol (T4) and the lowest (38.59) values of *L** were found for the variety Karpooravalli in honey (T6) treated samples. The colour values denoting *a** colour value of IM banana ranged between -3.42 and 8.98, which were respectively recorded for the variety Njalipoovan in fruit slices immersed in sucrose solution (T1) and for the variety Nendran in fruit slices immersed in palm sugar solution (T5). The highest (22.16) values denoting *b** colour value were recorded for variety Yangambi km5 (AAA) in fruit slices immersed in sucrose solution (T1) and the lowest (3.48) *b** colour value was recorded for Njalipoovan in fruit slices treated using sucrose solution (T1).

Table 10: Effect of osmotic agents and varieties on the colour values (*L*, a*, b) of IM banana**

Treatment	Nendran			Pisang Lilin			Karpooravalli			Njalipoovan			Grand Naine			Yangambi km5		
	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**	*L**	*a**	*b**
T1	76.44^{bc}	0.56^{cd}	10.56^{bc}	78.23^{a}	0.30^{e}	13.41	34.21^{c}	4.34^{a}	17.22	86.07^{b}	-3.42^{e}	3.48^{d}	79.21^{bc}	0.25^{b}	15.58^{ab}	66.13	1.33^{d}	22.16
T2	83.27^{ab}	0.33^{de}	9.90^{bc}	61.48^{c}	2.34^{a}	18.40	68.31^{a}	1.36^{b}	15.92	93.49^{a}	-0.17^{c}	4.23^{d}	71.02^{d}	0.86^{a}	18.40^{a}	60.57	2.37^{b}	19.57
T3	84.86^{a}	0.12^{e}	7.11^{c}	64.83^{bc}	1.48^{b}	16.37	63.99^{ab}	1.85^{b}	17.38	80.19^{c}	0.28^{a}	11.64^{a}	84.37^{ab}	-0.50^{d}	12.94^{b}	63.65	1.84^{cd}	19.03
T4	74.12^{cd}	2.69^{b}	11.81^{bc}	71.72^{ab}	0.78^{c}	14.11	56.52^{b}	2.01^{b}	16.60	94.69^{a}	-0.19^{c}	4.35d	76.55^{cd}	0.17^{b}	15.29^{ab}	62.27	2.00^{bc}	17.60
T5	67.11^{de}	8.98^{a}	21.51^{a}	77.52^{a}	0.20^{f}	13.84	56.04^{b}	2.34^{b}	16.76	79.02^{c}	0.05^{b}	9.06^{c}	88.34^{a}	-1.34^{e}	12.87^{b}	57.79	5.30^{a}	10.73
T6	77.02^{abc}	0.36^{de}	13.38^{b}	73.48^{ab}	0.38^{e}	15.07	38.59c	4.33^{a}	17.56	90.72^{ab}	-1.29^{d}	10.52^{b}	83.33^{a}	-1.34^{e}	12.86^{b}	64.46	1.58^{cd}	16.50
T7	61.79^{e}	0.91^{c}	8.84^{bc}	79.14^{a}	0.65^{d}	11.41	61.61^{ab}	1.85^{b}	13.76	91.97^{a}	-1.26^{d}	10.21^{b}	87.64^{a}	-0.04^{c}	12.86^{b}	65.34	1.60^{cd}	17.01
Mean	74.94	1.99	11.87	72.34	0.88	14.66	54.18	2.58	16.46	88.02	-0.86	7.64	81.49	-1.94	14.40	62.89	2.29	17.51
CD	8.01	0.43	6.04	9.13	0.09	NS	10.97	1.17	NS	4.95	0.09	1.10	6.65	0.09	3.50	NS	0.52	NS

T1: Sucrose (60 ºBrix), Ascorbic acid(AA) 0.5%), Potassium metabisulphite(KMS)(0.25%)

T2: Glucose (60 ºBrix) AA (0.5%) KMS (0.25%)

T3: Sucrose+ sorbitol (50:50 ratio) (60 ºBrix), AA (0.5%). KMS 0.25%)

T4: Glucose+ sorbitol (50:50 ratio) (60 ºBrix), AA (0.5%). KMS 0.25%)

T5: Palm sugar (60 Brix), AA (0.5%). KMS (0.25%)

T6: Honey, AA (0.5%), KMS (0.25%)

T7: Sucrose (60 ºBrix), Sodium chloride (0.5%). KMS (0.25%)

4.2.2 Biochemical parameters

Biochemical characters of intermediate moisture (IM) banana such as total soluble solids (°Brix), titratable acidity (%), total ash (%), pH, reducing sugars (%), non-reducing sugars (%), total sugars (%), vitamin C (mg/100g), total carotenoids (µg/100g), total phenols (mg/100g) and non- enzymatic browning (NEB) are presented here.

4.2.2.1 Total soluble solids (°Brix)

Table 11 shows the total soluble solids (TSS) range of IM bananas prepared using different osmotic agents between 68.33 and 72.00 °Brix. No significant difference in the TSS of IM banana was observed among treatments, with the exception of variety Nendran. The maximum (72.00 °Brix) TSS was recorded for the variety Nendran in fruits immersed in honey solution (T6) and the minimum (68.33 °Brix) TSS was recorded for the variety Karpooravalli in fruits immersed in glucose solution (T2).

4.2.2.2 Titratable acidity (%)

Table 12 shows the titratable acidity of IM bananas prepared with different osmotic agents in the range between 0.20 and 0.40 per cent. A significant difference in the titratable acidity was observed in only two varieties, *viz.* Pisang Lilin and Grand Naine. Highest titratable acidity value of 0.40 per cent was recorded in the varieties Pisang Lilin and Grand Naine, both in fruits immersed in glucose+sorbitol solution (T4). The lowest titrable acidity of 0.20 per cent was recorded in varieties Pisang Lilin and Yangambi km5, both for fruits immersed in sucrose+NaCl solution (T7), while for variety Njalipoovan, the same (0.20 %) value for titrable acidity was recorded for fruits immersed in glucose+sorbitol solution (T4).

Table 11: Effect of osmotic agents on the total soluble solids (TSS) (°Brix) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	70.50[b]	69.75	69.67	69.25	69.00	69.75
T2	70.00[b]	70.25	68.33	70.25	69.50	70.00
T3	71.00[ab]	69.50	69.50	69.75	69.50	70.20
T4	70.00[b]	70.00	69.67	70.50	70.00	70.50
T5	70.00[b]	69.25	70.00	69.25	69.50	69.75
T6	72.00[a]	71.00	70.50	69.50	70.50	70.50
T7	70.75[b]	69.50	69.00	69.50	69.00	70.00
Mean	70.61	69.89	69.52	69.71	69.57	70.10
CD (0.05)	1.139	NS	NS	NS	NS	NS

Table 12: Effect of osmotic agents on the titratable acidity (TA) (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	0.34	0.24[cd]	0.24	0.27	0.30[bc]	0.24
T2	0.32	0.37[ab]	0.27	0.34	0.34[b]	0.27
T3	0.33	0.37[ab]	0.30	0.24	0.27[c]	0.24
T4	0.35	0.40[a]	0.30	0.20	0.40[a]	0.27
T5	0.28	0.30[bc]	0.37	0.34	0.27[c]	0.27
T6	0.30	0.37[ab]	0.24	0.30	0.30[bc]	0.30
T7	0.31	0.20[d]	0.24	0.24	0.34[b]	0.20
Mean	0.32	0.32	0.28	0.27	0.32	0.25
CD (0.05)	NS	0.1	NS	NS	0.06	NS

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)

4.2.2.3 Total ash (%)

The total ash of IM bananas prepared from different osmotic agents is presented in Table 13, with a significant difference in varieties Nendran, Pisang Lilin, Karpooravalli, Njalipoovan, and Grand Naine. A highest (16.93 %) total ash was observed in the variety Yangambi km5 in fruits immersed in honey solution (T6) and the lowest (2.83 %) total ash was in the variety Njalipoovan in fruits immersed in sucrose+sorbitol solution (T3).

4.2.2.4 pH

The pH value of IM bananas of different varieties prepared with different osmotic agents was between 3.50 and 4.63, where variation among the treatments was observed with the exception of Pisang Lilin (Table 14). Highest (4.63) pH values were recorded for the variety Njalipoovan in fruits immersed in glucose+sorbitol solution (T4), while the lowest (3.50) was for the variety Karpooravalli in fruits immersed in sucrose+sorbitol solution (T3).

4.2.2.5 Reducing sugars (%)

Table 15 reveals a significant difference in the reducing sugars of IM bananas of different varieties subjected to different osmotic agents. The highest (51.75 %) reducing sugars was recorded in the variety Yangambi km5 in fruits immersed in glucose solution (T2), and the lowest (4.23 %) values were recorded for the variety Nendran in fruits treated with palm sugar solution (T5).

4.2.2.6 Non- reducing sugars (%)

A significant difference in the non-reducing sugars of IM banana was observed among treatments, with values between 1.97 and 40.90 per cent (Table 16). Non-reducing sugars values were highest (40.90 %) in variety Yangambi (KM-5) in fruits immersed in sucrose solution (T1), while the lowest (1.97 %) values were recorded for variety Nendran in fruits treated with sucrose+NaCl solution (T7).

Table 13: Effect of osmotic agents on the total ash (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.63^{d}	7.80^{d}	4.80^{b}	3.30^{cd}	8.78^{d}	15.89
T2	6.67^{d}	7.96^{d}	6.02^{a}	3.05^{d}	7.75^{e}	10.74
T3	9.73^{b}	12.07^{a}	2.95^{c}	2.83^{d}	11.82^{b}	11.78
T4	4.63^{e}	7.98^{d}	3.18^{c}	3.77^{bc}	7.82^{e}	9.91
T5	4.93^{e}	8.01^{d}	3.15^{c}	4.13^{ab}	6.12^{f}	14.23
T6	13.17^{a}	9.92^{b}	4.49^{b}	4.45^{a}	16.52^{a}	16.93
T7	6.60^{d}	9.07c	2.98c	4.63^{a}	11.10^{c}	12.99
Mean	7.60	6.70	3.96	3.70	10.36	13.21
CD (0.05)	0.49	0.32	0.37	0.53	0.57	NS

Table 14: Effect of osmotic agents on the pH of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	3.62^{d}	4.01	4.14^{a}	4.13^{c}	3.83^{b}	3.61^{de}
T2	3.52^{e}	3.97	3.94^{b}	4.12^{c}	3.80^{b}	3.51^{e}
T3	3.72^{c}	4.04	3.50^{e}	4.51^{ab}	4.09^{a}	3.65^{d}
T4	3.64^{cd}	3.97	3.64^{de}	4.63^{a}	3.83^{b}	4.14^{a}
T5	3.94^{a}	4.20	3.81^{bcd}	4.62^{a}	3.81^{b}	4.05^{a}
T6	3.93^{a}	3.90	3.71^{cd}	4.18^{bc}	3.98^{a}	3.81^{c}
T7	3.83^{b}	4.13	3.91^{bc}	4.53^{a}	4.01^{a}	3.93^{b}
Mean	3.70	4.03	3.80	4.40	3.90	3.80
CD (0.05)	0.10	NS	0.20	0.33	0.13	0.11

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

Table 15: Effect of osmotic agents on the reducing sugars (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	12.54^{bcd}	8.41^{d}	13.84^{bc}	10.63^{d}	6.63^{cd}	10.98^{d}
T2	28.35^{a}	47.67^{a}	32.92^{a}	37.94^{a}	40.00^{a}	51.75^{a}
T3	8.82^{cd}	7.84^{d}	9.17^{cd}	7.89^{e}	5.49^{cd}	13.83^{d}
T4	17.35^{bc}	20.07^{c}	14.54^{b}	28.90^{c}	27.31^{b}	29.83^{c}
T5	4.23^{d}	11.25^{d}	6.49^{d}	11.20^{d}	4.90^{d}	11.36^{d}
T6	14.60^{bc}	30.68^{b}	30.85^{a}	37.16^{b}	15.20^{c}	45.30^{b}
T7	18.41^{b}	9.23^{d}	6.67^{d}	11.16^{d}	5.71^{cd}	10.79^{d}
Mean	14.90	19.31	16.35	20.70	15.03	24.83
CD (0.05)	9.54	3.89	5.30	0.63	9.72	4.53

Table 16: Effect of osmotic agents on the non-reducing sugars (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	16.14^{cd}	25.12^{a}	21.68^{a}	30.76^{b}	33.34^{ab}	40.90^{a}
T2	18.78^{bc}	4.14^{d}	3.02^{e}	6.13^{e}	23.50^{cd}	4.02^{de}
T3	32.80^{ab}	16.21^{bc}	9.90^{c}	21.17^{d}	24.51^{bcd}	18.91^{c}
T4	20.49^{bc}	11.70^{c}	7.08^{cd}	1.94^{f}	7.02^{e}	1.34^{e}
T5	36.37^{a}	19.35^{b}	23.98^{a}	32.89^{a}	36.46^{a}	32.40^{b}
T6	21.77^{abc}	5.72^{d}	4.46d^{e}	5.55^{e}	27.88^{abc}	8.61^{d}
T7	1.97^{d}	30.26^{a}	21.86^{a}	26.73^{c}	17.71^{d}	28.26^{b}
Mean	21.19	16.07	13.14	17.88	22.33	19.21
CD (0.05)	15.487	5.36	3.56	1.51	9.18	4.61

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

4.2.2.7 Total sugars (%)

The total sugar content of IM bananas differed significantly among different treatments, which showed a range of 19.07 to 63.50 per cent (Table 17). The highest (63.50 %) total sugar content was recorded in the variety Grand Naine in fruits immersed in glucose solution (T2), while the lowest (19.07 %) total sugar was recorded for the variety Karpooravalli in fruits treated with sucrose+sorbitol (T3).

4.2.2.8 Vitamin C (mg/100g)

Table 18 reveals a significant difference in the vitamin C content of IM bananas, where the vitamin C content ranged between 4.32 and 39.42 mg/100g among different treatments. The variety Grand Naine recorded the highest (39.42 mg/100g) vitamin C content in fruits treated with glucose+sorbitol solution (T4) and lowest (4.32 mg/100g) content of vitamin C was recorded for the variety Nendran in fruits immersed in sucrose+NaCl (T7).

4.2.2.9 Total carotenoids (µg/100g)

A significant effect of the total carotenoids content of IM bananas in response to different osmotic treatments is revealed in Table 19. In response to various osmotic agents, the variety Nendran had the highest (335.78 µg/100g) total carotenoids content, with fruits immersed in glucose+sorbitol (T4) and the lowest total carotenoids content of 13.47 µg/100g in the variety Grand Naine in fruits treated with glucose+sorbitol solution (T4).

4.2.2.10 Total phenols (mg/100g)

There was a substantial variation in total phenols of IM bananas in response to various osmotic agents, with total phenol values ranging from 18.33 to 335.00 mg/100g (Table 20). The variety Nendran recorded values of 335.00 mg/100g for total phenols in fruits immersed in sucrose+sorbitol solution (T3), which was not significantly different

from the 320.00 mg/100g of the same banana variety observed in fruits treated using honey (T6). The lowest phenol content was 18.33 mg/100g for the variety Karpooravalli in fruits treated with sucrose+NaCl solution (T7).

4.2.2.11 Non enzymatic browning (OD value)

Table 21 shows a significant difference in the non-enzymatic browning of IM bananas, where a range of 0.10 to 0.99 values was noticed among treatments. The highest non-enzymatic browning value was recorded as 0.99 for the variety Yangambi km5 in fruits immersed in palm sugar solution, followed by 0.88 in fruits treated with honey (T6) for the variety Nendran. Lowest (0.10) non-enzymatic browning values were observed in the variety Nendran in fruit slices immersed in sucrose+NaCl (T7).

Table 17: Effect of osmotic agents on the total sugars (%) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	28.68^{bc}	33.55^{bcd}	29.03^{b}	40.39^{bc}	39.92^{b}	51.88^{ab}
T2	47.13^{a}	51.83^{a}	34.94^{a}	44.57^{a}	63.50^{a}	55.77^{a}
T3	41.64^{ab}	24.05^{e}	19.07^{c}	29.07^{d}	30.00^{cd}	32.74^{ef}
T4	37.78^{ab}	26.06^{de}	21.62^{c}	30.84^{d}	34.33^{bc}	31.17^{f}
T5	40.60^{ab}	30.60^{cde}	30.47^{b}	43.59^{ab}	41.36^{b}	43.76^{cd}
T6	36.67^{ab}	36.39^{bc}	35.30^{a}	45.20^{a}	43.08^{b}	48.70^{bc}
T7	20.53^{c}	39.49^{b}	28.52^{b}	37.89^{c}	23.42^{d}	39.05^{de}
Mean	36.16	34.57	28.42	38.79	39.37	43.30
CD (0.05)	13.56	8.72	3.67	3.85	9.03	6.91

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

Table 18: Effect of osmotic agents on the vitamin C (mg/100g) content of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	12.84^{d}	20.20^{c}	15.73^{c}	25.25^{a}	23.73^{c}	24.80^{a}
T2	19.33^{b}	9.33^{d}	12.80^{cd}	10.67^{cd}	9.33^{d}	14.67^{b}
T3	23.17^{a}	28.05^{a}	20.53^{b}	16.85^{b}	30.40^{b}	12.80^{b}
T4	14.83^{c}	29.60^{a}	21.07^{b}	13.07^{bc}	39.42^{a}	13.05^{b}
T5	12.00^{d}	23.47^{b}	8.35^{e}	5.87^{e}	11.05^{d}	7.20^{c}
T6	12.83^{d}	24.27^{b}	30.65^{a}	14.68^{bc}	12.63^{d}	25.30^{a}
T7	4.32^{e}	9.30^{d}	10.66^{de}	6.67^{de}	9.34^{d}	13.33^{b}
Mean	14.19	22.49	17.11	13.29	19.41	15.88
CD (0.05)	1.56	2.60	3.67	4.21	3.98	2.69

Table 19: Effect of osmotic agents on the total carotenoids (µg/100g) content of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	175.89^{d}	19.24^{f}	59.44^{g}	27.27^{b}	19.63^{f}	100.14^{b}
T2	231.21^{c}	27.00^{e}	129.80^{d}	43.14^{a}	27.00^{d}	104.00^{b}
T3	233.87^{b}	13.43^{g}	83.67^{f}	43.14^{a}	23.85^{e}	56.08^{d}
T4	335.78^{a}	30.43^{d}	93.78^{e}	43.14^{a}	13.47^{g}	140.81^{a}
T5	157.18^{e}	57.35^{b}	178.20^{a}	39.93^{a}	57.70^{b}	49.18^{e}
T6	129.80^{f}	84.85^{a}	120.17^{d}	43.14^{a}	84.93^{a}	38.54^{f}
T7	120.17^{g}	32.39^{c}	158.68^{b}	30.93^{b}	32.39^{c}	74.06^{c}
Mean	197.70	37.81	117.68	38.67	37.00	80.40
CD (0.05)	0.585	0.766	2.44	8.48	0.786	5.58

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

Table 20: Effect of osmotic agents on the total phenol (mg/100g) content of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	214.00^{b}	110.00	92.33^{ab}	285.00^{a}	108.75	212.83
T2	158.33^{c}	106.67	85.67^{ab}	111.10^{c}	52.75	143.50
T3	335.00^{a}	110.67	90.67^{ab}	237.67^{b}	111.25	168.33
T4	204.50^{b}	143.33	70.00^{b}	33.87^{e}	95.75	135.00
T5	113.33^{d}	125.00	80.67^{b}	43.43^{e}	94.74	139.17
T6	320.00^{a}	134.00	110.50^{a}	76.33^{d}	107.00	210.50
T7	105.00^{d}	71.33	18.33^{c}	25.33^{e}	76.75	150.17
Mean	207.17	114.40	78.30	116.10	92.40	165.64
CD (0.05)	32.71	NS	24.93	30.56	NS	NS

Table 21: Effect of osmotic agents on non enzymatic browning (OD value) of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	0.31^{c}	0.44^{b}	0.17^{bc}	0.36^{ab}	0.18^{b}	0.33^{c}
T2	0.32^{c}	0.37^{bc}	0.09^{c}	0.20^{c}	0.16^{b}	0.37^{c}
T3	0.13^{de}	0.36^{bc}	0.17^{bc}	0.14^{d}	0.31^{a}	0.45^{bc}
T4	0.17^{d}	0.26^{cd}	0.16^{bc}	0.21^{c}	0.18^{b}	0.56^{bc}
T5	0.63^{b}	0.49^{b}	0.23^{ab}	0.31^{b}	0.35^{a}	0.99^{a}
T6	0.88^{a}	0.73^{a}	0.33^{a}	0.41^{a}	0.17^{b}	0.77^{ab}
T7	0.10^{e}	0.15^{d}	0.15^{bc}	0.21^{c}	0.09^{c}	0.52^{bc}
Mean	0.36	0.40	0.19	0.27	0.21	0.57
CD (0.05)	0.07	0.15	0.10	0.05	0.07	0.39

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

4.2.3 Microbial observations (cfu/g)

Microbial colonies of IM banana were detected in osmotic agents of sucrose and glucose solutions for varieties Pisang Lilin and Yangambi km5 (Table 22 and Plate 8). IM banana fruits of variety Pisang Lilin showed fungal colonies of 0.33 cfu/g in samples treated with glucose solution (T2). Bacteria (0.67 cfu/g) was detected in IM banana of variety Yangambi km5 in osmotic solution of sucrose (T1), whereas in IM banana of the same variety, both bacteria (0.67 cfu/g) and yeast (0.33 cfu/g) were detected in samples treated in glucose solution (T2). None of the IM banana varieties subjected to different osmotic agents detected *Escherichia coli*.

Table 22: Effect of osmotic agents and varieties on bacteria, *Eschechia coli*, fungi and yeast population (cfu/g) of IM banana

	Nendran				Pisang Lilin				Karpooravalli				Njalipoovan				Grand Naine				Yangambi km5			
Treatment	BT	EC	FN	YT	BT	EC	FN	YT	BT	EC	FN	YT	BT	EC	FN	YT	BT	EC	FN	YT	BT	EC	FN	YT
T1	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	0.67	a	a	a
T2	a	a	a	a	a	a	0.33	a	a	a	a	a	a	a	a	a	a	a	a	a	0.67	a	a	0.33
T3	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
T4	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
T5	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
T6	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
T7	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a

T1: Sucrose (60 ºBrix), Ascorbic acid(AA) 0.5%), Potassium metabisulphite(KMS)(0.25%)

T2: Glucose (60 ºBrix) AA (0.5%) KMS (0.25%)

T3: Sucrose+ sorbitol (50:50 ratio) (60 ºBrix), AA (0.5%). KMS 0.25%)

T4: Glucose+ sorbitol (50:50 ratio) (60 ºBrix), AA (0.5%). KMS 0.25%)

T5: Palm sugar (60 Brix), AA (0.5%). KMS (0.25%)

T6: Honey, AA (0.5%), KMS (0.25%)

T7: Sucrose (60 ºBrix), Sodium chloride (0.5%). KMS (0.25%)

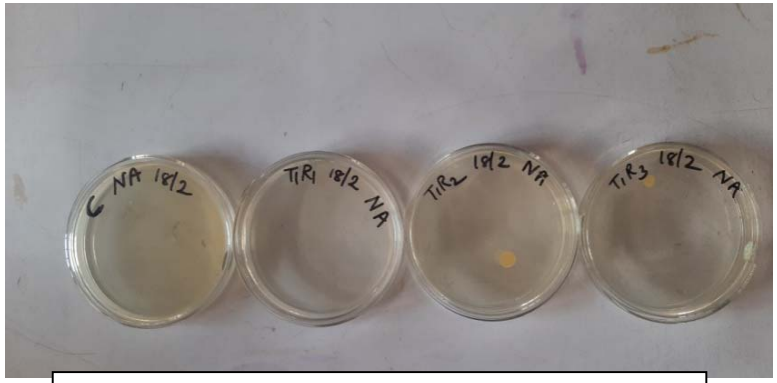
BT: Bacteria ($\times 10^{-5}$ cfu/g)

EC: Escherichia coli ($\times 10^{-5}$ cfu/g)

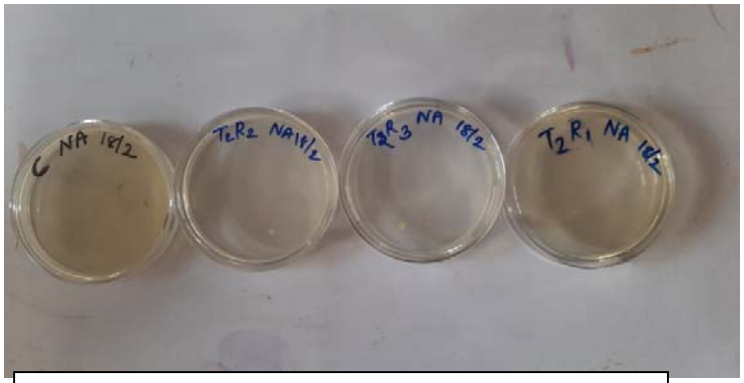
FN: Fungi ($\times 10^{-3}$ cfu/g)

YT: Yeast ($\times 10^{-4}$ cfu/g)

a: No micro-organism detected

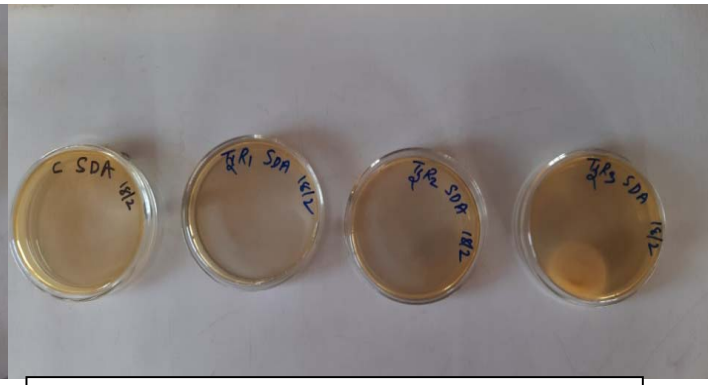


Bacterial colonies ($\times 10^{-5}$ cfu/g) of Yangambi km5 IM banana slices treated in sucrose solution



Bacterial colonies ($\times 10^{-5}$ cfu/g) of Yangambi km5 IM banana slices treated in glucose solution

Fungi colonies ($\times 10^{-3}$ cfu/g) of Pisang Lilin km5 IM banana slices treated in glucose solution



Yeast colonies ($\times 10^{-4}$ cfu/g) of Yangambi km5 IM banana slices treated in glucose solution

Plate 8: Microbiological proliferation on IM banana using different osmotic agents

4.2.4 Organoletic characteristics

The Intermediate Moisture (IM) banana was evaluated by a judging panel of fifteen people based on attributes like appearance, colour, flavour, texture, odour, taste, after taste, and overall acceptability using a 9-point hedonic scale, and the score results are given in Table 23.

4.2.4.1 Appearance

Table 231.1 and Appendix 1.1 reveal the organoleptic score of the appearance of IM bananas to be significant among different treatments, with the exception of varieties of Pisang Lilin and Yangambi km5. The highest score for appearance was recorded at 7.79, recorded for variety Nendran in fruits immersed in sucrose+sobitol solution (T3), followed by 7.73, scored for variety Grand Naine for fruits treated with sucrose (T1). The lowest score for the appearance of IM banana was 4.87 for the variety Njalipoovan in fruits treated with honey (T6).

4.2.4.2 Colour

Table 23.2 and Appendix 1.2 reveal the organoleptic scores for the colour of IM bananas to be significant among varieties Nendran, Njalipoovan, and Yangambi km5, whereas Pisang Lilin, Karpooravalli, and Grand Naine showed no variation. Nendran recorded the highest colour score of 7.60 in fruits immersed in sucrose+sorbitol (T3) and the lowest colour score of 4.67 was recorded in variety Njalipoovan in fruits treated with honey (T6).

Table 23 .1: Effect of osmotic agents on the appearance of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.07	7.33	6.00	7.40	7.73	6.80
T2	6.79	7.07	6.27	6.80	6.00	6.27
T3	7.79	6.80	7.33	6.27	6.87	7.20
T4	7.29	6.27	6.00	6.80	7.47	6.80
T5	6.14	6.67	6.80	6.00	6.60	6.07
T6	5.86	5.87	7.60	4.87	6.60	6.00
T7	7.43	6.73	7.27	7.07	7.33	6.73
Mean	6.91	6.67	6.75	6.46	6.94	6.55
KW	0.32**	0.17^{NS}	0.33**	0.43**	0.37**	0.15^{NS}

Table 23.2: Effect of osmotic agents on the colour of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.20	7.40	6.60	7.40	7.58	7.00
T2	6.80	7.13	6.27	6.20	6.67	6.67
T3	7.60	6.87	7.47	6.87	7.13	7.27
T4	7.00	6.40	6.87	6.67	7.40	7.13
T5	6.27	6.53	6.40	5.60	6.53	6.07
T6	6.07	5.80	6.33	4.67	6.53	6.20
T7	7.07	6.60	7.07	6.60	7.20	7.00
Mean	6.89	6.68	6.71	6.28	7.00	6.76
KW	0.21*	0.18^{NS}	0.18^{NS}	0.40**	0.18^{NS}	0.24**

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

4.2.4.3 Flavour

The organoleptic scores for flavour of IM bananas ranged between 5.13 and 7.60, with a significant difference among different osmotic treatments, with the exception of variety Grand Naine, where no variation of organoleptic scores was observed (Table 23.3 and Appendix 1.1) . Highest (7.60) score for flavour was for the variety Nendran in fruits immersed in sucrose solution (T1), followed by the variety Yangambi in fruits immersed in sucrose+sorbitol (T3). The variety Pisang Lilin recorded the lowest score of 4.87 for flavour in fruits immersed in honey (T6).

4.2.4.5 Texture

The organoleptic score for the texture of IM bananas among different treatments was recorded in the range between 5.07 and 7.40, with a significant difference observed in varieties of Karpooravalli and Njalipoovan, whereas no variation was observed in other varieties (Table 23.4 and Appendix 1.4). The variety Nendran had the highest (7.40) score for texture in fruits immersed in sucrose-treated solution (T1), followed by 7.20 in sucrose+sorbitol solution (T3) for the variety Njalipoovan. Lowest (5.07) scores of texture were observed for the variety Njalipoovan in fruits immersed in honey solution (T6).

4.2.4.6 Odour

Table 23.5 and Appendix 1.5 shows that the organoleptic scores for the odour of IM banana ranged from 5.13 to 7.53.No variation in the odour of IM banana among different osmotic treatments was revealed in varieties Nendran, Pisang Lilin, and Grand Naine, whereas for varieties Karpooravalli, Njalipoovan, and Yangambi km5, a significant difference in the scores among panelists was revealed. Variety Nendran was rated superior with highest score of 7.53 in fruits treated with sucrose solution (T1), followed by the fruits immersed in palm sugar solution (T5) of the same variety. Lowest

(5.13) scores for odour were recorded in the variety Njalipoovan for fruits treated with palm sugar solution (T5).

Table 23.3: Effect of osmotic agents on the flavour of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.60	6.13	6.13	7.07	6.67	6.80
T2	6.60	5.93	5.60	6.13	6.40	6.40
T3	7.07	7.13	6.53	7.00	7.33	7.40
T4	6.80	6.07	6.40	6.27	7.20	6.60
T5	6.93	5.33	6.47	5.40	6.80	6.47
T6	7.13	4.87	6.67	5.13	6.73	5.93
T7	7.20	5.40	6.87	6.40	7.13	6.87
Mean	7.04	5.83	6.38	6.20	6.89	6.64
KW	0.22*	0.31**	0.24**	0.25**	0.13^{NS}	0.25**

Table 23.4: Effect of osmotic agents on the texture of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.40	5.93	6.53	7.13	6.67	6.53
T2	7.00	5.47	6.33	6.07	5.93	6.13
T3	7.13	6.87	7.27	7.20	7.00	6.73
T4	6.40	6.33	6.73	6.80	7.00	6.87
T5	7.07	5.40	6.73	5.27	6.53	6.87
T6	6.67	5.20	7.33	5.07	6.40	6.33
T7	6.73	5.53	7.33	6.40	6.73	7.00
Mean	6.91	5.83	6.89	6.28	6.61	6.63
KW	0.14^{NS}	0.20^{NS}	0.26**	0.35**	0.18^{NS}	0.11^{NS}

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

Table 23.5: Effect of osmotic agents on the odour of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.53	6.07	6.00	6.53	6.73	6.80
T2	6.47	5.67	5.73	6.47	6.73	6.27
T3	7.07	6.33	6.47	6.80	7.13	6.27
T4	6.73	6.13	6.00	6.27	7.07	6.47
T5	7.27	5.40	6.67	5.40	6.73	6.87
T6	6.60	5.40	7.00	5.13	6.47	6.40
T7	6.73	5.40	6.73	6.27	6.73	6.20
Mean	6.91	5.77	6.37	6.12	6.80	6.47
KW	0.19^{NS}	0.11^{NS}	0.36**	0.27**	0.10^{NS}	0.21*

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

4.2.4.7 Taste

A panel of judges evaluated the taste of IM bananas treated with different osmotic agents and no significant difference was revealed in the taste of IM bananas of varieties Nendran and Grand Naine, whereas for IM bananas of varieties Pisang Lilin, Karpooravalli, Njalipoovan, and Yangambi km5, a significant difference in taste was revealed (Table 23.6 and Appendix 1.6). The range score for the taste of IM banana was between 5.00 and 7.80, with the highest score for variety Nendran recorded in fruits immersed in sucrose+sorbitol solution (T3), whilst the lowest scores were for both varieties of Pisang Lilin and Njalipoovan in fruits immersed in honey (T6).

4.2.4.8 After taste

The overall score for organoleptic evaluation of the after taste of IM bananas treated with different osmotic agents was recorded, with a significant variation recorded

among the banana varieties Karpooravalli, Njalipoovan, and Yangambi km5 (Table 23.7 and Appendix 1.7). The highest (7.67) score for after taste was recorded in variety Nendran with fruits treated using sucrose+sorbitol solution (T3) and the lowest score (4.80) was in honey (T6) treated samples of the banana variety Njalipoovan.

4.2.4.9 Overall acceptability

There was no variation in the overall acceptability of IM banana prepared using different osmotic agents on variety Nendran, whereas other varieties under observation showed variation (Table 23.8 and Appendix 1.8). The IM banana treated using different osmotic agents had an overall acceptability score which ranged from 4.53 to 7.67. Variety Nendran earned the highest (7.67) score for overall acceptance in fruits immersed in sucrose+sorbitol (T3) among all the treatments, and the lowest score (4.53) for overall acceptance was recorded for the variety Njalipoovan in fruits immersed in honey (T6).

Table 23.6: Effect of osmotic agents on the taste of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.53	6.07	5.73	7.47	6.93	6.87
T2	6.87	5.93	5.60	6.73	6.00	5.93
T3	7.80	6.80	7.00	6.93	7.20	6.87
T4	7.20	6.33	6.33	5.87	7.20	6.53
T5	7.60	5.33	6.73	5.20	6.93	6.33
T6	6.80	5.00	7.60	5.00	6.67	5.47
T7	7.20	5.47	7.07	6.40	7.33	7.20
Mean	7.28	5.85	6.58	6.29	6.89	6.46
KW	0.16^{NS}	0.24*	0.36**	0.40**	0.13^{NS}	0.25**

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

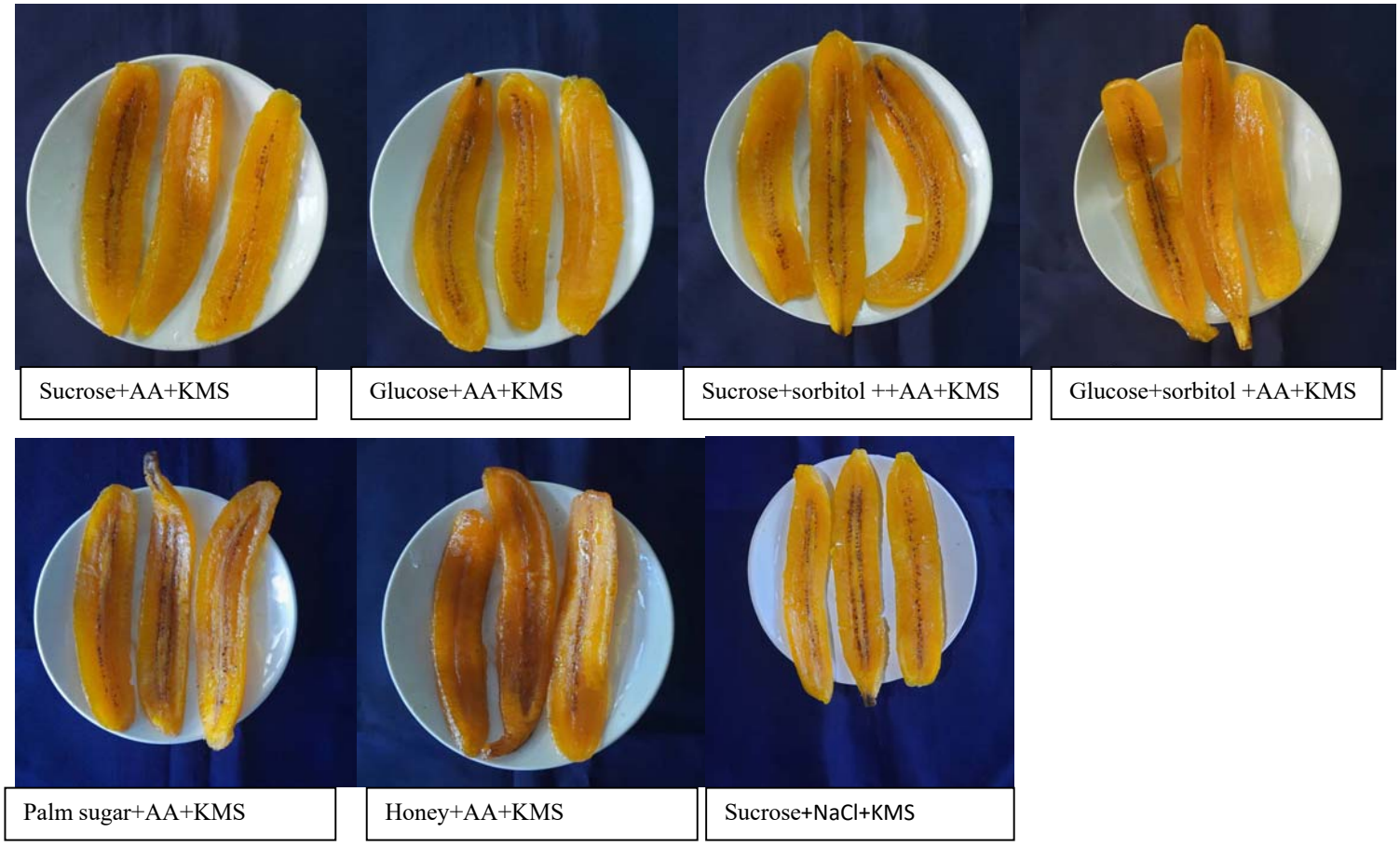


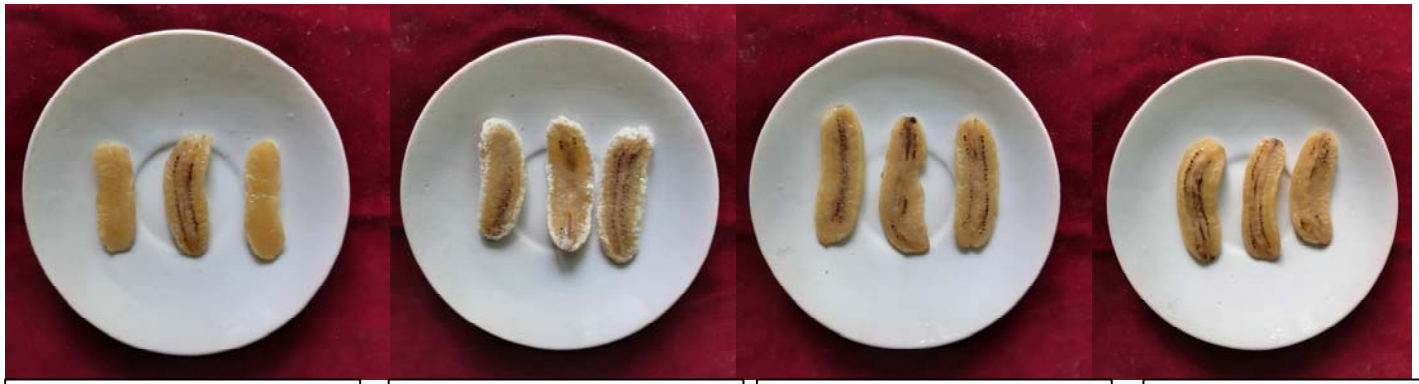
Plate 9.1: Effect of osmotic agent on the quality of intermediate moisture banana- Nendran variety [60$_{o}$Brix solution AA=ascorbic acid (0.5%), KMS=potassium metabisulphite (0.25%), NaCl=sodium chloride]

Plate 9.2: Effect of osmotic agent on the quality of intermediate moisture banana- Pisang Lilin variety [60^{o}Brix solution AA=ascorbic acid (0.5%), KMS=potassium metabisulphite (0.25%), NaCl=sodium chloride]

Sucrose+AA+KMS | Glucose+AA+KMS | Sucrose+sorbitol +AA+KMS | Glucose+sorbitol +AA+KMS

Palm sugar+AA+KMS | Honey+AA+KMS | Sucrose+NaCl+KMS

Plate 9.3: Effect of osmotic agent on the quality of intermediate moisture banana- Karpooravalli variety [60^{o}Brix solution AA=ascorbic acid (0.5%), KMS=potassium metabisulphite (0.25%), NaCl=sodium chloride]



Sucrose+AA+KMS | Glucose+AA+KMS | Sucrose+sorbitol +AA+KMS | Glucose+sorbitol +AA+KMS

Palm sugar+AA+KMS | Honey+AA+KMS | Sucrose+NaCl+KMS

Plate 9.4: Effect of osmotic agent on the quality of intermediate moisture banana- Njalipoovan variety [60^{o}Brix solution AA=ascorbic acid (0.5%), KMS=potassium metabisulphite (0.25%), NaCl=sodium chloride]

Plate 9.5: Effect of osmotic agent on the quality of intermediate moisture banana- Grand Naine variety [60°Brix solution AA=ascorbic acid (0.5%), KMS=potassium metabisulphite (0.25%), NaCl=sodium chloride]

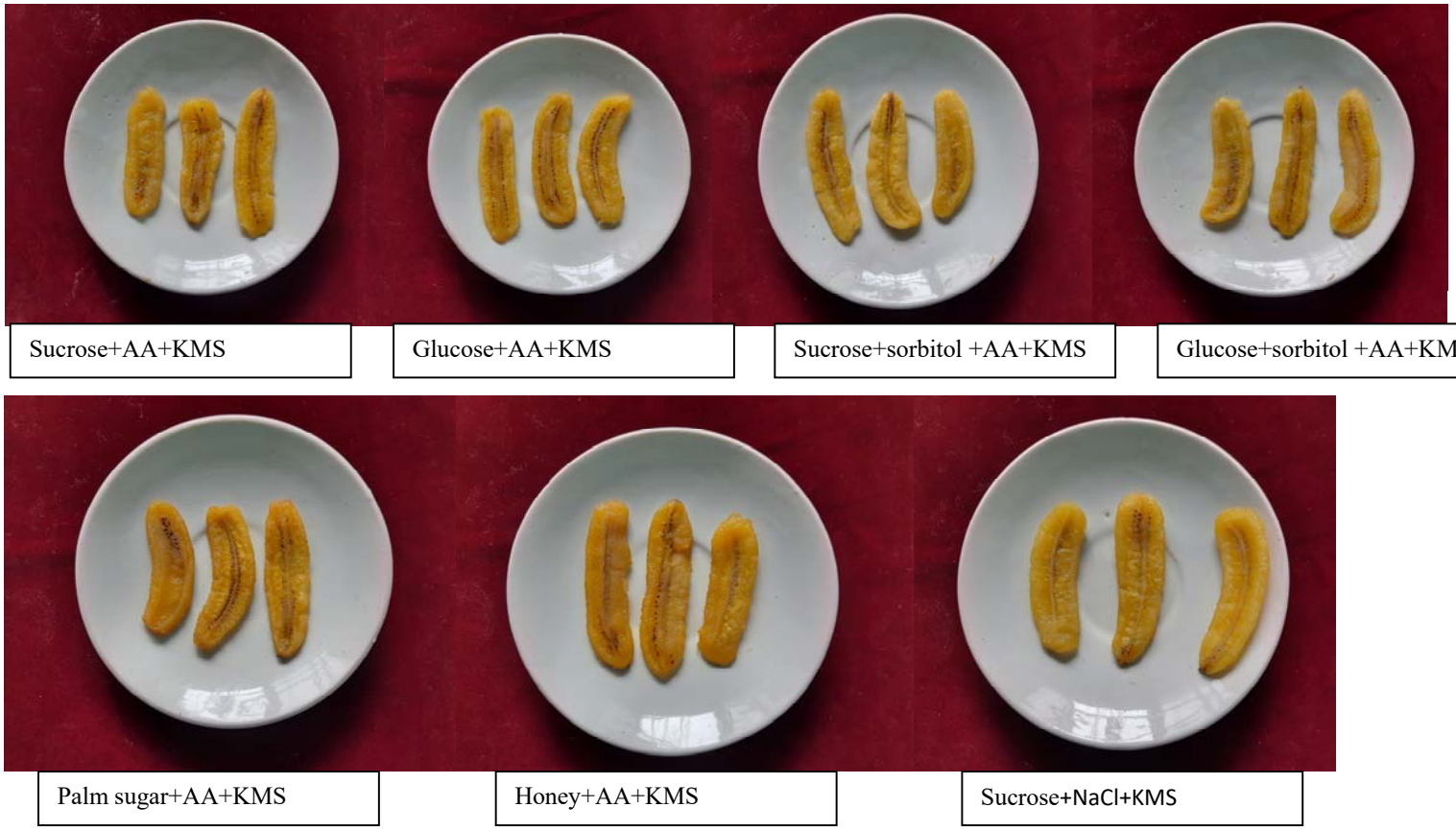


Plate 9.6: Effect of osmotic agent on the quality of intermediate moisture banana- Yangambi km5 variety [60^{o}Brix solution AA=ascorbic acid (0.5%), KMS=potassium metabisulphite (0.25%), NaCl=sodium chloride]

Table 23.7: Effect of osmotic agents on the after taste of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.53	5.73	5.47	6.67	6.93	6.40
T2	6.73	5.27	6.07	6.13	5.93	5.07
T3	7.67	6.27	6.20	6.47	7.00	6.27
T4	7.33	5.53	6.47	6.00	6.93	6.20
T5	7.67	5.20	6.60	5.33	6.67	5.93
T6	7.20	5.00	7.20	4.80	6.73	5.33
T7	7.33	5.47	7.13	6.27	7.07	7.13
Mean	7.35	5.50	6.45	5.95	6.75	6.05
KW	0.13^{NS}	0.12^{NS}	0.30**	0.21*	0.15^{NS}	0.31**

Table 23.8: Effect of osmotic agents on the overall acceptability of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi km5 (AAA)
T1	7.40	6.47	6.00	7.60	6.87	7.00
T2	6.73	6.13	6.27	6.33	6.07	5.87
T3	7.67	7.00	7.33	6.73	7.07	6.87
T4	7.27	6.13	6.60	6.40	7.33	6.47
T5	7.40	5.33	6.80	5.53	6.80	6.20
T6	7.07	5.27	7.60	4.53	6.67	6.07
T7	7.53	5.40	7.27	6.27	7.00	7.20
Mean	7.30	5.96	6.83	6.20	6.83	6.53
KW	0.13^{NS}	0.26**	0.33**	0.36**	0.17*	0.21**

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

4.2.5 Cost of production

The cost of production per 100g fruit of IM bananas treated with different osmotic agents is presented in Figure 1 and Appendix 2. The cost of raw materials and inputs required to make an IM product using the technology of osmodehydration was taken into account (Appendix 2). Variation in the cost of production was found on the type of osmotic agent used, with the highest cost observed in sucrose-based osmotic agents, *viz.*, sucrose, sucrose+sorbitol, and sucrose+NaCl. No significant difference was found in the cost of production among banana varieties. Variety Njalipoovan showed the highest (Rs. 201.84) cost of production in fruits treated with sucrose solution (T1) and the lowest (Rs. 97.34) cost was observed with the fruits immersed in palm sugar solution (T5) in varieties of Pisang Lilin, Karpooravalli, Grand Naine, and Yangambi km5. When the present worth of IM fruit is Rs. 70/100g, the cost benefit ratio of IM bananas developed with osmotic solution at room temperature ranges between 0.35 and 0.72 on the products developed using sucrose solution and palm sugar solution, respectively.

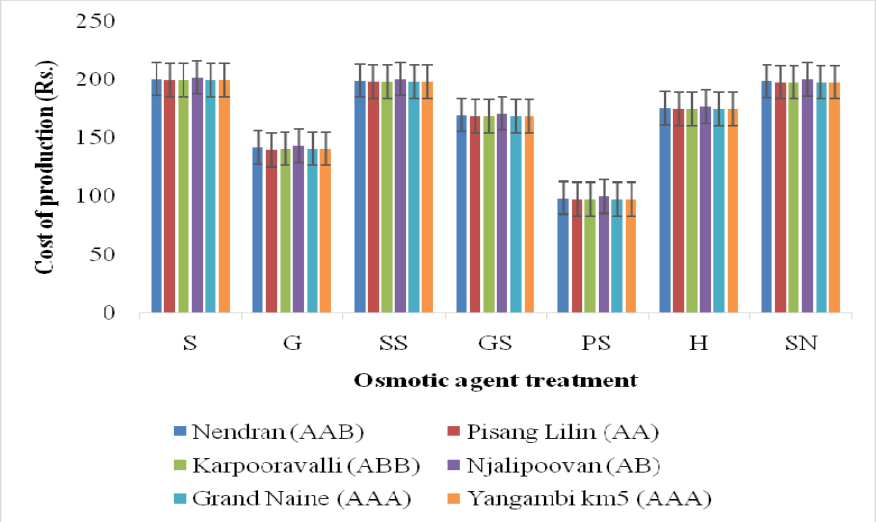


Figure 1: The effect of osmotic agents on the cost (Rs.) of production of 100g of IM banana[S=sucrose solution; G=glucose solution; SS=sucrose+sorbitol solution; GS= glucose+sorbitol solution; PS= palm sugar solution; H= honey; SN= sucrose+NaCl solution]

4.2.6 Effect of osmotic agent and subsequent dehydration in vacuum and cabinet drier on quality of Intermediate Moisture (IM) banana

The next sections describe the results of comparing the quality of Intermediate Moisture (IM) bananas dehydrated in vacuum and cabinet driers using the best treatment obtained in Experiment 2 above.

4.2.6.1 Effect of vacuum and cabinet drying on the physical quality of Intermediate Moisture (IM) banana
4.2.6.2 Effect of vacuum and cabinet drying on the biochemical quality of Intermediate Moisture (IM) banana
4.2.6.3 Effect of vacuum and cabinet drying on the microbial load of Intermediate Moisture (IM) banana
4.2.6.4 Effect of vacuum and cabinet drying on the organoleptic characteristics of Intermediate Moisture (IM) banana
4.2.6.5 Effect of vacuum and cabinet drying on cost of production of Intermediate Moisture (IM) banana

4.2.6 Effect of vacuum drying and cabinet drying on the physical quality of Intermediate Moisture (IM) banana

The physical quality of IM bananas is illustrated in Table 24 after vacuum drying and cabinet drying. Vacuum dried IM bananas had higher physical qualities than cabinet dried bananas, including moisture content (29.97 %), solid gain (26.34 %), and b^* color value (9.57). In terms of weight loss, water loss, water activity, ERH, and color values L^* and a^*, there was no significant difference between IM bananas dried using different fruit dehydrators.

4.2.7 Effect of vacuum drying and cabinet drying on the biochemical quality of IM banana

The effect of vacuum drying and cabinet drying on the biochemical quality of IM bananas is shown in Table 25. IM banana subsequently dried using a vacuum drier has better biochemical characteristics in terms of their titratable acidity (0.60 %), vitamin C (34.67 mg/100g), carotenoids (502.42 µg/100g) and total phenols (290.00 mg/100g) compared to cabinet dried IM banana. Compared to vacuum dried IM bananas, cabinet dried fruits had high sugar content in terms of reducing sugars (8.18 %), non-reducing sugars (31.08 %) and total sugars (39.27 %), while no significant difference was observed in the biochemical characteristics such as total soluble solids, total ash, pH and non-enzymatic browning.

4.2.8 Effect of vacuum drying and cabinet drying on the microbial load of IM banana

Table 26 shows the effect of vacuum drying and cabinet drying on the microbial load of IM bananas. None of the microorganisms tested was detected in any sample of vacuum-dried or cabinet-dried IM banana.

4.2.9 Effect of vacuum drying and cabinet drying on the organoleptic quality of IM banana

Although sensory attributes among IM bananas recorded a score above six, vacuum-dried IM bananas had the highest scores in terms of appearance, colour, flavour, texture, odour, taste, after taste, and overall acceptability compared to cabinet-dried IM bananas (Table 27 and Appendix 3).

4.2.10 Effect of vacuum drying and cabinet drying on the cost of production of IM banana

The cost of producing 100g of vacuum and cabinet dried IM bananas was recorded as Rs. 198.86 (Figure 2 and Appendix 4).

Table 24: Effect of vacuum drying and cabinet drying on the physical quality of Intermediate Moisture (IM) banana

Treatment	Moisture content (%)	Weight loss (%)	Solid gain (%)	Water loss (%)	Water activity (a_w)	ERH (%)	Colour values		
							*L**	*a**	*b**
Vacuum dried IM banana	29.97[a]	21.67	26.34[a]	48.00	0.79	79.33	90.83	-0.087	9.57[a]
Cabinet dried IM banana	20.73[b]	21.11	14.35[b]	35.46	0.80	80.33	92.94	0.047	8.06[b]
CD	0.71	NS	5.95	NS	NS	NS	NS	NS	0.47

ERH= Equilibrium relative humidity

Table 25: Effect of vacuum drying and cabinet drying on the biochemical quality of IM banana

Treatment	TSS (°Brix)	TA (%)	Total ash (%)	pH	Reducing sugars (%)	Non reducing sugars (%)	Total sugars (%)	Vitamin C (mg/100g)	Carotenoids (µg/100g)	Phenols (mg/100g)	Non enzymatic browning (OD value)
Vacuum dried IM banana	69.67	0.60[a]	9.08	3.54	6.50[b]	24.43[b]	31.03[b]	34.67[a]	502.48[a]	290.00[a]	0.25
Oven dried IM banana	70.33	0.36[b]	8.08	3.54	8.18[a]	31.08[a]	39.27[a]	28.27[b]	247.92[b]	245.67[b]	0.27
CD	NS	0.173	NS	NS	0.94	5.87	5.11	3.62	55.06	30.25	NS

Table 26: Effect of vacuum drying and cabinet drying on the bacteria, *Eschechia coli*, fungi, yeast population in IM banana (cfu/g)

Treatment	BT ($\times 10^{-5}$)	EC($\times 10^{-5}$)	FN($\times 10^{-3}$)	YT($\times 10^{-4}$)
Vacuum oven IM banana	a	a	a	a
Cabinet dried IM banana	a	a	a	a

BT: Bacteria; EC: Escherichia coli; FN: Fungi; YT: Yeast

a: No micro-organism detected

Table 27: Effect of vacuum drying and cabinet drying on organoleptic quality of intermediate moisture (IM) banana

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
Vacuum oven dried IM banana	8.27	8.33	7.73	7.67	6.67	7.20	7.07	7.73
Cabinet dried IM banana	7.53	7.80	6.73	6.33	6.47	6.80	6.60	7.00
Kendal's W test	0.53*	0.53*	0.68*	0.60*	0.00^{NS}	0.20*	0.47*	0.53*

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

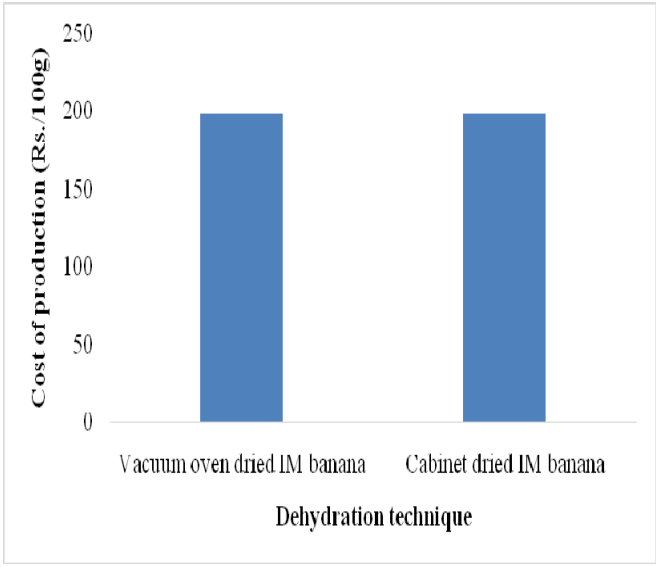


Figure 2: The effect of vacuum drying and cabinet drying on the cost (Rs.) of producing 100g of intermediate moisture (IM) banana

Experiment 3

4.3 Standardization of fruit to osmotic solution ratio and duration of immersion on quality of Intermediate Moisture (IM) banana

Banana fruit slices from the best osmotic solution and variety from Experiment II was placed at different ratios of fruit to solution (1:1, 1:2, 1:3, and 1:4) for varying periods of immersion (4, 8, and 12 hours). The osmotic solution temperature was set at 40 ^{o}C the osmotic solution concentration of 60 ^{o}Brix. Liquid glucose was incorporated as one of the osmotic agents in the best final selected treatment. The osmodehydydrated fruits were then dehydrated using the best technique from Experiment II to constant moisture.

4.3.1 Physical characteristics

The physical parameters, *viz.,* moisture content (%), weight loss (%), solid gain (%), water loss (%), equilibrium relative humidity (%) and colour values (L^*, a^*, b^*) for standardized procedures of fruit to osmotic solution ratio and duration of immersion of intermediate moisture banana were recorded.

4.3.1.1 Standardization of fruit to osmotic solution ratio and duration of immersion on the moisture content (%) of Intermediate Moisture (IM) banana

The moisture content of IM bananas among different treatments ranged between 19.47 and 40.10 per cent (Table 28). The highest (40.10 %) moisture content of fruit slices of IM banana in fruit: osmotic solution ratio of 1:1 and duration of immersion of 12 hours. The lowest (19.47 %) moisture content of fruit slices of IM banana was in fruit: osmotic solution ratio of 1:2 and duration of immersion of four hours.

4.3.1.2 Standardization of fruit to osmotic solution ratio and duration of immersion on the weight loss (%) of Intermediate Moisture (IM) banana

The weight loss of IM bananas between various treatments ranged between 20.13 and 31.73 per cent (Table 29). The highest (31.73 %) weight loss of fruit slices of IM banana was in fruit: osmotic solution ratio of 1:4 and duration of immersion of eight hours. The lowest (20.13 %) weight loss of fruit slices of IM banana was in fruit: osmotic solution ratio of 1:1 and duration of immersion of eight hours.

Table 28: Effect of fruit to osmotic solution ratio and duration of immersion on moisture content (%) of IM banana

Ratio of fruit to osmotic solution	**Time (hours)**			
	4	8	12	Mean A
1:1	33.53^{c}	37.66^{ab}	40.10^{a}	37.10
1:2	19.47^{e}	27.07^{d}	37.00^{b}	27.85
1:3	20.91^{e}	25.67^{d}	26.87^{d}	24.47
1:4	26.85^{d}	19.83^{e}	21.52^{e}	22.74
Mean B	25.19	27.55	31.37	
Factors	CD	SE(m)	Fcalc.	
Factor A	1.47	0.50	163.01**	
Factor B	1.27	0.47	51.57**	
A×B	2.53	0.87	32.13**	

****Significant at 1%**

Table 29: Effect of fruit to osmotic solution ratio and duration of immersion on weight loss (%) of IM banana

Ratio of fruit to osmotic solution	**Time (hours)**			
	4	8	12	Mean A
1:1	21.87	20.13	26.33	22.78
1:2	27.27	26.07	28.27	27.20
1:3	27.93	31.67	28.33	29.31
1:4	29.47	31.73	30.87	30.69
Mean B	26.33	27.40	28.45	
Factors	CD	SE(m)	Fcalc.	
Factor A	2.75	0.94	13.43**	
Factor B	NS	0.82	1.25^{NS}	
A×B	NS	1.63	1.70^{NS}	

****Significant at 1%**

4.3.1.3 Standardization of fruit to osmotic solution ratio and duration of immersion on the solid gain (%) of Intermediate Moisture (IM) banana

The solid gain of IM banana did not differ significantly between treatments, ranging from 18.00 to 28.93 per cent (Table 30).The highest (28.93 %) solid gain of fruit slices of IM banana was in fruit: osmotic solution ratio of 1:1 and duration of immersion of eight hours. The lowest (18.00 %) solid gain of fruit slices of IM banana was in fruit: osmotic solution ratio of 1:4 and duration of immersion of 12 hours.

4.3.1.4 Standardization of fruit to osmotic solution ratio and duration of immersion on the water loss (%) of Intermediate Moisture (IM) banana

No significant difference in the water loss was recorded among treatments of IM banana (Table 31), which ranged between 45.70 and 51.70 per cent. The water loss of IM banana was highest (51.60 %) in fruit: osmotic solution ratio of 1:3 and duration of eight hours and lowest (45.70 %) at an osmotic solution ratio of 1:1 and duration of four hours.

4.3.1.5 Standardization of fruit to osmotic solution ratio and duration of immersion on the water activity of Intermediate Moisture (IM) banana

The water activity of IM banana significantly varied among treatments (Table 32), which ranged from 0.66 to 0.81. Fruits immersed in fruit: osmotic solution of 1:1 had the highest water activity of all durations of immersion compared to other treatments. The highest (0.81) water activities of IM banana were recorded in the fruit: osmotic solution ratio 1:1 and four-hour immersion time. The lowest water activity of 0.66 and 0.67 were both recorded in the fruit: osmotic solution 1:3 at eight and twelve hours of immersion time, respectively.

4.3.1.6 Standardization of fruit to osmotic solution ratio and duration of immersion on the equilibrium relative humidity (ERH) (%) of Intermediate Moisture (IM) banana

The ERH of IM banana significantly varied among treatments (Table 33), which ranged from 65.57 to 81.00 per cent. Fruits immersed in fruit: osmotic solution ratio of 1:1 had high ERH for all durations of immersion compared to other treatments. The highest (81.00 %) ERH of IM banana was recorded in the fruit: osmotic ratio 1:1 and four-hour immersion time. The lowest ERH of 65.57 and 66.53 per cent were both recorded in the fruit: osmotic solution ratio of 1:3 at eight and twelve hours of immersion time, respectively.

Table 30: Effect of fruit to osmotic solution ratio and duration of immersion on solid gain (%) of IM banana

Ratio of fruit: osmotic solution	**Time (hours)**			
	4	8	12	Mean A
1:1	23.93	28.93	16.37	23.08
1:2	21.80	23.40	22.67	22.62
1:3	19.33	19.33	18.80	19.36
1:4	20.20	16.37	18.00	18.19
Mean B	21.32	22.16	18.53	
Factors	CD	SE(m)	Fcalc.	
Factor A	NS	1.70	2.01^{NS}	
Factor B	NS	1.47	1.27^{NS}	
A×B	NS	2.94	1.30^{NS}	

****Significant at 1%**

Table 31: Effect of fruit to osmotic solution ratio and duration of immersion on water loss (%) of IM banana

Ratio of fruit: osmotic solution	**Time (hours)**			
	4	8	12	Mean A
1:1	45.70	49.07	46.80	47.19
1:2	49.13	49.47	50.93	49.84
1:3	47.47	51.60	47.13	48.73
1:4	46.40	46.80	48.80	47.33
Mean B	47.18	49.23	48.42	
Factors	CD	SE(m)	Fcalc.	
Factor A	NS	1.86	0.46^{NS}	
Factor B	NS	1.61	0.42^{NS}	
A×B	NS	3.22	0.24^{NS}	

****Significant at 1%**

Table 32: Effect of fruit to osmotic solution ratio and duration of immersion on water activity (a_w) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	0.81[a]	0.80[a]	0.79[a]	0.80
1:2	0.80[a]	0.71[cd]	0.74[b]	0.75
1:3	0.73[bc]	0.66[e]	0.67[e]	0.68
1:4	0.80[a]	0.79[a]	0.69[d]	0.76
Mean B	0.78	0.74	0.72	
Factors	CD	SE(m)	Fcalc.	
Factor A	0.01	0.01	104.72**	
Factor B	0.01	0.00	56.28**	
A×B	0.02	0.01	15.46**	

****Significant at 1%**

Table 33: Effect of fruit to osmotic solution ratio and duration of immersion on equilibrium relative humidity (%) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	81.00[a]	80.20[a]	78.90[a]	80.03
1:2	80.03[a]	70.60[cd]	74.07[b]	74.90
1:3	72.60[bc]	65.57[e]	66.53[e]	68.23
1:4	78.90[a]	78.73[a]	69.13[d]	75.59
Mean B	78.13	73.77	72.16	
Factors	CD	SE(m)	Fcalc.	
Factor A	1.38	0.48	104.72**	
Factor B	1.20	0.41	56.28**	
A×B	2.41	0.82	15.46**	

****Significant at 1%**

4.3.1.7 Colour values (*L**, *a**, *b**)

The colour values (*L**, *a**, *b**) varied among different treatments (Table 34). The fruit: osmotic solution ratios of 1:3 and 1:4 recorded higher values of *L** at a duration of eight hours, recorded as 97.10 and 97.13, respectively, which were not significantly different. Lowest (86.80) colour value of *L** was recorded in fruit: osmotic solution of 1:1

for 4 hours, which also recorded higher (-0.01) colour values for a^*. The lowest values for colour denoting a^* were recorded in the treatment with a fruit: osmotic solution ratio of 1:4 and duration of four hours. In the case of the colour values denoting b^*, highest (12.84) and lowest (-4.49) colour values for fruit: osmotic solution ratio were recorded at 1:1 and 1:4, respectively, both at duration of four hours.

Table 34: Effect of fruit to osmotic solution ratio and duration of immersion on the colour values (*L, *a**, *b**) of IM banana**

L* **values**					***a**** **values**					***b**** **values**				
Ratio of fruit: osmotic solution	**Time (hours)**				**Ratio of fruit: osmotic solution**	**Time (hours)**				**Ratio of fruit: osmotic solution**	**Time (hours)**			
	4	**8**	**12**	**Mean A**		**4**	**8**	**12**	**Mean A**		**4**	**8**	**12**	**Mean A**
1:1	86.80^{g}	93.95^{cd}	95.77^{ab}	92.17	**1:1**	-0.01^{a}	-2.43^{e}	-0.11^{ab}	-0.85	**1:1**	12.84^{a}	6.90^{d}	6.00^{f}	8.58
1:2	90.63^{f}	95.22^{bc}	95.14^{bc}	93.66	**1:2**	-0.14^{ab}	-0.29^{bcd}	-0.35^{d}	-0.26	**1:2**	9.92^{b}	6.52^{e}	6.92^{d}	7.79
1:3	95.19^{bc}	97.10^{a}	91.31^{ef}	94.54	**1:3**	-0.29^{bcd}	-0.28^{bcd}	-0.20^{bcd}	-0.26	**1:3**	5.79^{f}	4.97^{g}	9.97^{b}	6.91
1:4	82.53^{h}	97.13^{a}	92.47^{de}	90.71	**1:4**	-6.27^{f}	-0.18^{abcd}	-0.32^{cd}	-2.26	**1:4**	-4.49^{i}	4.20^{h}	8.40^{c}	2.70
Mean B	88.53	95.85	93.68		**Mean B**	-1.68	-0.79	-0.25		**Mean B**	6.02	5.65	7.82	
Factors	**CD**	**SE(m)**	**Fcalc.**		**Factors**	**CD**	**SE(m)**	**Fcalc.**		**Factors**	**CD**	**SE(m)**	**Fcalc.**	
Factor A	0.99	0.34	24.72**		**Factor A**	0.11	0.04	632.52		**Factor A**	0.19	0.06	1585.95**	
Factor B	0.86	0.29	152.08**		**Factor B**	0.10	0.03	494.74		**Factor B**	0.06	0.17	4.17.47**	
A×B	1.71	0.59	41.39**		**A×B**	0.19	0.06	940.34		**A×B**	0.11	0.33	1597.07**	

****Significant at 1%**

4.3.2. Biochemical characteristics

Biochemical characters such as total soluble solids (°Brix), titratable acidity (%), total ash (%), pH, reducing sugars (%), non- reducing sugars (%), total sugars (%), vitamin C (mg/100g), total carotenoids (µg/100g), total phenols (mg/100g) and non- enzymatic browning (NEB) for standardized procedures of fruit to osmotic solution ratio and duration of immersion of intermediate moisture banana were recorded.

4.3.2.1 Total soluble solids (°Brix)

Table 35 reveals that the total soluble solids (TSS) of IM banana fruit slices prepared in sucrose+sorbitol solution (T3) at a temperature of 40 °C varied significantly between different fruit to osmotic solution ratios and immersion durations, with the TSS range recorded between 48.33 and 69.67 °Brix. IM banana slices had high TSS values after four hours of immersion, with the highest (69.67 °Brix) recorded when the fruit to osmotic solution ratio was 1:1. TSS was shown to be lowest in IM banana fruit slices treated with a 1:1 fruit to osmotic solution ratio for eight hours.

4.3.2.2 Titratable acidity (%)

The results in Table 36 reveal a significant difference in the titratable acidity (TA) of IM banana fruit slices prepared with sucrose+sorbitol solution (T3) at a temperature of 40 °C osmotic solution temperature when subjected to different osmotic solution ratios and durations of immersion. Treatment of 1:4 and four hours recorded a high TA value for IM banana of 0.80 per cent, while the osmotic solution ratio of 1:3 and eight-hour duration of immersion had the lowest TA value of 0.29 per cent.

Table 35: Effect of fruit to osmotic solution ratio and duration of immersion on total soluble (°Brix) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	69.67[a]	48.33[e]	53.17[de]	57.06
1:2	63.00[abc]	62.33[bc]	59.50[cd]	62.61
1:3	69.50[a]	67.67[ab]	68.33[ab]	68.60
1:4	69.33[a]	58.33[cd]	68.83[ab]	65.50
Mean B	67.88	59.17	68.83	
Factors	CD	SE(m)	Fcalc.	
Factor A	4.03	1.38	13.06**	
Factor B	3.49	1.20	13.48**	
A×B	6.99	2.93	5.29**	

****Significant at 1%**

Table 36: Effect of fruit to osmotic solution ratio and duration of immersion on titratable acidity (%) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	0.66[b]	0.60[b]	0.54[cd]	0.60
1:2	0.47[de]	0.44[e]	0.45[e]	0.45
1:3	0.62[bc]	0.29[f]	0.45[e]	0.45
1:4	0.80[a]	0.42[e]	0.49[de]	0.57
Mean B	0.64	0.44	0.48	
Factors	CD	SE(m)	Fcalc.	
Factor A	0.05	0.02	21.19**	
Factor B	0.04	0.02	51.37**	
A×B	0.03	0.09	10.80**	

****Significant at 1%**

4.3.2.3 Total ash (%)

The total ash of IM banana from sucrose and sorbitol solution (T3) at an osmotic temperature of 40 °C ranged from 4.12 to 10.47 per cent (Table 37). Total ash values were highest (10.47 %) for the IM banana from a fruit: osmotic solution ratio of 1:4 and

an eight-hour immersion, and lowest (4.12 %) for the fruit: osmotic solution ratio of 1:1 and an eight-hour immersion time.

4.3.2.4 pH

The pH of IM banana prepared from sucrose+sorbitol solution (T3) at 40 ºC osmotic temperature varied significantly between different fruit: osmotic solution ratios and immersion durations, with values ranging from 3.46 to 3.63 (Table 38).The IM banana prepared with fruit: osmotic solution ratio of 1:4 and a twelve-hour immersion time had the highest (3.63) pH values, and the lowest (3.46) was for the fruit: osmotic solution ratio of 1:1 and an four-hour immersion time.

Table 37: Effect of fruit to osmotic solution ratio and duration of immersion on the total ash (%) of IM banana

Ratio of fruit: osmotic solution	**Time (hours)**			
	4	8	12	Mean A
1:1	6.05^{e}	4.12^{g}	4.90^{f}	5.02
1:2	7.15^{d}	4.24^{g}	5.53^{e}	5.64
1:3	8.23^{c}	9.80^{b}	7.40^{d}	8.48
1:4	9.51^{b}	10.47^{a}	8.60^{c}	9.52
Mean B	7.38	7.16	6.61	
Factors	CD	SE(m)	Fcalc.	
Factor A	0.35	0.12	339.72**	
Factor B	0.10	0.30	30.48**	
A×B	0.21	0.60	33.09**	

****Significant at 1%**

Table 38: Effect of fruit to osmotic solution ratio and duration of immersion on the pH of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	3.46^{g}	3.57^{bc}	3.56^{cd}	3.53
1:2	3.57^{bc}	3.52^{de}	3.60^{ab}	3.56
1:3	3.55^{cd}	3.50^{ef}	3.62^{b}	3.56
1:4	3.49^{fg}	3.48^{fg}	3.63^{a}	3.52
Mean B	3.52	3.52	3.60	
Factors	CD	SE(m)	Fcalc.	
Factor A	0.02	0.01	5.18^{NS}	
Factor B	0.02	0.01	63.72**	
A×B	0.04	0.01	15.45**	

****Significant at 1%**

4.3.2.5 Reducing sugars (%)

The reducing sugars of IM banana prepared with sucrose and sorbitol solution (T3) at an osmotic temperature of 40 ºC varied significantly among different treatments (Table 39). The reducing sugar values of IM bananas ranged from 5.67 to 20.83 per cent. The IM banana prepared with fruit: osmotic solution ratio of 1:3 and a twelve-hour immersion period had the highest (20.83 %) values for reducing sugars, and the lowest (5.67%) values were in fruit: osmotic solution of 1:3 and an eight-hour immersion time**.**

4.3.2.6 Non reducing sugars (%)

Table 40 shows the non-reducing sugars of IM bananas prepared with sucrose and sorbitol solution (T3) at an osmotic temperature of 40 ºC among different treatments. The non-reducing sugar content of the IM bananas varied significantly with different fruit: osmotic solution ratios and duration of immersion, where non-reducing sugar values ranged from 4.77 percent to 25.03 per cent. The IM banana prepared from fruit: osmotic solution ratio of 1:3 and a four-hour immersion duration had the highest (25.03 %) non-reducing sugars and the lowest (4.77 %) values for non-reducing sugars was in fruit: osmotic solution ratio of 1:4 and a twelve-hour immersion time.

Table 39: Effect of fruit to osmotic solution ratio and duration of immersion on the reducing sugars (%) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	12.45^{d}	11.37^{e}	12.43^{d}	12.09
1:2	13.20^{cd}	7.85^{g}	10.37^{ef}	10.47
1:3	13.83^{c}	5.67^{h}	20.83^{a}	13.44
1:4	10.37^{ef}	9.90^{f}	16.83^{b}	12.37
Mean B	12.47	8.70	15.12	
Factors	CD	SE(m)	Fcalc.	
Factor A	0.61	0.21	34.37**	
Factor B	0.53	0.18	316.13**	
A×B	1.06	0.36	97.34**	

****Significant at 1%**

Table 40: Effect of fruit to osmotic solution ratio and duration of immersion on the non reducing sugars (%) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	16.23^{d}	11.33^{f}	14.03^{e}	13.87
1:2	18.33^{c}	16.33^{cd}	20.57^{b}	18.44
1:3	25.03^{a}	17.50^{cd}	7.83^{g}	16.79
1:4	16.97^{cd}	21.53^{b}	4.77^{h}	14.42
Mean B	19.09	16.75	11.80	
Factors	CD	SE(m)	Fcalc.	
Factor A	1.00	0.34	38.88**	
Factor B	0.86	0.30	158.68**	
A×B	1.73	0.59	99.23**	

****Significant at 1%**

4.3.2.7 Total sugars (%)

Table 41 shows the total sugars in IM bananas made with sucrose+sorbitol (T3) at a temperature of 40 ^{o}C in an osmotic solution. A significant difference among different treatments in the total sugar content of IM bananas was recorded, which ranged from 21.60 to 38.87 per cent. Total sugars were highest (38.87 %) in the IM banana prepared

with an osmotic solution ratio of 1:3 and a four-hour immersion time, and lowest (21.60 %) in the fruit with an osmotic ratio of 1:4 and twelve-hour duration of immersion.

4.3.2.8 Vitamin C (mg/100g)

The ascorbic acid content of IM bananas prepared with sucrose and sorbitol solution (T3) at an osmotic temperature of 40 ºC is presented in Table 42. The ascorbic acid content of IM bananas varied significantly among different treatments, which ranged between 13.97 and 48.17 mg/100g. At fruit: osmotic ratio of 1:3 and a four-hour duration of immersion, the highest ascorbic acid content of IM banana was recorded, and the lowest ascorbic acid content was noted when the fruit: osmotic solution ratio was at 1:1 and a twelve-hour immersion time.

Table 41: Effect of fruit to osmotic solution ratio and duration of immersion on the total sugars (%) of IM banana

Ratio of fruit: osmotic solution	**Time (hours)**			
	4	8	12	Mean A
1:1	28.70^{c}	22.70^{fg}	26.47^{de}	25.96
1:2	31.17^{b}	24.47^{fg}	32.73^{b}	29.46
1:3	38.87^{a}	23.17^{fg}	28.67^{c}	30.23
1:4	27.33^{cd}	31.43^{b}	21.60^{g}	26.79
Mean B	31.52	25.44	27.37	
Factors	CD	SE(m)	Fcalc.	
Factor A	1.16	0.40	26.67**	
Factor B	1.01	0.36	80.93**	
A×B	2.02	0.69	54.42**	

****Significant at 1%**

Table 42. Effect of fruit to osmotic solution ratio and duration of immersion on the vitamin C content (mg/100g) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	24.27^{c}	23.97^{c}	13.97^{d}	20.73
1:2	27.93^{c}	26.10^{c}	26.10^{c}	26.70
1:3	48.17^{a}	34.83^{b}	24.27^{c}	35.76
1:4	39.13^{b}	38.37^{b}	25.73^{c}	34.41
Mean B	34.88	30.81	22.52	
Factors	CD	SE(m)	Fcalc.	
Factor A	3.03	1.04	45.74	
Factor B	2.62	0.90	476.04	
A×B	5.25	1.80	76.89	

****Significant at 1%**

4.3.2.9 Total carotenoids (µg/100g)

Table 43 shows the total carotenoids content of IM bananas prepared with sucrose and sorbitol solution (T3) at an osmotic temperature of 40 ºC with various fruit: osmotic solution ratios and immersion times. The total carotenoid concentration of IM bananas varied significantly, ranging from 142.98 µg/100g to 1149.58 µg/100g. The highest (1149.58 µg/100g) carotenoids content of IM bananas was recorded at fruit: osmotic solution ratio of 1:3 and a four-hour immersion time, while the lowest (142.98 µg/100g) carotenoids content was recorded at fruit: osmotic solution ratio of 1:4 and an eight-hour immersion time.

4.3.2.10 Total phenols (mg/100g)

The total phenol content of IM bananas prepared with sucrose and sorbitol solution (T3) at an osmotic temperature of 40 ºC using different osmotic solution ratios and immersion times is shown in Table 44. The total phenol content of IM bananas ranged from 71.83 mg/100g to 384.00 mg/100g, indicating a significant difference. The highest (384.00 mg/100g) total phenol content of IM bananas was found at a 1:4 fruit: osmotic solution ratio and a four-hour immersion period, while the lowest (71.83

mg/100g) was found at a 1:1 fruit: osmotic solution ratio and a twelve-hour immersion time.

Table 43. Effect of fruit to osmotic solution ratio and duration of immersion on the total carotenoids (µg/100g) content of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	389.87^{g}	186.55^{h}	454.83^{f}	343.75
1:2	808.80^{c}	449.48^{f}	558.07^{e}	605.45
1:3	1149.58^{a}	383.73^{g}	749.05^{d}	759.78
1:4	718.20^{d}	142.98^{i}	874.83^{b}	578.67
Mean B	766.61	290.68	658.45	
Factors	CD	SE(m)	Fcalc.	
Factor A	25.08	8.59	399.55**	
Factor B	21.72	7.44	1123.73**	
A×B	43.45	14.89	150.24**	

****Significant at 1%**

Table 44. Effect of fruit to osmotic solution ratio and duration of immersion on total phenol content (mg/100g) of IM banana

Ratio of fruit: osmotic solution	Time (hours)			
	4	8	12	Mean A
1:1	157.67^{d}	186.33^{c}	71.83^{g}	138.61
1:2	188.00^{c}	198.50^{c}	75.00^{g}	153.83
1:3	266.67^{b}	122.83^{e}	101.50^{f}	163.67
1:4	384.00^{a}	162.83^{d}	93.90^{f}	213.58
Mean B	249.08	167.23	85.56	
Factors	CD	SE(m)	Fcalc.	
Factor A	10.68	3.66	78.66**	
Factor B	9.25	3.17	665.80**	
A×B	18.50	6.34	104.07**	

****Significant at 1%**

4.3.2.11 Non enzymatic browning (OD value)

The values of non-enzymatic browning (NEB) of IM bananas prepared with sucrose and sorbitol solution (T3) at an osmotic temperature of 40 ^{o}C using different osmotic solution ratios and immersion times are shown in Table 45. The non-enzymatic

browning values of IM bananas ranged from 0.13 to 0.42, indicating a significant difference. The lowest NEB values of 0.13 and 0.17 were respectively recorded in 1:2 and 1:3 fruit to osmotic solution ratios at a twelve-hour immersion time. The highest (0.42) NEB value of IM bananas was found at a 1:2 fruit to osmotic solution ratio and a four-hour immersion period.

Table 45. Effect of fruit to osmotic solution ratio and duration of immersion on non enzymatic browning (OD value) of IM banana

Ratio of fruit: osmotic solution	**Time (hours)**			
	4	8	12	Mean A
1:1	0.30^{bcd}	0.31^{bcd}	0.35^{b}	0.32
1:2	0.42^{a}	0.26^{d}	0.13^{e}	0.27
1:3	0.28^{cd}	0.29^{cd}	0.17^{e}	0.25
1:4	0.32^{bc}	0.31^{bcd}	0.27^{d}	0.30
Mean B	0.33	0.29	0.23	
Factors	CD	SE(m)	Fcalc.	
Factor A	0.03	0.01	10.12**	
Factor B	0.03	0.01	33.16**	
A×B	0.05	0.02	16.48**	

****Significant at 1%**

4.3.3 Microbial observation

The microbial population of IM banana with various treatments of fruit: osmotic ratio and duration was observed in Table 46 and Plate 10. Yeast population of 3.67 $\times 10^{-4}$ cfu/g was observed in fruit: osmotic ratio of 1:1 and four-hour duration of immersion of fruits which also detected fungal population of 0.10 $\times 10^{-3}$ cfu/g from the same fruit to osmotic solution ratio and duration of immersion. Bacteria population of 0.33 cfu/g $\times 10^{-5}$ cfu/g was detected when fruit to osmotic solution ratio was at 1:1 and eight-hour immersion time. No population of *Escherichia coli* was detected in any of the IM banana development.

4.3.4 Organoleptic evaluation

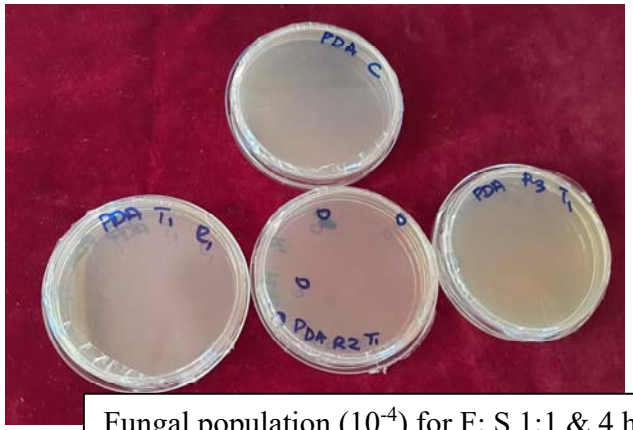
Table 47 and Appendix 5 shows the organoleptic evaluation of IM bananas pre-treated with sucrose+sorbitol solution (T3) at various osmotic solution ratios and immersion periods at 40ºC. In the organoleptic evaluation of the IM banana, a significant difference was seen, with excellent agreement across judges. In terms of appearance (8.13), colour (7.93), flavour (7.93), texture (7.53), taste (8.13), and overall acceptability (8.20), the 1:3 fruit: osmotic solution ratio and four-hour immersion duration (T3) had the highest scores. The lowest ratings were found in 1:3 fruit: osmotic solutions at twelve hours, which had the lowest scores in terms of texture (6.13), odour (5.80), taste (5.73), and overall acceptability (6.13).

Table 46: Effect of fruit to osmotic solution ratio and duration of immersion on bacteria, *Escherichia coli*, fungi and yeast population (cfu/g) of IM quality of banana

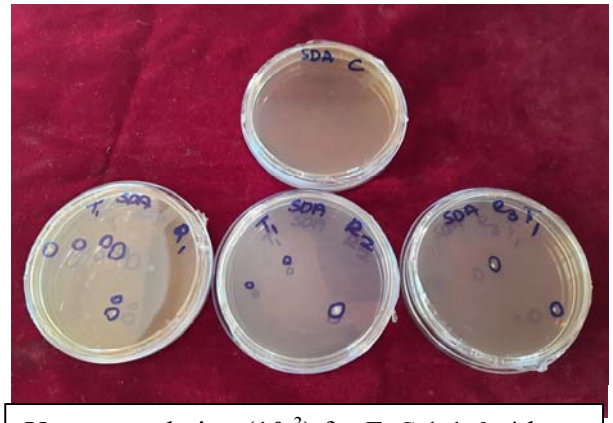
Treatment	Bacteria (10^{-5})	*E. coli* (10^{-5})	Fungi (10^{-3})	Yeast (10^{-4})
T1	a	a	0.1	3.67
T2	a	a	a	a
T3	a	a	a	a
T4	a	a	a	a
T5	0.33	a	a	a
T6	a	a	a	a
T7	a	a	a	a
T8	a	a	a	a
T9	a	a	a	a
T10	a	a	a	a
T11	a	a	a	a
T12	a	a	a	a

T1 for osmotic ratio of 1:1 and duration of immersion of four hours
T2 for osmotic ratio of 1:2 and duration of immersion of four hours
T3 for osmotic ratio of 1:3 and duration of immersion of four hours
T4 for osmotic ratio of 1:2 and duration of immersion of four hours
T5 for osmotic ratio of 1:1 and duration of immersion of eight hours
T6 for osmotic ratio of 1:2 and duration of immersion of eight hours
T7 for osmotic ratio of 1:3 and duration of immersion of eight hours
T8 for osmotic ratio of 1:4 and duration of immersion of eight hours
T9 for osmotic ratio of 1:1 and duration of immersion of twelve hours
T10 for osmotic ratio of 1:2 and duration of immersion of twelve hours
T11 for osmotic ratio of 1:3 and duration of immersion of twelve hours
T12 for osmotic ratio of 1:4 and duration of immersion of twelve hours

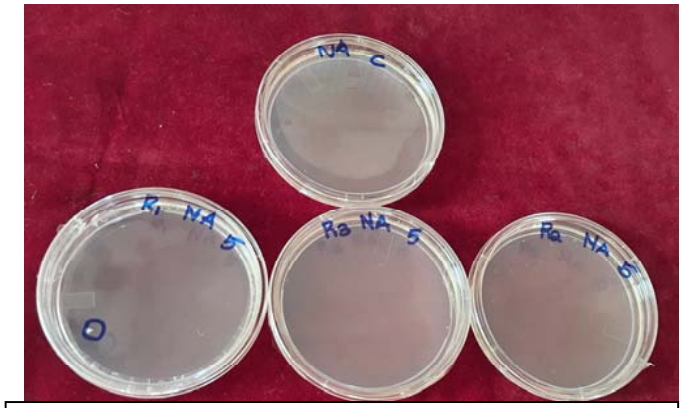
BT: Bacteria; EC: Escherichia coli; FN: Fungi; YT: Yeast
a: No micro-organism detected



Fungal population (10^{-4}) for F: S 1:1 & 4 hrs



Yeast population (10^{-3}) for F: S 1:1 & 4 hrs



Bacteria population (10^{-5}) for F: S 1:1 & 8 hrs

Plate 10. Microbiological proliferation on IM banana standardized using different fruit to osmotic solution ratio and duration of immersion

Table 47. Effect of fruit to osmotic solution ratio and duration of immersion on organoleptic quality of IM banana

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	7.87	7.47	7.47	6.93	6.73	6.20	5.67	6.20
T2	7.13	7.27	7.26	6.27	7.00	6.67	6.27	7.07
T3	8.13	7.93	7.93	7.53	6.87	8.13	6.80	8.20
T4	7.27	8.00	8.03	6.87	6.73	6.27	5.93	6.87
T5	7.13	6.80	6.80	6.47	6.73	6.13	6.20	6.40
T6	7.87	6.87	6.93	6.60	6.60	6.67	6.13	6.80
T7	7.87	7.67	7.67	7.40	6.87	7.33	7.47	7.67
T8	6.47	7.53	7.53	7.07	6.33	6.13	6.13	6.47
T9	7.80	7.47	7.47	7.07	6.73	7.40	7.20	7.20
T10	6.53	7.33	7.33	6.73	6.20	5.67	5.27	6.33
T11	7.60	7.47	7.47	6.13	5.80	5.73	5.53	6.13
T12	7.40	7.33	7.33	6.40	6.20	5.53	6.27	6.60
Kendal's W test	0.48**	0.26**	0.26**	0.28**	0.24**	0.60**	0.38**	0.40**

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively.

T1 for osmotic ratio of 1:1 and duration of immersion of four hours
T2 for osmotic ratio of 1:2 and duration of immersion of four hours
T3 for osmotic ratio of 1:3 and duration of immersion of four hours
T4 for osmotic ratio of 1:2 and duration of immersion of four hours
T5 for osmotic ratio of 1:1 and duration of immersion of eight hours
T6 for osmotic ratio of 1:2 and duration of immersion of eight hours
T7 for osmotic ratio of 1:3 and duration of immersion of eight hours
T8 for osmotic ratio of 1:4 and duration of immersion of eight hours
T9 for osmotic ratio of 1:1 and duration of immersion of twelve hours
T10 for osmotic ratio of 1:2 and duration of immersion of twelve hours
T11 for osmotic ratio of 1:3 and duration of immersion of twelve hours
T12 for osmotic ratio of 1:4 and duration of immersion of twelve hours

4.3.5 Cost of production

The cost of production of IM banana subjected to different fruit: osmotic solution ratios and duration of immersion is presented in Figure 3 and Appendix 6. The highest cost of production of Rs. 378.62 was at a 1:4 fruit: osmotic ratio and a twelve-hour immersion time, while the lowest cost of production of Rs. 163.98 was recorded at an fruit: osmotic ratio of 1:1 and a four-hour immersion time.

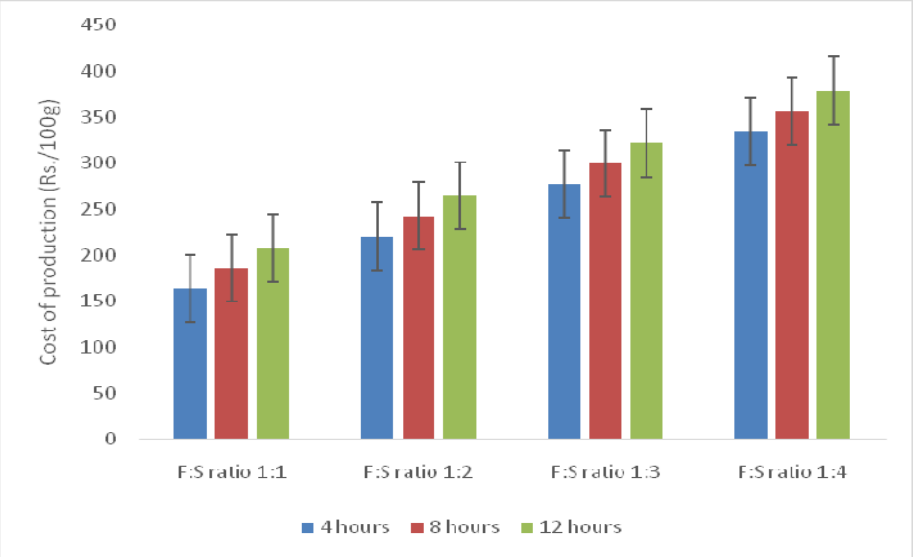


Figure 3: The effect of the fruit to osmotic solution ratio and duration of immersion on the cost (Rs.) of production of 100g of IM banana

4.3.6 Comparison between sucrose+sorbitol solution and glucose syrup both subjected to fruit: osmotic solution 1:3 and four hour duration of immersion

The next sections describe the results of comparing the quality of Intermediate Moisture (IM) bananas which were both subjected to osmotic solution of sucrose+sorbitol and glucose syrup at fruit: osmotic solution 1:3 and duration of immersion at four hours time under the following subheadings;

4.3.6.1 Effect of sucrose+sorbitol solution and glucose syrup on the physical quality of Intermediate Moisture (IM) banana

4.3.6.2 Effect of sucrose+sorbitol solution and glucose syrup on the biochemical quality of Intermediate Moisture (IM) banana

4.3.6.3 Effect of sucrose+sorbitol solution and glucose syrup on the microbial load of Intermediate Moisture (IM) banana

4.3.6.4 Effect of sucrose+sorbitol solution and glucose syrup on the organoleptic characteristics of Intermediate Moisture (IM) banana

4.3.6.5 Cost of production of Intermediate Moisture (IM) banana with sucrose+sorbitol solution and glucose syrup

4.3.6.1 Effect of sucrose+sorbitol solution and glucose syrup on the physical quality of Intermediate Moisture (IM) banana

In Table 48, the effect of sucrose+sorbitol solution and glucose syrup on the physical quality of the Intermediate Moisture (IM) banana is given. IM bananas immersed in sucrose+sorbitol solution had superior physical characteristics such as moisture (21.31%), weight loss (27.17%), water loss (46.70%), and water activity (0.70) compared to fruits immersed in glucose syrup. However, glucose syrup had better colour values, such as a lower colour value denoting *a** (-0.49) and a higher *b** value (8.00).

4.3.6.2 Effect of sucrose+sorbitol solution and liquid glucose on the biochemical quality of Intermediate Moisture (IM) banana

The effect of sucrose+sorbitol solution and glucose syrup on the biochemical quality of the Intermediate Moisture (IM) banana is shown in Table 49, where variation in the product's biochemical qualities was observed with the exception of titratable acidity. IM bananas immersed in sucrose+sorbitol had superior physical characteristics such as total soluble solids (69.33 ^{o}Brix), titratable acidity (0.57 %), total ash (8.24 %),

and pH (3.62) compared to IM bananas treated with glucose syrup. In comparison to IM bananas immersed in sucrose+sorbitol, IM bananas treated with glucose syrup had inferior biochemical qualities in terms of high (52.93 %) total sugars, lower contents of vitamin C (26.83 mg/100g), total carotenoids (174.427 g/100g), total phenols (55.00 mg/100g), and a higher browning (0.64) index.

4.3.6.3 Effect of sucrose+sorbitol solution and glucose syrup on the microbial load of Intermediate Moisture (IM) banana

The effect of sucrose+sorbitol solution and glucose syrup on the microbial load of IM banana was observed in Table 50. None of the microorganisms tested was detected in any of the samples immediately after development.

Table 48. Effect of sucrose+sorbitol solution and glucose syrup on the physical quality of Intermediate Moisture (IM) banana

Treatment	Moisture content (%)	Weight loss (%)	Solid gain (%)	Water loss (%)	Water activity (a_w)	ERH (%)	Colour values		
							L	*a*	*b*
Sucrose+sorbitol	21.31	27.17[a]	19.53	46.70	0.70[b]	69.83[b]	96.04	-0.21[a]	3.74[b]
Glucose syrup	31.92	21.27[b]	17.83	39.10	0.80[a]	80.33[a]	92.74	-0.49[b]	8.00[a]
CD	3.31	2.06	NS	NS	0.01	1.04	NS	0.14	0.56

ERH= Equilibrium relative humidity

Table 49. Effect of sucrose+sorbitol solution and glucose syrup on the biochemical quality of Intermediate Moisture (IM) banana

Treatment	TSS (°Brix)	TA (%)	Total ash (%)	pH	Reducing sugar (%)	Non reducing sugar (%)	Total sugar (%)	Vitamin C (mg/100g)	Total carotenoids (µg/100g)	Total phenols (mg/100g)	Non enzymatic browning
Sucrose+sorbitol	69.33[a]	0.57	8.24[a]	3.62[b]	15.33[b]	24.10[a]	39.43[b]	44.32[a]	1183.33[a]	268.33[a]	0.29[b]
Glucose syrup	60.33[b]	0.53	5.53[b]	3.87[a]	45.23[a]	7.70[b]	52.93[a]	26.83[b]	174.27[b]	55.00[b]	0.64[a]
CD	1.31	NS	1.35	0.15	6.93	5.01	10.77	9.20	168.34	29.26	0.08

TA= Titratable acidity

Table 50. Effect of sucrose+sorbitol solution and glucose syrup on the Intermediate Moisture (IM) banana on bacteria, *Eschechia coli*, fungi, and yeast population

Treatment	BT	EC	FN	YT
Sucrose+sorbitol	a	a	a	A
Glucose syrup	a	a	a	A

BT: Bacteria; EC: Escherichia coli; FN: Fungi; YT: Yeast

a: No micro-organism detected

4.3.6.4 Effect of sucrose+sorbitol solution and glucose syrup on the organoleptic characteristics of Intermediate Moisture (IM) banana

When compared to IM banana fruits immersed in glucose syrup, the panel of judges unanimously agreed that IM bananas treated with sucrose+sorbitol solution had higher organoleptic quality in terms of colour (8.33), flavour (7.73), taste (7.20), after taste (7.07), and overall acceptability (7.80), compared to IM bananas immersed in glucose syrup, which had lower scores for colour (7.73), flavour (6.65), taste (6.33), after taste (5.80) and overall acceptability (6.66) (Table 51 and Appendix 7). The organoleptic scores for appearance, texture, and odor of IM banana slices immersed in sucrose+sorbitol solution and glucose syrup revealed no significant difference, with acceptable scores greater than 5.50.

4.3.6.5 Cost of production of Intermediate Moisture (IM) banana with sucrose+sorbitol solution and glucose syrup

The cost of production for 100g of Intermediate Moisture (IM) banana was higher in fruits treated with sucrose+sorbitol solution at Rs. 277.74 and lower in those treated with glucose syrup at Rs. 269.79 (Figure 4 and Appendix 8).

Table 51. Effect of sucrose+sorbitol solution and glucose syrup on the organoleptic characteristics of Intermediate Moisture (IM) banana

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
Sucrose+sorbitol	8.27	8.33	7.73	7.67	6.67	720	7.07	7.80
Glucose syrup	8.07	7.73	6.65	6.60	6.13	6.33	5.80	6.66
Kendal's W test	0.08^{NS}	0.30^{*}	0.80**	0.47^{NS}	0.11^{NS}	0.36*	0.80**	0.49**

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

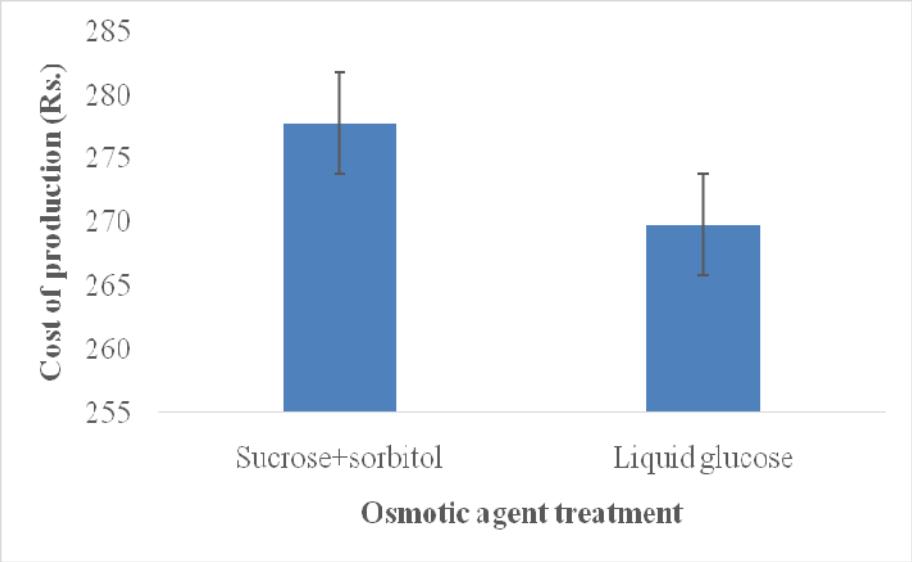


Figure 4: The effect of sucrose+sorbitol solution and glucose syrup on the cost (Rs.) of production for 100g of Intermediate Moisture (IM) banana

Experiment 4

4.4 Study on packaging materials and storage temperature on quality of Intermediate Moisture (IM) banana

4.4.1 Physical characteristics

4.4.1.1 Study on packaging materials and storage temperature on the moisture content (%) of Intermediate Moisture (IM) banana

The moisture content of intermediate moisture (IM) bananas varied significantly when held in different packaging materials and kept at different storage temperatures over a three-month period (Table 52). The moisture content of IM bananas increased after one month of storage. Following that, regardless of packaging material or storage temperature, the moisture content of IM bananas decreased with storage. The moisture content of IM bananas stored in LDPE (200 gauge) and kept at room temperature showed the greatest variation by the end of three months of storage, at 17.29 per cent compared to the initially prepared value of 21.41 per cent. IM bananas held in polyethylene laminated aluminum pouches and stored at a low temperature retained the highest moisture content of 28.70 per cent at the end of the three-month period.

4.4.1.2 Study on packaging materials and storage temperature on the water activity of Intermediate Moisture (IM) banana

The water activity of intermediate moisture (IM) bananas was evaluated on a monthly basis during three months of storage (Table 53). The water activity of IM banana increased significantly during storage, regardless of packaging material or storage temperature. IM bananas held in LDPE (200 gauge) and kept at room temperature recorded the highest water activity peaking from the initial value of 0.71 to 0.85 by the end of the three month period. IM bananas held in polyethylene laminated aluminium pouches and kept at a low temperature had the lowest (0.80) water activity by the end of the storage period.

Table 52. Effect of package material and storage temperature on moisture content (%) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34 °C)	Low (5-7 °C)	Ambient (32-34 °C)	Low (5-7 °C)
Initial	21.41^{f}	21.41^{f}	21.41^{f}	21.41^{f}
1MAS	28.71^{d}	35.80^{b}	30.20^{c}	37.55^{a}
2MAS	17.94^{h}	22.20^{f}	29.50^{cd}	37.13^{a}
3MAS	17.29^{h}	19.76^{g}	27.46^{e}	28.70^{d}
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	0.80	0.28	0.39	577.68**
Factor B	0.43	0.15	0.21	127.70**
A×B	0.39	1.14	0.55	80.69**

****Significant at 1%**

Table 53. Effect of package material and storage temperature on water activity (a_w) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34 °C)	Low (5-7 °C)	Ambient (32-34 °C)	Low (5-7 °C)
Initial	0.71^{f}	0.71^{f}	0.71^{f}	0.71^{f}
1MAS	0.82^{b}	0.74^{e}	0.78^{d}	0.75^{e}
2MAS	0.85^{a}	0.81^{c}	0.83^{b}	0.80^{c}
3MAS	0.85^{a}	0.81^{c}	0.83^{b}	0.80^{c}
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	0.01	0.00	0.00	241.53**
Factor B	0.00	0.00	0.00	283.28**
A×B	0.01	0.00	0.01	17.81**

****Significant at 1%**

4.4.1.3 Study on packaging materials and storage temperature on the colour values (*L*, a*, b**) of Intermediate Moisture (IM) banana

The colour values (*L*, a*, b**) of intermediate moisture (IM) bananas were evaluated on a monthly basis during three months of storage (Table 54). The colour value *L** of IM banana varied significantly with storage period, regardless of packaging material or storage temperature. IM bananas held in polyethylene laminated aluminum pouches and kept at low temperatures retained *L** colour values of 94.91, similar to 94.48 of the initially prepared samples. When IM bananas were held in LDPE (200 gauge) and kept at room temperature, the *L** value was recorded at 92.72, which was significantly varied from the initially prepared IM banana.

A significant effect on the package material used for storage of IM bananas was observed, whereas both low and ambient temperatures had no effect on the colour value of *a** during storage (Table 54). The IM banana slices had an initial *a** value of -0.28, which increased to 0.42 by the end of the three month period when the IM bananas were held in LDPE (200 gauge) and kept at room temperature. A slight decrease in colour value *a** was observed from -0.28 to -0.47 when IM bananas held in polyethylene laminated aluminum and kept at ambient temperature.

There was a significant difference in the colour value of *b** due to storage temperature and the type of packaging material used during the three-month storage of IM bananas (Table 54). IM bananas held in polyethylene laminated aluminum retained the ***b**** value similar to the initially prepared samples when compared to IM bananas vacuum packaged in LDPE (200 gauge). Low temperature storage caused significant *b** value degradation, whereas ambient temperature preservation preserved a high *b** value. IM bananas held in LDPE (200 gauge) and kept at ambient temperature showed a high *b** value, which had increased from 5.52 to 7.70 by the end of three months of storage. IM bananas held in LDPE (200 gauge) and kept at a low temperature showed the lowest *b** value of 2.27, which had declined from 5.52 by the end of storage.

Table 54. Effect of package material and storage temperature on colour values (*L*, a,* b **) of IM banana

L* **values**					***a**** **values**					***b**** **values**				
	LDPE (200 gauge) ambient	**LDPE (200 gauge) low**	**PAL ambient**	**PAL low**		**LDPE (200 gauge) ambient**	**LDPE (200 gauge) low**	**PAL ambient**	**PAL low**		**LDPE (200 gauge) ambient**	**LDPE (200 gauge) low**	**PAL ambient**	**PAL low**
Initial	95.48^{de}	95.48^{de}	95.48^{de}	95.48^{de}	**Initial**	-0.28	-0.28	-0.28	-0.28	**Initial**	5.52^{c}	5.52^{c}	5.52^{c}	5.52^{c}
1MAS	96.03^{bcde}	97.92^{a}	95.87^{bcde}	95.59^{cde}	**1MAS**	-0.06	-0.07	-0.18	-0.28	**1MAS**	5.31^{cd}	2.66^{f}	4.94^{d}	5.52^{c}
2MAS	91.14^{g}	95.38^{de}	96.65^{bc}	96.84^{ab}	**2MAS**	-0.267	-0.243	-0.47	-0.24	**2MAS**	6.75^{b}	4.01^{e}	5.55^{c}	5.59^{c}
3MAS	92.72^{f}	96.11^{bcd}	94.91^{e}	95.78^{bcde}	**3MAS**	0.42	0.06	-0.47	-0.26	**3MAS**	7.70^{a}	2.27^{f}	6.57^{b}	3.96^{e}
Factors	**CD**	**SE(±m)**	**Fcalc.**		**Factors**	**CD**	**SE(m)**	**Fcalc.**		**Factors**	**CD**	**SE(m)**	**Fcalc.**	
Factor A	0.82	0.28	12.80**		**Factor A**	0.19	0.07	11.08**		**Factor A**	0.36	0.12	24.51**	
Factor B	0.44	0.15	47.57**		**Factor B**	NS	0.03	0.00^{NS}		**Factor B**	0.20	0.07	497.23**	
A×B	1.56	0.40	17.93**		**A×B**	NS	0.09	2.14^{NS}		**A×B**	0.51	0.17	60.23**	

****Significant at 1%**

PAL for polyethylene laminated aluminum pouches

4.4.1.4 Equilibrium relative humidity (ERH) (%)

During three months of storage, the equilibrium relative humidity of intermediate moisture (IM) bananas was measured on a monthly basis (Table 55). The equilibrium relative humidity was affected by both the storage temperature and the package material used. IM banana held in LDPE (200 gauge) stored at room temperature showed highest ERH throughout the three-month storage period, increasing from 71.00 to 85.00 per cent by the end of the three-month period. The lowest increase in equilibrium relative humidity of IM banana of the initially prepared samples was observed after three months of storage at 71.00 per cent to 80 per cent with samples held in polyethylene-laminated aluminum pouches and kept at a low temperature.

4.4.1.5 Critical moisture content

The moisture isotherms of IM bananas on the relationship between equilibrium moisture content and the number of days required for the product to reach equilibrium at a given relative humidity (Table 56). When the relative humidity of IM banana was below 50 percent, the product became pale and hard to chew, whereas it slightly changed colour when the relative humidity was over 80 percent (Plate 11). At 89.60 per cent relative humidity, the IM banana was severely affected by mould after seven days, whereas at a relative humidity of 100 per cent, the mould growth on the product occurred within three days.

50 per cent Relative Humidity | 70 per cent Relative Humidity | 89.60 per cent Relative Humidity

Plate 11. The response of intermediate moisture banana subjected to different relative humidity (%)

Table 55. Effect of package material and storage temperature on equilibrium relative humidity (ERH) (%) of IM banana

Duration (months)	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34 ºC)	Low (5-7 ºC)	Ambient (32-34 ºC)	Low (5-7ºC)
Initial	71.00^{f}	71.00^{f}	71.00^{f}	71.00^{f}
1MAS	82.43^{b}	74.33^{e}	78.00^{d}	75.23^{e}
2MAS	85.00^{a}	81.00^{c}	83.13^{b}	80.00^{c}
3MAS	85.00^{a}	81.00^{c}	83.13^{b}	80.00^{c}
	CD	SE(m)	SE (±d)	Fcalc.
Factor A	0.01	0.00	0.00	241.53**
Factor B	0.00	0.00	0.00	283.28**
A×B	0.01	0.00	0.01	17.81**

Table 56: The effect of package material and storage temperature on the critical moisture content (%) of IM banana (Initial moisture 21.4)

Equilibrium relative humidity (%)	Equilibrium moisture content (%)	Number of days to reach equilibrium (days)	Remarks
50	15.10	18	Slightly pale in colour and hard in texture
69.83	22.05	14	Good texture, easy to chew
70	28	10	Good texture, easy to chew
80	32	7	Slightly changed in colour, easy to chew
89.60	39.2	5	Product became dark colour ,very soft and mould occurred after 7 days
100	43.09	3	Very soft and dark colour , mould growth after 4 days

4.4.2.1 Total soluble solids (°Brix)

The total soluble solids (TSS) of intermediate moisture (IM) bananas were measured monthly over three months of storage and were significantly affected by packaging material and temperature conditions (Table 57). There was the lowest decrease of TSS from 69.50 °Brix of the initially prepared sample to 69.00°Brix when IM banana was held in polyethylene laminated aluminum pouches and kept at ambient temperature over the storage duration. The TSS of IM bananas held in LDPE (200 gauge) and kept at a low temperature, on the other hand, significantly decreased with storage, showing the highest TSS decrease from 69.50°Brix to 40.67°Brix by the end of a three-month storage duration.

4.4.2.2 Titratable acidity (%)

The titratable acidity (TA) of intermediate moisture bananas was measured monthly for three months and was significantly influenced by package material and temperature conditions (Table 58). With IM bananas held in polyethylene laminated aluminum pouches and kept at a low temperature, a slight increase in TA was observed from 0.62 per cent of the initially prepared to 0.63 per cent of titratable acidity by the end of storage. The titratable acidity (TA) of IM banana held in LDPE (200 gauge) and kept at ambient temperature decreased steadily over three months, reaching the lowest (0.54) TA values by the end of storage.

4.4.2.3 Total ash (%)

The total ash of intermediate moisture bananas was measured monthly for three months and was significantly influenced by package material and temperature conditions (Table 59). The total ash of IM banana decreased during storage from 8.12 percent of the initially prepared sample to 7.33 per cent when samples were held in polyethylene laminated aluminum pouches and kept at a low temperature. A rapid decrease from 8.12 per cent of the initially prepared sample to 5.72 per cent of the total ash content of IM

banana during storage was observed when samples were held in LDPE (200 gauge) and stored at ambient temperature.

Table 57. Effect of package material and storage temperature on total soluble solid (°Brix) content of IM banana

Duration (Months)	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	69.50[a]	69.50[a]	69.50[a]	69.50[a]
1MAS	69.12[a]	53.67[b]	69.33[a]	50.00[c]
2MAS	69.33[a]	47.33[d]	69.50[a]	69.50[a]
3MAS	55.00[b]	40.67[e]	69.00[a]	67.67[a]
	CD	SE(m)	SE (±d)	Fcalc.
Factor A	1.77	0.61	0.86	166.23**
Factor B	0.95	0.33	0.47	517.24**
A×B	2.50	0.86	1.22	59.80**

Table 58. Effect of package material and storage temperature on titratable acidity (%) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	0.62[b]	0.62[b]	0.62[b]	0.62[b]
1MAS	0.62[b]	0.63[a]	0.62[b]	0.63[a]
2MAS	0.56[d]	0.61[c]	0.63[a]	0.63[a]
3MAS	0.54[e]	0.62[b]	0.62[b]	0.63[a]
	CD	SE(m)	SE (±d)	Fcalc.
Factor A	0.00	0.00	0.00	233.94**
Factor B	0.00	0.00	0.00	628.94**
A×B	0.01	0.00	0.01	134.18**

Table 59. Effect of package material and storage temperature on the total ash content (%) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	**Low (5-7°C)**	**Ambient (32-34°C)**	**Low (5-7°C)**
Initial	8.12[a]	8.12 [a]	8.12 [a]	8.12 [a]
1MAS	6.87[d]	6.97[d]	6.96[d]	7.63[b]
2MAS	5.76[g]	6.04[f]	6.85[d]	7.47[bc]
3MAS	5.72[g]	5.82[g]	6.28[e]	7.33[c]
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	0.14	0.05	0.07	273.21**
Factor B	0.08	0.03	0.037	115.17**
A×B	0.20	0.07	0.10	15.52**

4.4.2.3 pH

The pH of intermediate moisture bananas was measured monthly for three months and was significantly influenced by the package material. However, temperature conditions had no effect on the pH of intermediate moisture bananas during storage (Table 60). A stead decline on the pH of intermediate-moisture bananas from 3.57 of the initially prepared sample to 3.36 was observed when the product was held in LDPE (200 gauge) and kept at room temperature during storage. IM bananas held in polyethylene laminated aluminum pouches and kept at low temperatures maintained a constant pH of 3.54 throughout storage.

4.4.2.4 Reducing sugars (%)

The reducing sugars of intermediate moisture bananas were measured monthly for three months and were significantly influenced by the package material and temperature conditions (Table 61). The highest decline in reducing sugars of IM banana was observed with samples held in LDPE (200 gauge), with the lowest decline from 14.55 per cent of the initially prepared sample to 9.29 per cent when samples were kept at ambient

temperature. IM bananas held in polyethylene-laminated aluminum pouches showed a slight increase in reducing sugars. When IM bananas were stored in polyethylene laminated aluminum pouches and kept at a low temperature until the end of storage, the highest increase in reducing sugars, from 14.55 per cent to 15.39 per cent, was observed.

4.4.2.5 Non- reducing sugars

The non-reducing sugars in intermediate moisture bananas decreased during storage, regardless of packaging material or temperature conditions (Table 62). A decline in non-reducing sugar was observed in samples vacuum packaged in polyethylene laminated aluminum pouches and kept at a low temperature, which retained a high reducing sugar of 7.97 by the end of three months of storage compared to the 25.03 percent of the initially prepared sample. In IM banana samples vacuum packaged in polyethylene laminated aluminum pouches but kept at room temperature, there was a highly significant reduction in reducing sugar from 25.03 percent to 3.50 percent.

Table 60. Effect of package material and storage temperature on pH of IM banana

Duration	**Vacuum packing in LDPE (200 gauge)**		**Vacuum packaging in polyethylene laminated aluminum pouches**	
	Ambient (32-34°C)	**Low (5-7°C)**	**Ambient (32-34°C)**	**Low (5-7°C)**
Initial	3.57^{ab}	3.57^{ab}	3.57^{ab}	3.57^{ab}
1MAS	3.58^{a}	3.56^{abcd}	3.58^{a}	3.54^{cd}
2MAS	3.53^{d}	3.56^{abcd}	3.58^{a}	3.54^{cd}
3MAS	3.36^{f}	3.45^{e}	3.57^{ab}	3.54^{cd}
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	0.03	0.01	0.02	48.74**
Factor B	NS	0.01	0.01	0.34^{NS}
A×B	0.04	0.01	0.02	7.22**

Table 61. Effect of package material and storage temperature on reducing sugars (%) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	14.55^{e}	14.55 ^{e}	14.55 ^{e}	14.55 ^{e}
1MAS	12.06^{f}	17.52^{d}	21.71^{c}	27.30^{a}
2MAS	9.35^{g}	11.62^{f}	17.00^{d}	23.59^{b}
3MAS	9.29^{g}	10.41^{g}	14.59^{e}	15.35^{e}
	CD	SE(m)	SE (±d)	Fcalc.
Factor A	0.85	0.29	0.42	312.77**
Factor B	0.46	0.16	0.22	195.64**
A×B	1.21	0.59	0.42	20.97**

Table 62. Effect of package material and storage temperature on non reducing sugars (%) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	25.03^{a}	25.03 ^{a}	25.03 ^{a}	25.03 ^{a}
1MAS	15.51^{b}	13.18^{c}	8.77^{ef}	10.02^{d}
2MAS	8.96^{def}	7.20^{g}	2.38^{h}	9.48^{de}
3MAS	7.80^{fg}	7.03^{g}	3.50^{h}	7.97^{fg}
	CD	SE(m)	SE (±d)	Fcalc.
Factor A	0.85	0.29	0.41	557.92**
Factor B	0.45	0.16	0.22	26.60**
A×B	1.20	0.41	0.58	35.28**

4.4.2.6 Total sugars (%)

The total sugars in intermediate moisture bananas decreased during storage, regardless of packaging material or temperature conditions (Table 63). A slow decline from 39.58 per cent to 23.39 per cent in total sugar was observed in samples vacuum packaged in polyethylene laminated aluminum pouches and kept at a low temperature during storage. IM banana samples held in LDPE (200 gauge) and kept at ambient temperature conditions rapidly decreased the total sugar content from 39.58 per cent to 17.08 per cent during three-month storage of IM banana.

4.4.2.7 Vitamin C (mg/100g)

The vitamin C in intermediate moisture bananas significantly decreased during storage, regardless of packaging material or temperature conditions (Table 64). Lowest decline in vitamin C content from 48.02 to 42.63 mg/100g was observed with IM bananas held in polyethylene laminated aluminum pouches and kept at a low temperature. The highest decline in vitamin C content from 48.02 to 6.93 mg/100g was observed when IM banana was held in LDPE (200 gauge) and kept at room temperature during storage.

4.4.2.7 Total carotenoids (µg/100g)

The total carotenoids in intermediate moisture (IM) bananas significantly decreased during storage, regardless of packaging material or temperature conditions (Table 65). Total carotenoids in IM bananas stored in polyethylene laminated aluminum pouches at a low temperature decreased from 1492.67 µg/100g of the initially prepared sample to 1338.67 µg/100g at the end of three months of storage. The highest decrease in IM banana total carotenoids was observed in samples held in LDPE (200 gauge) and stored at room temperature, with total carotenoids of 1012.00 µg/100g recorded by the end of storage.

4.4.2.8 Total phenols (mg/100g)

The total phenol content in intermediate moisture bananas increased during storage, regardless of packaging material or temperature conditions (Table 66). The highest increase in total phenols of IM banana was observed with IM banana held in polyethylene laminated aluminum pouches and kept at a low temperature, which was from 251.67 of the initially prepared sample to 311.67 mg/100g by the end of three months of storage. The lowest increase of total phenols from 251.67 mg/100g of the initially prepared sample to 281.00 mg/100g was observed with IM banana held in LDPE (200 gauge) and kept at ambient temperature by the end of three months of storage.

Table 63. Effect of package material and storage temperature on the total sugars (%) of IM banana

Duration	**Vacuum packing in LDPE (200 gauge)**		**Vacuum packaging in polyethylene laminated aluminum pouches**	
	Ambient (32-34°C)	**Low (5-7°C)**	**Ambient (32-34°C)**	**Low (5-7°C)**
Initial	39.58^{a}	39.58 ^{a}	39.58 ^{a}	39.58 ^{a}
1MAS	27.57^{e}	30.70^{d}	30.49^{d}	37.32^{b}
2MAS	18.31^{hi}	18.82^{gh}	19.38^{g}	33.08^{c}
3MAS	17.08^{j}	17.44^{ij}	18.09^{hi}	23.39^{f}
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	0.70	0.33	0.24	1169.92**
Factor B	0.38	0.13	0.18	538.52**
A×B	1.00	0.34	0.49	102.77**

Table 64. Effect of package material and storage temperature on the vitamin C content (mg/100g) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	48.02 ^{a}	48.02 ^{a}	48.02 ^{a}	48.02 ^{a}
1MAS	16.33^{g}	28.60^{f}	46.27^{ab}	47.30^{ab}
2MAS	8.87^{i}	17.57^{g}	38.10^{d}	45.83^{b}
3MAS	6.93^{j}	11.00^{h}	36.17^{e}	42.63^{c}
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	1.36	0.47	0.66	1214.83**
Factor B	0.73	0.25	0.35	263.44**
A×B	1.92	0.66	0.94	21.56**

Table 65: Effect of package material and storage temperature on the total carotenoids (µg/100g) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	1492.67^{a}	1492.67 ^{a}	1492.67 ^{a}	1492.67 ^{a}
1MAS	1215.00^{cd}	1319.49^{bc}	1192.57^{d}	1459.33^{a}
2MAS	1054.00^{ef}	1208.57^{cd}	1139.25^{de}	1421.67^{ab}
3MAS	1012.00^{f}	1203.67^{cd}	1113.33^{def}	1338.67^{b}
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	82.76	28.57	40.40	20.87**
Factor B	44.24	15.27	21.60	230.72**
A×B	117.04	40.40	57.14	64.21**

Table 66: Effect of package material and storage temperature on the total phenols content (mg/100g) of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	251.67^{f}	251.67 ^{f}	251.67 ^{f}	251.67 ^{f}
1MAS	250.67 ^{f}	274.33 ^{de}	267.33^{e}	282.73^{bc}
2MAS	267.33 ^{e}	293.50^{c}	275.07^{de}	304.00^{ab}
3MAS	281.00 ^{d}	298.00^{bc}	295.00^{bc}	311.67^{a}
	CD	SE(m)	SE (±d)	Fcalc.
Factor A	7.37	2.54	3.59	47.31**
Factor B	3.94	1.36	1.92	89.74**
A×B	10.42	3.60	5.09	3.52**

4.4.2.8 Non enzymatic browning

Non enzymatic browning on intermediate moisture banana increased during storage irrespective of packaging material used and temperature condition (Table 67). The IM banana held in LDPE (200 gauge) and kept at ambient temperature showed a highest increase in the non-enzymatic browning from 0.12 to 0.86 by the end of three months of storage, while the lowest increase in browning from 0.12 to 0.17 was observed with IM banana held in polyethylene laminated aluminum pouches and kept at a low temperature.

4.4.2.8 Shelf life (days)

The shelf life of package material was affected by packaging material and storage temperature during storage (Figure 5). IM banana held in LDPE (200 gauge) and kept at ambient temperature had changed its colour into brown and rendered unmarketable by the end of 60 days storage, followed by samples held in LDPE (200 gauge) and kept at low temperature where a slight brown colour change was observed on the product with 90 days of storage. IM banana held in polyethylene laminated aluminum pouches retained

high sensory, physico-chemical quality as well as the least microbiological counts during storage.

Table 67. Effect of package material and storage temperature on the non enzymatic browning of IM banana

Duration	Vacuum packing in LDPE (200 gauge)		Vacuum packaging in polyethylene laminated aluminum pouches	
	Ambient (32-34°C)	Low (5-7°C)	Ambient (32-34°C)	Low (5-7°C)
Initial	0.12^{g}	0.12^{g}	0.12^{g}	0.12^{g}
1MAS	0.61^{cd}	0.36^{e}	0.13^{fg}	0.13^{fg}
2MAS	0.73^{b}	0.57^{d}	0.20^{f}	0.17^{fg}
3MAS	0.86^{a}	0.67^{bc}	0.31^{e}	0.17^{fg}
	CD	**SE(m)**	**SE (±d)**	**Fcalc.**
Factor A	0.05	0.02	0.00	226.62**
Factor B	0.03	0.01	0.01	71.09**
A×B	0.07	0.03	0.04	8.16**

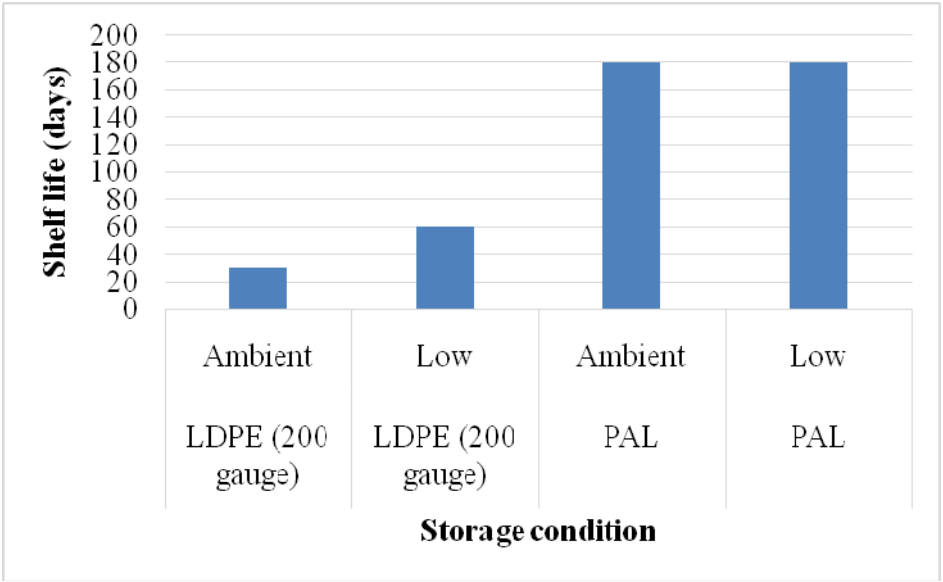
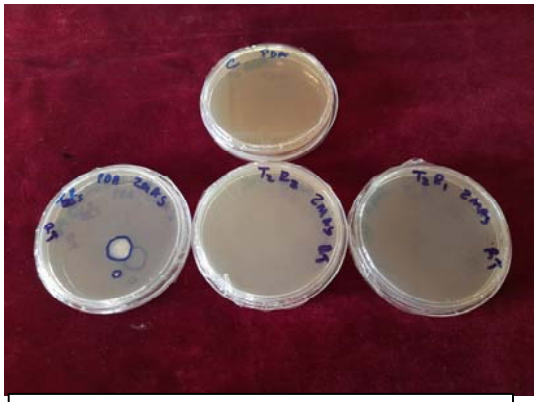


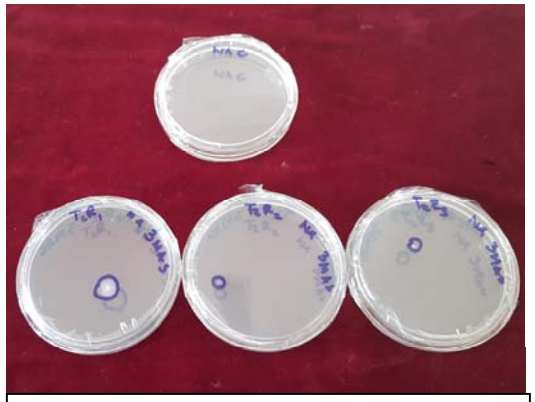
Figure 5: Effect of package material and storage temperature on the shelf life (days) of IM banana

4.2.3 Microbiological observations of intermediate moisture banana during storage

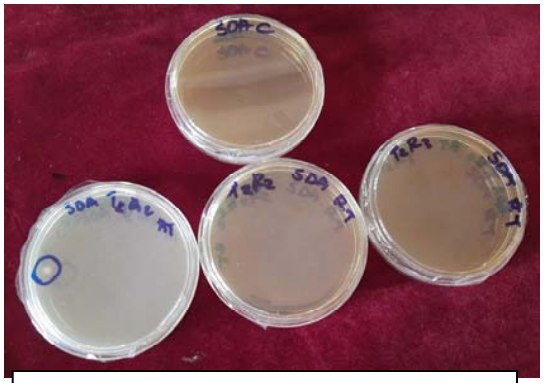
The microbial population of the stored samples was assessed at monthly intervals for period of three months and the results are presented in Table 68. The initial population of bacteria, *Escherichia coli*, fungi and yeast were not detected. The gradual increase in microbial population of intermediate moisture banana during storage was detected in samples vacuum packaged in LDPE (200 gauge) and kept at ambient temperature was fungi (0.67×10^{-3} cfu/g) during the second month of storage. The microbial growth recorded three months after storage in LDPE (200 gauge) and kept at ambient temperature was bacteria (1.00×10^{-5} cfu/g) and yeast (0.33×10^{-4} cfu/g) while for IM banana vacuum packaged in LDPE (200 gauge) and kept at low temperature was fungi (0.67×10^{-3} cfu/g). Among the packaging material, IM banana vacuum packaged in polyethylene laminated aluminum pouches did not detect any microbial proliferation.



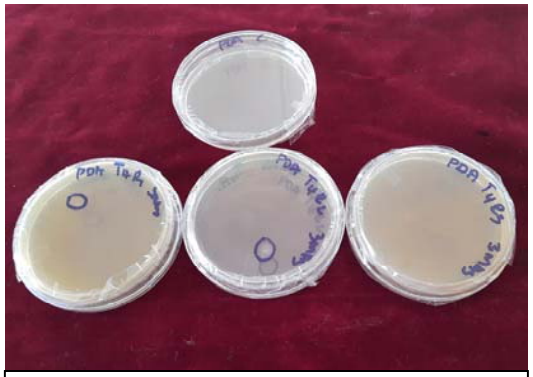
Fungal population (10^{-3}) after 2MAS



Bacteria population (10^{-5}) after 3MAS



Yeast population (10^{-4}) after 3MAS



Fungal population (10^{-3}) after 3MAS

Plate 12. Microbiological population (cfu/g) during three months storage of intermediate moisture banana

Table 68. Effect of package material and storage temperature on bacteria, *Eschechia coli*, fungi, and yeast population (cfu/g) of IM banana during storage

	Initial				1MAS (cfu/g)				2MAS (cfu/g)				3MAS (cfu/g)			
	BT	EC	FN	YT	BT	EC	FN	YT	BT	EC	FN	YT	BT	EC	FN	YT
T1	a	a	a	a	a	a	a	a	a	a	0.67	a	1.00	a	a	0.33
T2	a	a	a	a	a	a	a	a	a	a	a	a	a	a	0.67	a
T3	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
T4	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a

BT: Bacteria; EC: Escherichia coli; FN: Fungi; YT: Yeast
a: No micro-organism detected

4.2.4 Organoleptic evaluation of intermediate moisture (IM) banana during storage

The sensory evaluation of packaged samples was evaluated at monthly intervals during storage and results presented in Table 69 and Appendix 9. IM banana vacuum packaged in polyethylene laminated aluminum pouches and kept at low temperature secured the highest scores of sensory attributes throughout the storage while the least was observed in IM banana vacuum packaged in LDPE (200 gauge) and kept at ambient temperature. The mean ranks of appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability of IM banana vacuum packaged in polyethylene laminated aluminum pouches was 7.70, 8.10, 7.60, 7.60, 7.60, 7.50, 7.30 and 8.10, respectively. IM banana vacuum packaged in LDPE (200 gauge) and kept at ambient temperature was unmarketable by the end of three month storage.

4.2.5 Cost of production (Rs.) of intermediate moisture (IM) banana

The cost of 100g vacuum packaged intermediate moisture banana ranged between Rs. 279.24 and Rs. 283.74 for samples packaged in LDPE (200 gauge) and polyethylene laminated aluminum pouches respectively (Table 70). When the present worth of IM fruit is Rs. 70/100g, the cost benefit ratio of IM bananas developed with osmotic solution temperature placed at 40 ^{o}C and kept in different packaging materials of LDPE (200 gauge) and polyethylene laminated aluminum pouches was 0.25.

Table 69.1. Effect of package material and storage temperature on organoleptic attributes of IM banana (1MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	5.80	5.10	5.70	5.90	5.90	5.80	5.40	5.30
T2	7.10	7.60	6.10	6.40	6.70	5.90	6.20	6.00
T3	7.40	7.60	6.60	7.00	6.60	7.00	6.90	6.80
T4	7.20	7.60	7.00	6.90	6.50	6.90	6.90	7.20
Kendal's W test	0.12^{NS}	0.21^{NS}	0.12^{NS}	0.17^{NS}	0.05^{NS}	0.31*	0.23^{NS}	0.33*

Table 69.2. Effect of package material and storage temperature on organoleptic attributes of IM banana (2MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	UM	UM	UM	UM	UM	UM	UM	UM
T2	6.70	6.00	7.30	6.90	7.00	7.40	6.70	6.40
T3	8.20	8.00	6.90	6.60	6.80	7.00	6.20	7.00
T4	8.20	8.30	7.30	7.50	6.90	7.20	7.00	7.80
Kendal's W test	0.41*	0.84**	0.20^{NS}	0.18^{NS}	0.04^{NS}	0.14^{NS}	0.35*	0.27^{NS}

Table 69.3. Effect of package material and storage temperature on organoleptic attributes of IM banana (3MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	UM	UM	UM	UM	UM	UM	UM	UM
T2	5.60	5.60	6.90	6.40	6.30	6.40	5.90	6.30
T3	7.60	7.90	7.70	7.80	7.80	8.00	7.60	7.90
T4	7.70	8.10	7.60	7.60	7.60	7.50	7.30	8.10
Kendal's W test	0.00**	0.00**	0.33*	0.65**	0.75**	0.84**	0.67**	0.75**

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively.

T1 for vacuum packaging in LDPE 200gauge (32-34^{o}C).
T2 for vacuum packaging in LDPE 200 gauge (5-7^{o}C).
T3 for vacuum packaging in polyethylene laminate pouches (32-34^{o}C).
T4 for vacuum packaging in polyethylene laminate pouches (5-7^{o}C).
UM for umarketable

Table 70. Effect of package material and storage temperature on the cost of production of IM banana

Package 1			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.5g	2069.56/100g	3.15
Cost of KMS	0.75 per cent	341.72/500g	0.51
Cost of sucrose	90g	940.94/kg	84.60
Cost of sorbitol	90g	457.72/500g	82.38
Water costs	120ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6hours	5.50Kwh	33.00
Cost of production			277.74
LDPE (200gauge)	1 pack	Rs.1.50/pack	1.50
Total cost (100g)			279.24
Package 2			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.5g	2069.56/100g	3.15
Cost of KMS	0.75 per cent	341.72/500g	0.51
Cost of sucrose	90g	940.94/kg	84.60
Cost of sorbitol	90g	457.72/500g	82.38
Water costs	120ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6hours	5.50Kwh	33.00
Cost of production			277.74
Polyethylene laminate pouches	1 pack	Rs. 6.00/pack	6.00

DISCUSSION

5. DISCUSSION

The discussion to the study is presented under the following heads;

5.1 Characterization of banana varieties for horticultural and biochemical traits

5.2 Evaluation of osmotic agents on quality of Intermediate Moisture (IM) banana

5.3 Standardization of fruit to osmotic solution ratio and duration of immersion on quality of IM banana

5.4 Study on packaging materials and storage temperature on quality of IM banana

5.1 Characterization of banana varieties for horticultural and biochemical traits

5.1.1 Fruit horticultural characteristics of banana varieties

5.1.1.1 Fruit morphological characteristics of banana varieties

Fruits of six varieties of banana of different genomic groups *viz*. Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) collected from Banana Research Station, Kannara were evaluated for morphological characteristics. There were differences on the morphological characteristics among the six selected banana varieties. Nendran (AAB) had the lowest number of individual fruits per hand, which were perpendicular to the stalk but large in terms of fruit size, fruit pedicel length, and pedicel width. The fruit peel was thick, medium green in colour and turned yellow with maturity. The fruit pulp of Nendran (AAB) was light orange yellow at immature stage, which upon ripening changed to an attractive orange yellow colour with a firm pulp that has a sweet taste. Due to its large, sweet and firm pulp, the fruit is popular for both dessert and culinary purposes. The present study conforms to the findings of other authors who described fruits of AAB genomic group as large with thick peel and firm textured pulp (Ningsih and Megia, 2019; Hapsari *et al*., 2016).

Grand Naine (AAA) was smaller in terms of size than Nendran (AAB), but was observed to be larger than other varieties of different genomic groups selected for this study. A medium green peel was observed on Grand Naine (AAA) at immature stage which upon ripening turned bright yellow with a cream coloured, soft and sweet pulp. This variety is a favourite dessert banana and due to its soft pulp, puree can be obtained by mashing the fruit using a fork (Aurore *et al.,* 2009).

Although Yangambi km5 (AAA) belongs to the same genomic group as Grand Naine (AAA), several differences with respect to the morphological traits were observed (Table 1). Yangambi km5 fruits were found to be small with light yellowish green coloured peel at immature stage which upon maturity turned yellow, with a soft, cream coloured pulp. Within the AAA genomic group, there were differences with regard to orientation, compactness and shape; therefore further grouping into subgroups have been done (Karamura *et al*., 1995). The differences between Yangambi km5 and Grand Naine can be attributed to the different subgroups within the same genomic group. Yangambi km5 is characterized as a small fruited banana that belongs to Ibota subgroup while in the case of Grand Naine, the fruit size is relatively large and it belongs to the Cavendish subgroup (Menon *et al*., 2016). Karpoorvalli (ABB), a triploid banana variety, was discovered to have a distinct feature of having an ashy green peel that when ripened turned yellow with an ashy tint, and a pulp that was firm, cream coloured, and fell under the predominant taste group of mild, slightly tasty, and tasteless. Prem *et al.* (2019) reported that the quality of Karpoorvalli (ABB) is highly dependent on seasonal variability and that it is occasionally seeded with ash-coated golden yellow fruits, which is consistent with the current study's findings.

The present study revealed two diploid banana varieties being small in size but having differences in terms of the peel and pulp colour, as well as the taste. Pisang Lilin (AA) had a medium green peel that turned yellow upon ripening with a firm, cream coloured pulp that was sweet and acidic. The sweet and acidic characteristic flavour of Pisang Lilin is most valued among supermarket processed products (Aurore *et al*., 2009).

Njalipoovan (AB) was the only variety that had equal ploidy levels of A and B characterized as a small sized banana of light green peel that turned yellow upon maturity and had a white coloured, firm flesh with a sweet taste. The white flesh of Njalipoovan is often confused with cultivars from 'Silk' subgroup of AAB genomic group but has poor keeping qualities due to its thin peel (TANUVASU 2021, Hazarika *et al*., 2014). The triploids had superior fruit qualities when compared to the diploids. It is reported that with an increase in ploidy level there is an increase in the chromosome number of banana fruit which causes an increase in the quality parameters such as its adaptability to the environment (Amah *et al*., 2019). The overall findings reveal that although the anatomy, physiology and the development of banana varieties was the same, there were differences in the morphological traits of bananas even within the same genomic group as observed between 'AAA' group Grand Naine and Yangambi km5. Therefore, further characterization based on subgroup is essential to differentiate the banana varieties.

5.1.1.2 Cluster analysis of morphological characteristics of banana varieties

A dendogram was created using the morphological characteristics of six banana cultivars from various genomic groups, which are listed in Table 1. The major degree of similarity and difference among the six bananas of different genomic groups was revealed by a taxonomic distance in Figure 6. The dissimilarity level in the current study was estimated to be between 1 and 25.

Among the banana varieties, three clusters were observed, with one consisting of Karpooravalli (ABB), Njalipoovan (AB), and Yangambi km5 (AAA), with a taxonomic distance of less than 2.5 per cent. The second cluster was dominated by the 'A' genome group, which included the entire banana varieties mentioned above, with the exception of Karpooravalli (ABB) and the addition of two banana varieties, Grand Naine (AAA) and Pisang Lilin (AA). The taxonomic distance was found to be greater in this cluster, with an estimated value of 12.50 per cent. The third and final cluster category included banana

varieties Grand Naine (AAA), Pisang Lilin (AA), and Nendran (AAB), with a taxonomic distance of 25 per cent.

Although Grand Naine (AAA) and Yangambi km5 (AAA) were in the same genomic group, the taxonomic distance revealed a significant difference between the two varieties. Onyango *et al.* (2011) reported similar variations within the same genomic group, where Muraru (AA) differed from Sucrier (AA) and Banksii (AA), but was very similar to triploids Gros Michel (AAA) and Cavendish (AAA) from a different genomic group.

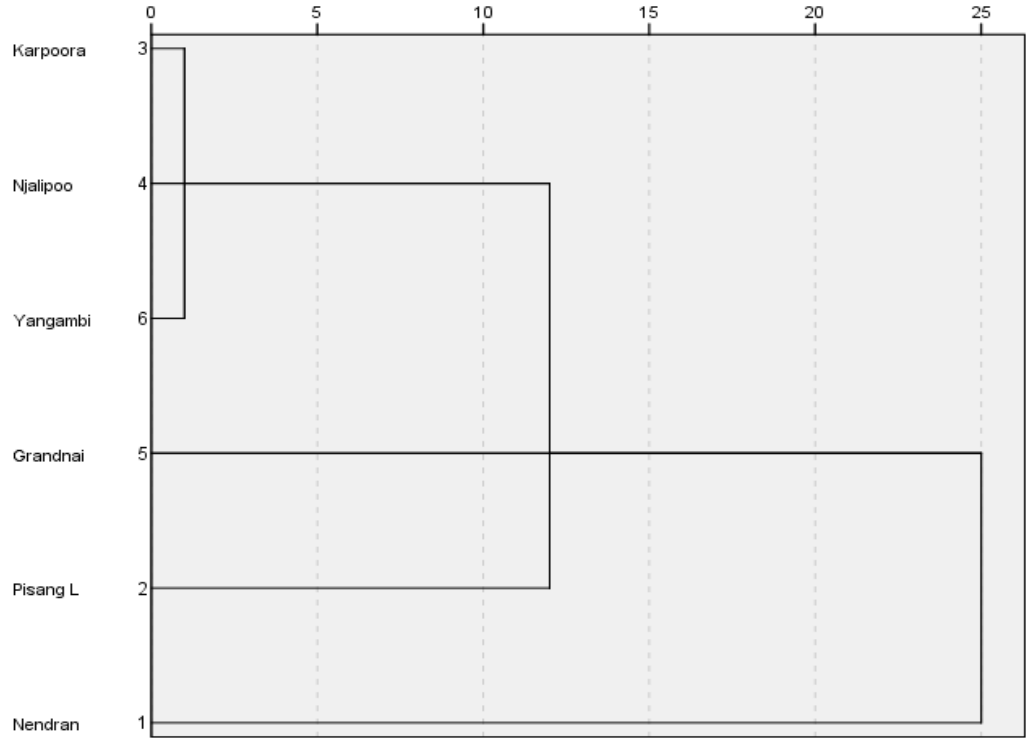


Figure 6: Dendrogram showing clustering patterns of banana (*Musa spp*.) varieties based on the morphological descriptors [Karpora= Karpooravalli (AAB); Njalipoo= Njalipoovan (AB); Yangambi= Yangambi km5 (AAA); Grandnai=Grand Naine; (AAA) Pisang L=Pisang Lilin (AA); Nendran=Nendran (AAB)]

5.1.1.3 Horticultural characteristics of banana varieties

Horticultural characteristics of banana (*Musa* spp.) varieties of different genomic groups harvested at a fully ripe stage show significant differences in all horticultural characteristics except the number of fruits per bunch. In terms of fruit length, Nendran (AAB) and Grand Naine (AAA) had the longest, whereas the fruit lengths of banana varieties Pisang Lilin (AA), Njalipoovan (AB), and Yangambi km5 (AAA) were nearly the same, and Karpooravalli (ABB) had the shortest of the banana varieties studied.

Similar studies using 26 banana accessions by Mattos *et al.* (2010) revealed a significant difference in fruit length, with a range of 6.87-18.67 cm recorded. The varieties with the longest fruit length had higher levels of ploidy, which is thought to be influenced by an increase in the size of cell nuclei, which results in an increase in the size of plant tissues (Mattos *et al*., 2010; Venkatachalam *et al*., 2008).

Although the current study found that diploids Pisang Lilin (AA) and Njalipoovan (AB) had small fruits, while triploids Nendran (AAB) and Grand Naine (AAA) had the largest fruits, this was not the case for other triploid cultivars such as Yangambi km5 (AAA) and Karpooravalli (ABB), which had small fruits. This demonstrates the difficulties in describing banana varieties by using only the level of ploidy to identify similarities and differences between banana varieties. As a result, other identification methods, such as the unweighted paired group method with mean arithmetic (UPGMA) and DNA markers (RAPD and ISSR), are recommended (Menon *et al*., 2016; Venkatachalam *et al*., 2008).Similarities in fruit pedicel length between Nendran (AAB) and Njalipoovan (AB) could be attributed to horticultural character overlap between the AAB and AB genomes, which could result in difficulties distinguishing these genomes (Debnath *et al*., 2019).

The triploid banana cultivars had higher values in terms of peel thickness, with the exception of Karpooravalli (ABB), while lower values were recorded in the diploid varieties. The thick peel thickness of triploid banana varieties Nendran (AAB), Grand

Naine (AAA), and Yangambi km5 (AAA) indicates that they have better storage and transportation qualities than Karpooravalli (ABB) and other diploid banana varieties with thinner fruit peels, such as Pisang Lilin (AA) and Njalipoovan (AB). The study also revealed that, while Nendran (AAB) had the highest fruit pulp and peel weight, the pulp in the fruit was lower than in other cultivars, as evidenced by the low fruit pulp: peel ratio (1.8). The highest value of fruit pulp (4.81) was found in Karpooravalli (ABB), indicating that the majority of the fruit is pulp.

Fruit softening is one of the physiological changes that occur during fruit ripening as a result of changes in the composition of cell wall pectic substances (Sharma, 2010). The fruit firmness data shown in Table 2 revealed a significant difference between banana fruits from different genomic groups. Njalipoovan (AB) and Nendran (AAB) had the highest values for fruit firmness, which were at 0.09 cm^2 kg^{-1} and 0.08 cm^2 kg^{-1}, respectively. The lowest values for fruit flesh firmness were recorded in triploid varieties of the same genomic groups, *i.e.,* Grand Naine (AAA) and Yangambi (AAA), which had the same values of 0.04 cm^2 kg^{-1}. Cultivars with a "B" genome such as AAB have the highest level of lignins (catechins and chlorogenic acids) and are firm like cooked bananas, while those of the AAA genome group contain lower levels of phenylpropanoid (essential components for cell wall structures); hence they are softer and are used for dessert purposes (Drapal *et al*., 2020; Tsamo *et al*., 2014).

5.1.2 Fruit biochemical characteristics of banana varieties

The biochemical characteristics of banana (*Musa* spp.) varieties presented in Table 2 reveal variations and similarities in the fruit composition of different banana genomic groups. There was no significant difference in titratable acidity between banana varieties from different genomic groups in this study. However, the study proved that triploid banana varieties tend to be more acidic than diploids at the ripening stage. The accumulation of organic acids, primarily malic acid, as a result of fruit ripening may be associated with acidity in the pulp of six banana cultivars from different genomic groups.

According to Gomez *et al*. (2022), fruits are acidic in nature and the interaction of sugars and organic acids is important in the development of fruity flavour.

The study also revealed a close association between total soluble solid content and total carbohydrate content in banana varieties (Table 2). The banana varieties with high total soluble solids were found to have higher carbohydrate content whereas those with the least total soluble solid revealed lower carbohydrate content. Nendran (AAB) had the highest total soluble solid content (23.90^{o}Brix), it also had the highest carbohydrate content (37.51 g/100g), and likewise, Njalipoovan (AB) having the least values of total soluble solid content (16.43^{o}Brix) had the lowest total carbohydrate content of 25.67 g/100g. Despite having different genomic groups, banana varieties had the same protein and fat content with values ranging from 1.84–2.72 g/100 g and 0.13–0.41 per cent, respectively (Table 2). The current findings are consistent with previous research findings by Siji and Nandini (2017) and Mohapatra *et al.* (2010), which found protein and fat content ranging between 1–2.5 per cent and 1 per cent, respectively. The biochemical compounds of banana fruits are also expected to differ depending on the genome type, variety, physiological stage of the fruit, environmental conditions, and altitude.

Total ash is the amount of inorganic matter of the fruit and it represents the total mineral content in food products. Triploids with plantain genome 'B', *i.e.,* Nendran (AAB) and Karpooravalli (ABB) had a significantly ($p = .05$) higher total ash content compared to the triploid cultivars of Grand Naine (AAA) and Yangambi (AAA), which are dominated by the ‘A’ of dessert banana (Table 2). The diploids Pisang Lilin (AA) and Njalipoovan (AB) showed intermediate values between the triploids of "A" and that of "B" with regard to the total ash content. The high ash content in triploid banana varieties with a ‘B’ genome composition corresponds to a high mineral content compared to the banana dominated by ‘A’ genome where the ash content was lower (Onyango *et al*., 2011). The diploid varieties irrespective of their genomic composition were observed to have intermediary values with respect to the total ash content. Triploid banana cultivars dominated by ‘A’ genome with lower total ash content can be used for purposes other

than cooking. Dotto *et al.* (2019) discovered a lower total ash content of bananas grown in Tanzania, ranging between 0.87 and 1.12 per cent, whereas Prem *et al.* (2019) discovered a total ash content of banana cultivated in Kerala ranging between 2.31 and 10.22 per cent, which is consistent with the current study.

In the case of vitamin C, the highest values were in Karpooravalli (ABB) at 17.33 mg/100g and the lowest in Yangambi km5 (AAA) at 8.00 mg/100g. The results revealed that triploids having 'B' genome had higher vitamin C than the cultivars with dominant 'A' genome. The findings are consistent with those reported by Deshmukh *et al.* (2009) and Ashokkumar *et al.* (2018), who both found high levels of ascorbic acid in banana cultivars with the "B" genomic group. Adults require 90 mg of vitamin C per day, and bananas for the present study can supply 8.88–19.25 per cent of that amount to supplement the diet and boost the body's resistance to diseases such as corona virus disease 2019 (COVID-19) (Abobaker *et al.*, 2020).

Significant difference was found in calcium content between the varieties which ranged between 69.90 and 168.90 mg/100g. Yangambi km5 (AAA) was the only banana variety with the highest calcium level of 168.90 mg/100 g, which was significantly greater than other banana varieties. However, the lowest calcium concentration of 69.90 mg/100 g was recorded in variety Grand Naine (AAA). Devarajan *et al*. (2021) reported the values for calcium content of Indian banana pulp to be in the ranges from 32 to 3523 mg/kg with an average of 530 mg/kg, which is consistent with the present study. Emaga *et al.* (2007) also reported the high calcium content of Yangambi km5 (AAA) compared to banana varieties of French Clair (AAB), Big Ebanga (AAB), Pelipita (ABB) and CRBP039 (039) (AAAB), which is in agreement with the present study.

Iron content recorded for banana varieties in different genomic group revealed no significant difference (Table 2). However, Njalipoovan (AB) had a higher iron content of 0.89 mg/100g, while the lowest was in Yangambi km5 (AAA) at 0.40 mg/100g**.** Iron, a mineral vital for the proper functioning of haemoglobin has the potential to alleviate

micro-nutrient deficiency in human diet. This mineral represents up to 2 per cent of total weight at the ripening stage of the fruit which conforms to the present study (Kookal and Thimmaiah, 2018; Elayaban *et al*., 2017).

The potassium content of banana varieties ranged between 187.27 and 406.60 mg/100g. The variety Grand Naine (AAA) had the lowest potassium concentration, which was 187.27 mg/100g while Yangambi km5 had the highest potassium level at 406.60 mg/100g. The average adult's daily potassium requirement is 4700 mg, so 100g of Yangambi km5 (AAA) and Grand Naine (AAA) banana pulp would provide 8.65 and 1.49 percent of the K requirement, respectively (Sulaiman *et al*., 2011). Yangambi km5 is more nutritious than the other dessert varieties due to its relationship with the plantain group, which causes it to resemble the *Balbisiana* group more than the *Acuminata group*. The potassium content ranges correspond to those reported in the banana literature (Hapsari and Lestari 2016; Oyeyinka and Afolayan, 2019; Devarajan *et al*., 2021).

Food containing phytochemicals with potential antioxidant activities reduces the risk of human diseases such as cancer, atherosclerosis, arthritis, diabetes, and other ageing diseases (Musa *et al*., 2011). ABTS radical has the advantage of allowing antioxidant determination with minimal hindrances, whereas FRAP can provide a more accurate picture of overall antioxidant capacity than DPPH (Alotham *et al*., 2009).

Yangambi km5 had high antioxidant levels for DPPH, FRAP, and ABTS, which were 134 µg/mL, 0.33 mg/AAE/g, and 0.03 µg/mL, respectively. Although Pisang Lilin showed the highest (0.02 µg/mL) ABTS value, which was not significantly different from other banana varieties, it generally had the lowest antioxidant levels as indicated by DPPH and FRAP values of 271.27 µg/mL and 0.37 mg/AAE/g, respectively.

Bashmil *et al.* (2021) reported FRAP values of Australian grown bananas ranging from 0.36 to 1.77 mgAAE/g whereas Suresh Kumar *et al.* (2019) reported the DPPH values of banana ranging from 144 to 614 µg/mL and FRAP values ranging from 0.5 to 7 µmol of $FeSO_4$/mL of extract which corroborates to the findings of the present study.

Darsini *et al.* (2012) reported lower ABTS scavenging activity of the banana pulp in the range of 6 to 29 µg/mL. According to Sheng *et al*. (2011), antioxidant scavenging variation among banana fruits may be due to the type of solvent used, as well as extraction temperature and time, in addition to environmental and cultivation factors, which may explain some variations in antioxidant scavenging activity in the current study with other authors. While comparing banana varieties, Bennet *et al.* (2010) discovered that triploid banana varieties had higher antioxidant levels compared to diploid varieties, which are stimulated by the release of hydroxycinnamic acid during ripening.

The highest phenol content was observed in Grand Naine (AAA) at 57.50mg/100g, almost twice the amount of Njalipoovan (AB) which had 39.12 mg/100g and the lowest total phenol content was recorded in Nendran (AAB) and Pisang Lilin (AA) which recorded 20.00 and 13.23 mg/100g respectively. Similar findings were reported by other authors (Aurore *et al*., 2009; Borges *et al*., 2014). However, some other authors reported total phenols content in the range of 0.05-76.37 mg/g, expressed as gallic acid equivalents (Baskar *et al*., 2011; Sulaiman *et al*., 2011). Banana varieties with the *Balbisiana* genome, such as Nendran, have high total phenol content, whereas another study discovered that the triploid 'Highgate' banana cultivar with a AAA genome has the highest total phenol content when compared to other cultivars from different genomic groups (Borges *et al*., 2014; Suresh Kumar *et al*., 2019). *Musa* spp. has a sufficiently high degree of variability in total phenol content due to variations in antioxidants such as carotenoids and flavonoids, which is a positive factor in the selection for functional food development (Sulaiman *et al*., 2011).

Crude fibre is an important dietary component with a variety of health benefits, including healthy laxation and a lower risk of heart disease and cancer. The crude fibre of banana varieties which had a "B" genome, such as Nendran (AAB), Karpooravalli (ABB) and Njalipoovan (AB), was high compared to those consisting of only the "A" genome, such as Yangambi km5 (AAA), Grand Naine (AAA) and Pisang Lilin (AA) (Table 3). Oyeyinka and Afolayan (2019) reported that the crude fibre of dessert banana pulp was

lower than that of plantain banana, which recorded 0.73 and 10.24 per cent, respectively, which conforms to the present study.

The level of carotenoids was highest (533.55 µg/100g) in Nendran (AAB), followed by Yangambi km5 (AAA) (433.27 µg/100g). Although Grand Naine (AAA) belonged to the same genomic group with Yangambi km5 (AAA), it had the lowest carotenoid value among all the six banana cultivars which recorded 151.50 µg/100g (Table 3). Similar studies confirm that the total carotenoid content in banana was in the range of 4.7-10.0 µg/g and that the genomic group AAB of Nendran had the maximum carotenoid content (Deshmukh *et al*., 2009; Ashokkumar *et al*., 2018). Carotenoids, characterised by yellow/orange colouration, is an important precursor of vitamin A, essential for prevention of chronic diseases. The recommended daily allowance for vitamin A ranges from 400-900 µg equivalent per day among children up to 18 years. Nendran (AAB) and Yangambi km5 (AAA) are good cultivars for incorparating in children's food to reduce the incidence of diseases associated with vitamin A deficiency such as problems of eye and vision, cellular differentiation and functionality of humoral and cell mediated immune system (Awasthi, 2020).

5.2 Evaluation of osmotic agents on quality of Intermediate Moisture (IM) banana

5.2.1 Effect of osmotic agents on the physical characteristics of Intermediate Moisture (IM) banana

5.2.1.1 Effect of osmotic agents on the moisture content (%) of Intermediate Moisture (IM) banana

The shelf life of food is extended when the moisture content is reduced. IM banana from variety Njalipoovan had highest (27.46 %) moisture content in fruit slices immersed in palm sugar solution and lowest (13.53 %) recorded for Nendran in fruit slices immersed in sucrose+NaCl solution. The moisture content of IM banana was

found to exhibit the nature of an osmotic agents used as indicated by the amorphous nature of palm sugar, which is hygroscopic in nature which competes for water thereby preventing the moisture diffusion out of the tissues (Saputro *et al*., 2020).

On the other hand, the orderly arrangement of sugars with crystalline structures such as sucrose is reported to be less hygroscopic in nature, while sodium chloride penetrates into the cell to enhance the release of water from the tissues during osmodehydration (Tortoe *et al*., 2009). Therefore, the low moisture content of IM bananas treated with sucrose+NaCl solution may be explained by the improved pressure gradients of the osmotic solution, resulting in increased moisture release from the banana slices, while IM bananas treated with palm sugar solution absorbed moisture from the environment.

Panwar *et al*. (2013) observed the moisture content of intermediate moisture aonla segments to vary from 24.67 to 31.33 per cent when samples were treated with glycerol and sucrose solution and Rai *et al.* (2004) reported a moisture content of 17.42 to 21.4 per cent on intermediate moisture papaya cheese which is consistent with the findings of moisture content of intermediate moisture banana of the present study.

5.2.1.2 Effect of osmotic agents and varieties on the weight loss (%) of Intermediate Moisture (IM) banana

For ease of transport and storage, fruit weight loss while preserving their original shape during processing is very critical. IM banana from Njalipoovan had the highest weight reduction (45.40 %) in fruit slices immersed in honey solution, while the variety Pisang Lilin had the lowest (19.13 %) in fruit slices immersed in glucose+sorbitol solution. When compared to larger molecular weight osmotic agents like sucrose (342.30 g/mol), palm sugar (256.50 g/mol), and sorbitol (182.17 g/mol), honey's low molecular weight (180.16 g/mol) may have raised the osmotic pressure in the osmotic solution

during the development of IM fruit, allowing for increased driving force for water loss with minimal solid gain and subsequent weight reductions.

IM banana slices treated with glucose+sorbitol solution had minimal weight loss despite having a glucose (180.16 g/mol) osmotic agent that has the same molecular weight as honey. The use of low molecular weight osmotic agents resulted in minimal weight loss, which can be attributed to sorbitol's protective effect during the subsequent dehydration, leading to the stabilization of physico-chemical properties of the products, explaining the widespread use of sorbitol in the food and pharmaceutical industries (Zhang *et al*., 2020).

Similarly, high weight loss when honey was used as osmotic agent compared to sucrose solution was reported by Bawa and Gujral (2000) during the development of intermediate moisture raisins with weight reductions reported between 2 and 25 per cent. Riva *et al.* (2005) found that osmotic agents in combination with sorbitol osmotic pretreatment have minimal changes in geometric features during the development of osmo-dried apricot cubes while Chavan *et al.* (2010) noticed a weight loss of 10 to 36 per cent on osmodehydrated banana slices which is also in agreement with the findings of the present study.

5.2.1.3 Effect of osmotic agents and varieties on the solid gain (%) of Intermediate Moisture (IM) banana

Highest (23.55 %) solid gain was recorded in banana variety Grand Naine in fruit slices immersed in glucose solution and lowest (5.83 %) in variety Karpooravalli in fruit slices immersed in honey. According to Ahmed *et al.* (2016), the osmotic agent with a lower molecular weight can easily penetrate into the cells of fruits as compared to the osmotic agent with a higher molecular weight. Since the molecular weight of both glucose and honey is the same, which is 180.16 g/mol, the variability of solid gain in fruits may be reflected by structural and biochemical differences between varieties of

banana which affect the diffusion between the fruit and the osmotic agent, giving rise to considerable differences in solid gains (Tortoe, 2010). The high solid gain with the Grand Naine variety may be explained by its soft texture, which makes it more permeable for mass exchange than the variety Karpooravalli, which has a firm texture.

Shanmugasundaram and Haripriya (2014) reported a solid gain of 2.03–12.26 per cent, and they also discovered that the semi-permeable nature of the banana variety Dwarf Cavendish (AAA) allowed more solids to penetrate into the fruit than the Poovan (AAB) variety, confirming the current study. These solid gain values of the present study are found to be consistent with those reported by Tippanna *et al.* (2019) and Ibitwar *et al.* (2008) on osmodehydrated pineapple and osmodehydrated plum, respectively.

.2.1.4 Effect of osmotic agents and varieties on the water loss (%) of Intermediate Moisture (IM) banana

The principle of dehydration is to draw out moisture from the cell tissues to a desired moisture level. Major water losses of IM banana were observed to be more with fruits immersed in honey followed by glucose solution and a combination of osmotic agents with sorbitol across all the banana varieties. The high (62.12 %) water loss was IM banana slices immersed in honey and variety Karpooravalli showed lower (29.77 %) water loss in fruit slices immersed in sucrose+ NaCl solution. Honey's high water loss as an osmotic agent is caused by its lower molecular weight, which results in a higher osmotic pressure gradient in the cytoplasm and vacuole, resulting in water loss.

Though sodium chloride has a lower molecular weight (58.40 g/mol) than all the osmotic agents used in the present study, its diffusion through the fruit material was found to be delimited by the presence of sucrose, which has a large (342.30 g/mol) molecular weight and has a tendency of forming a barrier on the surface tissue leading to slower rates of water loss (Tortoe, 2010). Despite sucrose's barrier formation and high molecular weight, which reduces the rate of water loss, sucrose in combination with

sorbitol was found to effectively reduce water as honey, achieving more than 50 % water reduction, while variety Nendran was found to have the highest water losses among all banana varieties, regardless of the osmotic solution used.

Chauhan *et al.* (2011) similarly reported high water loss estimated at 42.15 per cent with osmotic agents of lower molecular weight, such as honey, during osmodehydration of apple slices compared to 40.69 per cent of samples treated in sucrose solution. Sethi and Kaur (2019) also observed a high dehydration effect of honey when used as an osmotic agent on pineapple slices compared to sucrose solutions. Chavan *et al*. (2010) reported water loss values for osmodehydrated banana slices ranging from 14.6 to 49.2 per cent, whereas Brochier *et al.* (2015) observed optimal water losses during osmodehydration of yacon slices ranging from 45 to 60 per cent which is in agreement with the present study.

5.2.1.4 Effect of osmotic agents on the water activity of Intermediate Moisture (IM) banana

A direct relationship exists between high water activity and food spoilage. The highest (0.87) water activity values were in the variety Nendran (0.87) in fruit slices treated with palm sugar solution. The IM banana showed the lowest (0.74) water activity in fruits immersed in glucose+sorbitol solution. Among the six banana varieties tested, the water activity of IM banana slices immersed in honey did not exceed 0.80. This could be attributed to honey's high water reduction effects, which lower the product's water activity, whereas the high water activity of IM bananas treated with palm sugar solution could be attributed to the osmotic agent's amorphous and hygroscopic nature. The results also revealed that when glucose and sucrose were combined with sorbitol, they performed better in terms of water activity reduction than when the osmotic agents were used singly.

Yadav and Singh (2014) discovered that combining osmotic agents was effective in lowering the water activity of fruits and vegetables due to the combination of properties of both solutes, which supported the current study when low water activity was found with sucrose and glucose in combination with sorbitol rather than when used alone. Rodriguez *et al.* (2015) reported a_w values ranging from 0.44 to 0.85 in osmo-air dried plums, while Din *et al.* (2019) reported aw values ranging from 0.40 to 0.70 in IM muskmelon chunks, which were similar to the water activity of IM banana in the current study.

5.2.1.5 Effect of osmotic agents on the equilibrium relative humidity (%) of Intermediate Moisture (IM) banana

The ERH of IM banana treated with honey was low regardless of banana variety, with values ranging from 75.23 to 77.87 per cent, with Nendran having the lowest and Pisang Lilin having the highest. The highest (87.20%) equilibrium relative humidity (ERH) of intermediate moisture (IM) banana slices were recorded in Nendran banana slices treated with palm sugar. The ERH of IM banana, like its moisture content and water activity, was found to be influenced by the hygroscopic nature of palm sugar as an osmotic agent which has the ability to absorb moisture from the surrounding environment, while honey, which is viscous in nature, had low ERH values because viscous particles take longer to reach equilibrium, resulting in a less hygroscopic IM banana (Saputro *et al*., 2020; Da Silva *et al*., 2015).

Lower ERH values values of 50 to 60 per cent were reported by Suresh Kumar *et al.* (2008) on osmovacuum dried mango slices which had a good texture, colour, flavour, and chew ability. ERH values of 67.50 per cent were reported by Moraga et *al.* (2004) in strawberries, while Bawa and Gujral (2000) reported 20 per cent in raisins of intermediate moisture, with sugar-treated samples having a better overall appearance than honey-dried raisins.

5.2.1.6 Effect of osmotic agents on the colour values (*L**, *a**, *b**) of Intermediate Moisture (IM) banana

Colour is a key sensory aspect in the food industry, providing an instant sense of a product's overall quality. Three colour variables, *L** (lightness), *a** (redness), and *b** (yellowness), are used in the food processing industry to assess how product quality is deteriorating in terms of browning and darkening. Higher *L** and *b** values with corresponding lower *a** values in the case of IM banana indicate better colour retention in the product.

In osmotic agents with sorbitol in combination with sucrose and glucose, high *L** values of IM banana were observed. Fruits treated with glucose+sorbitol solution in the variety Njalipoovan had the highest (94.69) *L** values, since sorbitol not to undergo the Maillard reaction which result in less browning of IM banana slices treated with this osmotic agent (Zhang *et al*., 2020). The lowest (38.59) *L** colour value in fruits immersed in honey of the variety Karpooravalli can be attributed to the IM banana's conformity to honey, which is naturally dark in colour and has been reported to have low *L** values in the range of 36.64 to 51.37 (Da Silva *et al*., 2015).

Highest *a** (8.98) values of IM banana were found in fruits immersed in palm sugar from the variety Nendran, whereas lowest *a** (-3.42) values were found in fruits treated with sucrose solution from the variety Njalipoovan. Browning of IM banana slices treated with palm sugar could be attributed to the browning products found in palm sugar, such as furans, pyrazine fatty acids, and ketones, as well as reducing sugars that combine with amino acids or proteins in the product to form browning compounds (Srikaeo *et al.* 2019). Sucrose, on the other hand, is not a reducing sugar and does not react with proteins to form a brown colour, which explains its low colour value for redness (*a**).

Highest (22.16) and lowest (3.48) *b** values were found in Yangambi km5 and Njalipoovan varieties, respectively. The role of sucrose solution in colour preservation as

an osmotic agent was observed on both fruits, with Yangambi km5 having a cream-coloured pulp and Njalipoovan having a white pulp, as previously observed with the initial colour of their fresh pulp.

Naknaen *et al.* (2013) linked the high *L** values and low *a** values in osmo-dried cantaloupe slices to colour preservation and lack of participation of osmotic agents in Maillard reactions to the type of osmotic agent used. Sethi and Kaur (2019) observed colour changes when honey was used as an osmotic agent for dehydrated pineapple slices, with colour values matching those in the current study. In osmodehydrated apple slices, Chauhan *et al*. (2011) found *L** values in the range of 52.45 and 85.75, while *a** colour values were higher in honey treated samples at 5.85. The *b** colour values of 24.23 were reported in intermediate moisture pineapple slices Gomez *et al*. (2022), which were higher than the IM banana developed in the present study.

5.2.2 Effect of osmotic agents on the biochemical characteristics of Intermediate Moisture (IM) banana

5.2.2.1 Effect of osmotic agents on the total soluble solids (°Brix) of Intermediate Moisture (IM) banana

Total soluble solids are an important parameter that represents the amount of soluble solids in a dehydrated product and can indicate the level of sweetness. Total soluble solids were found to be highest (72.00°Brix) in IM banana slices immersed in honey in banana variety Nendran, and lowest (68.33°Brix) in banana variety Karpooravalli with IM banana slices immersed in glucose solution. The high TSS of IM banana immersed in honey of variety Nendran could be attributed to the concentration of pure honey used in this experiment as well as the banana variety Nendran's initial TSS, which was the highest among all banana varieties studied. According to Da Silva *et al.* (2015), honey has total soluble solids of 65 to 80°Brix, which is higher than the concentration of 60 °Brix in the other osmotic solutions under study. The high TSS of IM

banana treated with honey may also be explained by the sweetness index of fructose, the most abundant sugar in honey, which is estimated to be 1.2 compared to the 1.0 and 0.6 of sucrose and glucose, respectively (Hull, 2010).

Similarly, Dhungana *et al.* (2017) discovered that using honey as an osmotic agent on yacon slices resulted in a higher (36.6 %) TSS difference compared to samples treated with sucrose solution. Priyanka *et al.* (2018) found total soluble solids of 62.20^{o}Brix in osmo-air dried banana figs, while Chavan *et al.* (2010) found an average of 65.00^{o}Brix in osmo-air dried banana slices, which agrees with the current findings.

5.2.2.2 Effect of osmotic agents on the titrable acidity (%) of Intermediate Moisture (IM) banana

Titratable acidity is an important quality parameter that contributes to the flavour of the fruit. Highest (0.40 %) titratable acidity was observed in IM banana slices immersed in glucose+sorbitol solution in the varieties Pisang Lilin and Grand Naine. Lowest (0.20 %) titratable acidity was observed in IM banana slices of variety Njalipoovan when fruit slices was immersed in glucose+sorbitol solution as well as when fruit slices of varieties Pisang Lilin and Yangambi km5 when fruit slices were immersed in sucrose+NaCl solution.

Glucose is an intermediate product of glycolysis which coincides with fruit ripening and the accumulation of organic acids. The immersion of banana slices in glucose solution during osmotic treatment may have triggered malic acid synthesis and its accumulation, thereby increasing the levels of organic acids in the glucose treated IM bananas, while sorbitol stabilised the acidity of the product developed (Sharma, 2010; Zhang *et al*., 2020). The titratable acidity of the original ripe banana, which was previously mentioned in the 0.18 to 0.34 per cent range, was found to be stabilised by other osmotic agents, including the osmotic agents where low (0.20 %) titratable acidity was recorded.

According to Gomez *et al.* (2022), higher acidity is frequently disliked by consumers, whereas an appropriate blend of acids and sugars produces the fruity flavour of fruit-based products, which is preferred by the majority of consumers. As a result, the combination of osmotic agents such as the ones used in this study may provide an adequate blend of acids and sugars that the consumer may prefer. Konopacka *et al.* (2009) reported titratable acidity of osmo-convective dried sour cherry, blackcurrant, and apple in the range of 0.49 and 3.47 per cent, which is dependent on the osmotic agent used, while Ramakrishnan (2014) reported titratable acidity of intermediate moisture mango in the range of 0.52 to 1.0 per cent, which was in line with the present results.

5.2.2.3 Effect of osmotic agents on the total ash (%) of Intermediate Moisture (IM) banana

Ash content is a quality indicator that assesses the mineral status of intermediate moisture (IM) bananas. The ash content of IM banana slices treated with honey was found to be highest (16.93 %) in variety Yangambi km5 and lowest (2.83 %) ash content of IM banana was fruit slices immersed in sucrose + sorbitol solution of the Njalipoovan variety.

Several authors have reported that infusing fruits with osmotic agents results in a developed product with osmotic agent properties (Tortoe, 2010; Ahmed *et al*., 2016). The improved nutritional quality of IM banana slices immersed in honey may have been influenced by macro and microelement minerals found in honey. The initial biochemical composition of fruits as well as fruit permeability to mass transfer may have played a role in the nutrient absorption from the osmotic solution as well as nutrient retention. Although fruit dehydration causes nutrient loss, banana varieties such as Njalipoovan and Karpooravalli appear to be unable to retain better nutrients during IM banana processing when compared to other banana varieties, as evidenced by their lower total ash content, which makes them not ideal candidates for the development of IM banana.

While evaluating mango for the development of osmodehydrated mango products, Mishra *et al.* (2014) observed that variety Mallika was the best variety compared to Amrapali, Dashehari, and Chausa, which indicates that the varietal differences may result in differences in the suitability for a specific purpose. Mahomud *et al.* (2015) found that osmo-air dried banana slices treated with honey had a higher nutrient content than sucrose pretreated samples, while Singh *et al.* (2015) reported a total ash content range of 13.75 to 23.20 per cent in osmo-air dried papaya slices, which was in line with the present results. Sethi and Kaur (2019) reported that combining honey and sucrose solution gives a better total ash content of osmodried pineapple slices.

5.2.2.4 Effect of osmotic agents on the pH of Intermediate Moisture (IM) banana

Fruits are naturally acidic, but dehydration causes changes in pH due to the migration of water and dissolved substances. The fruits immersed in glucose+sorbitol solution of variety Njalipoovan showed highest (4.63) pH values while lowest (3.50) was in variety Karpooravalli in fruits immersed in sucrose+sorbitol solution. The mean pH values of IM banana Pisang Lilin and Njalipoovan, both diploids, was found to be higher than that of triploid varieties *viz.* Nendran and Karpooravalli.

The pH differences observed in this study could be attributed to differences in banana ploidy levels, with triploid varieties being more acidic than diploids. Davis *et al.* (2013) and Ahmed *et al.* (2020) discovered a low pH in triploid varieties of watermelon and citrus mandarin fruits compared to diploid varieties, which was attributed to a high translocation of organic acids from the vacuoles of the juice sacs to the rind/peel tissue during ripening. Because of the high level of organic acid translocation in triploid varieties, acidity degradation occurs, resulting in a lower pH (Ahmed *et al.* 2020).

The high pH of intermediate moisture (IM) banana fruit slices immersed in glucose+sorbitol solution could also be attributed to an osmotic agent that interfered with the acidic nature of bananas, resulting in a high (4.63) pH in the Pisang Lilin variety.

Using a sucrose+sorbitol solution for osmosis during the development of IM banana allowed the acidic nature of Karpooravalli fruit slices to be preserved in a desirable product with low (3.50) pH.

Naknean *et al.* (2013) observed that sorbitol enhances the release of organic acids from the fruit tissues, while Tortoe *et al.* (2009) observed that sucrose remains in the extracellular space of the plant material during osmodehydration, which results in the retention of low-acid dehydrated fruit, which is a desired property of IM banana.

Fasogbon *et al.* (2013) found pH values ranging from 4.34 to 4.95 in osmodried pineapple slices, while Kamran *et al.* (2008) reported pH values of 4.10 on intermediate moisture mango slices, which is consistent with the current study.

5.2.2.5 Effect of osmotic agents on the reducing sugars (%) of Intermediate Moisture (IM) banana

The reducing sugar content of IM bananas treated with glucose solution was highest (51.75 %) in the Yangambi km5 variety and lowest (4.23 %) in banana fruit slices immersed in palm sugar solution for the Nendran variety. The high reducing sugar content of IM banana slices treated with glucose could be explained by the product's conformity to the glucose solution used during the osmodehydration treatment, which is a non-reducing sugar. The current study's findings are consistent with the findings of Ahmed *et al.* (2016), who reported that the osmodehydrated product exhibits the characteristics of the osmotic agent used. Furthermore, the soft texture of Yangambi km5 and low the molecular weight of glucose solution may have allowed the osmotic agent to be easily penetrated into the fruit tissues resulting in high (51.75 %) reducing sugar.

The low (4.23 %) reducing sugar of IM banana slices immersed in palm sugar solution in variety Nendran, on the other hand, may also be explained by osmotic solution impurities as well as the tight arrangement of the fruit cells, which are responsible for the

limitation of mass exchange between the fruit and the osmotic agent during osmotic pretreatment (Saputro *et al.* 2020; Ahmed *et al.* 2016).

Renu *et al.* (2012) reported that banana fruit firmness, which is explained by the tight arrangement of the fruit cells, such as those observed with the Nendran banana variety of the current study, is essential for fruit structure preservation and future handling, whereas the soft-textured banana has a tendency to structural collapse, rendering the osmotic pretreatment inefficient.

Comparable reducing sugar values were reported by Alajil *et al.* (2020), who recorded reducing sugars of 37.10 percent in osmodehydrated apricots, whereas Suresh Kumar and Sagar (2016) reported 28.94 per cent of reducing sugars in osmo-vacuum dried guava slices. Chavan *et al.* (2010) reported lower reducing sugars of osmo-air dried bananas in the range between 10.2 and 11.7 percent, which were lower than those recorded in the present study.

5.2.2.6 Effect of osmotic agents on the non reducing sugars (%) of Intermediate Moisture (IM) banana

The non-reducing sugar content of IM bananas treated with sucrose solution was highest (40.90 %) in variety Yangambi km5 and lowest (1.97 %) in the Nendran variety treated with sucrose+NaCl. The conformity of IM banana to the dominant sugar present in the osmotic solution, which in this case was sucrose, a non-reducing sugar, may explain the highest non-reducing sugars of IM banana slices immersed in sucrose solution for variety Yangambi km5. Ahmed *et al.* (2016) discovered that sucrose solution has a tendency to be inverted to fructose and glucose in an acidic medium during osmodehydration, whereas Tortoe *et al*. (2009) discovered an antagonistic effect between sucrose and sodium chloride when sucrose+NaCl solution is used as an osmotic agent. Therefore, it is possible that the low non-reducing sugar content of IM bananas treated with sucrose+NaCl solution was caused by the inversion of sucrose to fructose and

glucose, as well as the limited uptake of osmotic agents into the fruit cells due to the antagonistic effects of sucrose and sodium chloride.

Wiktor *et al.* (2022) observed similar changes in the sugar profiles of osmodehydrated strawberries where the fruit conformed to the osmotic agent used. Fruits treated with sucrose solution had reducing sugar levels reduced by 23.80 to 37.50 per cent. Gurumenakshi and Varadharaju (2018) reported higher non-reducing sugars, which were estimated at 48.55 per cent of osmodried mango slices, while Atri *et al.* (2016) reported non-reducing sugars of 34.5 per cent on intermediate moisture products from papaya, which was in line with some of the non-reducing sugars recorded in the present study.

5.2.2.7 Effect of osmotic agents on the total sugars (%) of Intermediate Moisture (IM) banana

The total sugars of intermediate moisture fruit influences the taste and the acceptance of the dehydrated product. The highest (63.50 %) total sugars of IM banana was observed in fruits immersed in glucose solution of variety Grand Naine while lowest (19.07 %) total sugars were in fruits immersed in sucrose+sorbitol solution in variety Karpooravalli. The high total sugars of IM banana prepared using glucose solution may be explained by the high glycemic index of the sugar used which is more than 89 (Wolever, 2013). However, it was found to have a tendency to crystallize IM bananas and cause quality degradation of the product (Plate 13). On the other hand, when sucrose+sorbitol solution was used as an osmotic agent for the development of IM banana in the banana variety Grand Naine, the amount of total sugars was close to that of fresh banana, which is estimated at between 20 and 25 per cent (Maduwanthi and Marapana, 2019).

Aggarwal and Kaur (2014) reported a similar observation in kinnow orange candy, where fruit slices kept in glucose and then hot air dried showed sugar

Plate 13. Crystallization of IM banana slices subjected to glucose osmotic solution

crystallization compared to those immersed in sucrose and recommended a combination of sugars during osmodehydration pretreatment. Ahmed *et al.* (2016) and Tortoe (2010) also suggested combining osmotic agents to reduce sugar crystallization when the osmotic agent is used alone, thereby improving product quality.

According to Mishra *et al.* (2015), the optimal sugar content of intermediate moisture papaya cubes is 40 per cent and is accepted by the consumer, whereas total sugars above 50 and 60 per cent are disliked by the consumer and are also not considered healthy. As a result, all of the IM bananas developed in this study, with the exception of IM banana slices treated with glucose solution, were found to be healthy and can be incorporated as a snack for consumers who are on weight loss programmes due to their resemblance to fresh fruit. However, IM banana treated using glucose solution may be used to incorporate in the diet for the management of diabetics (Wolever, 2013). The current total sugar content of the present study is consistent with reports on the total sugar content of osmdehydrated mango, guava, aonla, and banana fruit slices by Kumar and Sagar (2014) and Patil *et al.* (2013).

5.2.2.6 Effect of osmotic agents on the vitamin C content (mg/100g) of Intermediate Moisture (IM) banana

Ascorbic acid (vitamin C) is the most important nutrient that is easily degraded and is frequently used to calculate nutrient losses during processing. Osmotic agents in combination with sorbitol recorded higher vitamin C content compared to other osmotic agents among all the banana varieties which were in the range of 13.07 and 39.42 mg/100g. Highest (39.42 mg/100g) vitamin C content of IM banana was observed in variety Grand Naine where banana slices have been treated with glucose+sorbitol solution whereas fruit slices prepared from Njalipoovan and immersed in sucrose+NaCl had lowest (4.32 mg/100g) vitamin C content.

The high vitamin C content observed in sorbitol-containing osmotic agents could be attributed to its important role as an intermediate in the manufacture of L-ascorbic acid (vitamin C), whereas the sucrose+NaCl solution could have leached out vitamin C from the tissues or been degraded due to its high solubility in water (Zhang *et al*., 2020; Phisut *et al*., 2013).

Wiktor *et al.* (2022) similarly observed a 30 per cent increase in the vitamin C when sorbitol was used as osmotic agent compared to sucrose solution during osmodehydration of strawberry fruit slices while Naknean *et al.* (2013) reported high (28.45 mg/100g) vitamin C values on osmo-dried cantaloupe treated using sorbitol. Tortoe *et al.* (2009) reported the limitation of solute uptake when sucrose+NaCl was used as osmotic agent on apple, potato and banana which implies that there was limitation in the countercurrent mass exchange where solid mass losses were more than solid gain which is in line with the present study.

5.2.2.7 Effect of osmotic agents on the total carotenoids (µg/100g) of Intermediate Moisture (IM) banana

The IM banana of variety Nendran showed the highest total carotenoids content, with fruits immersed in glucose+sorbitol having highest (335.78 µg/100g) total carotenoids content followed by sucrose+sorbitol (233.87 µg/100g) while the lowest (13.47 µg/100g) total carotenoids content was recorded in variety Grand Naine in fruits treated with glucose+sorbitol solution. Banana varieties with a "B" genomic constitution, such as Nendran and Karpooravalli, were also found to retain more total carotenoids than those with an "A" genomic constitution.

These disparities could be attributed to the soft texture of banana varieties in the "A" group, which is strongly related to the dessert group and is more permeable to allow total carotenoids to seep out than varieties in the "B" group, which is closely related to plantain banana and is firm textured. The glycolytic activity may have been favoured the

carotenoid biosynthetic pathway for the accumulation of carotenoids in Nendran and Karpooravalli banana varieties due to their high content of carbohydrates compared to varieties of 'A' genome (Duran-Soria *et al*., 2020).

Gomez *et al.* (2022) found similar total carotenoids content results, attributing the differences in total carotenoids content between Mauritius and Kew pineapple varieties to inherent differences rather than the different osmotic agents used. They also reported total carotenoid content ranging from 0.215 to 0.808 mg/100g, which agreed with the current findings. Ramakrishnan *et al*. (2014) discovered significant differences in carotenoids content between mango varieties, with the Ratna variety having the most (5463 g/100g) and the Vellaikolumban variety having the least (1431 g/100g).

5.2.2.8 Effect of osmotic agents on the total phenols (mg/100g) of Intermediate Moisture (IM) banana

Total phenolic compounds, which are found in plant-based processed foods and are commonly referred to as nutraceuticals, are high in natural antioxidants that inhibit mutagenesis and carcinogenesis (Pandey and Rizvi, 2009). Total phenols in IM banana slices were highest in sucrose+sorbitol-treated fruits, followed by honey and lowest in sucrose+NaCl-treated fruits. A twenty-fold high (335.00 mg/100g) total phenols was recorded in IM banana slices of the Nendran variety immersed in sucrose+sorbitol solution compared to IM banana slices immersed in sucrose+NaCl of the Karpooravalli variety, which recorded a low (18.33 mg/100g) total phenol content.

According to Hull (2010), when exposed to an acidic pH, sucrose is converted to glucose and fructose, whereas sorbitol is stable over a wide pH range. Because of the addition of ascorbic acid to the osmotic agents, their pH may have changed, causing the osmotic solutions to become acidic. Sucrose inversion into glucose and fructose may have resulted in phenolic compound oxidation and subsequent reductions in total phenols,

whereas the presence of sorbitol in the sucrose+sorbitol solution may have helped to stabilize the osmotic solution, thereby preventing total phenol degradation.

Although Wiktor *et al.* (2022) found lower total phenols in osmodehydrated strawberries, with a range of 16–17.3 mg/100g, they also found a protective effect of sucrose and polyol solutions on its polyphenol content. Gomez *et al.* (2022) reported a total phenol content of 150 to 220 mg/100g on intermediate moisture pineapple slices, whereas Mishra *et al.* (2015) reported a polyphenol content of 600 to 1217 units/100g.

5.2.2.9 Effect of osmotic agents on the non enzymatic browning (OD value) of Intermediate Moisture (IM) banana

Non-enzymatic browning (NEB) is a negative attribute in dehydrated fruits caused by the oxidation of phenolic substrates by polyphenol oxidase (PPO) and it is the most common cause of discolouration during food processing. The IM banana slices treated with palm sugar solution had highest (0.99) browning, which was almost seven times higher than those reported in IM banana slices immersed in solutions of sucrose +NaCl and sucrose+sorbitol of the variety Nendran which had lowest NEB values in the range between 0.10 and 0.13, respectively. High browning was also found in IM banana slices immersed in honey where browning values ranged between 0.17 and 0.88 across all banana varieties.

Palm sugar and honey contain sugars like glucose and fructose, as well as amino acids, proteins, and polyphenols, which are the main substrates and reactants in the Maillard reaction (Srikaeo *et al*., 2019; Da Silva *et al*., 2015). Browning of IM banana slices in both banana varieties may be related to the fruit product's conformity with the osmotic agents used, both palm sugar and honey being dark in colour. The protective effect of sucrose and salt, which both inhibit oxidative and non-enzymatic browning, could be attributed to the reduced browning of IM banana slices treated with sucrose+NaCl solution (Ahmed *et al*., 2016; Tortoe, 2010).

A lower non-enzymatic browning value at 0.15 on osmo-vacuum dried mango slices was reported by Suresh Kumar *et al.* (2008) while Sethi and Kaur (2019) found a much higher browning index of 9.95 in osmo-air dried pineapple slices. Although the non-enzymatic browning of the IM bananas in this study differs, the addition of ascorbic acid as an acidulant and antioxidant during osmotic pretreatment can be attributed to the low browning effect, which inhibits polyphenol oxidase (PPO) activity by limiting the availability of molecular oxygen required for browning reactions.

5.2.3 Effect of osmotic agents on the microbiological populations of Intermediate Moisture (IM) banana

Food pretreatment with osmodehydration is known to cause microbial cells to experience osmotic shock, resulting in water loss from the cell and, as a result, cell death or retarded growth (Hull, 2010). It has also been proposed that hypertonic solutions may interfere with cellular enzymes, limit oxygen solubility, or force cells to expend energy to exclude osmotic agent ions from the cell, all of which can slow growth (Frazier and Westhoff, 2014; Foster, 2020).

Bacterial growth in IM banana slices of 0.67 cfu/g was recorded in both glucose and sucrose solutions for variety Yangambi km5. Pisang Lilin recorded a fungal population of 0.33 cfu/g for IM banana slices immersed in glucose solution, while Yangambi km5 recorded a yeast population of 0.33 cfu/g in glucose solution.

The microbial population in IM bananas treated with glucose and sucrose solution may be explained by the inversion of sucrose to glucose in the presence of an acidic medium which then provides the energy source for both of microbial growth (Frazier and Westhoff, 2014). The IM bananas produced in this study are within the acceptable limits of microbiological standards, with the maximum levels as specified by FSSAI (2018) microbiological standards for bacteria and *Escherichia coli*, which have maximum limits

of 1.00×10^5 cfu/g and absent, respectively, while for fungi and yeast, the set limits, are at 1.00×10^4 cfu/g.

Although Azoubel *et al*. (2009) did not detect any microbiological population immediately after preparation of IM cashew apple, they reported that the aerobic bacteria and osmophillic yeast strains such as *Staphylopcoccus aureus* and *Saccharomyces* spp. can still grow on the dehydrate product with reduced water activity . Chavan *et al*. (2010) did not detect any microbial population for bacteria and fungi immediately after preparation of osmodried banana slices which they attributed to the addition of antimicrobials to the osmotic solution, which conforms to the findings in the present study. Yadav and Singh (2014) recommended a mixture of osmotic agents for a more effective reduction of microbial growth due to a combination of properties for both the solutes, as observed with the present investigation.

5.2.4 Effect of osmotic agents on the organoleptic quality of Intermediate Moisture (IM) banana

The variety Nendran had the highest acceptability for sensory attributes such as the appearance (7.79), colour (7.60), texture (7.40), odour (7.07), taste (7.80), after taste (7.67), and overall acceptability (7.67). Variety Njalipoovan was the least accepted in terms of its appearance (4.87), colour (4.67), texture (5.07), odour (5.13), taste (5.00), after taste (4.80) and overall acceptability (4.53). Sucrose+sorbitol (T3) was a highly ranked osmotic agent for the development of IM banana in terms of the appearance (7.79), colour (7.60), flavour (7.40),taste (7.80), after taste (7.67), and overall acceptability (7.67). The least acceptable osmotic agent was honey in terms of its appearance (4.87), colour (4.67), texture (5.07), odour (5.13), taste (5.00), after taste (4.80) and overall acceptability (4.53).

Firm fruit banana varieties such as Nendran were widely accepted due to their resistance to mechanical damage and maintained a higher (7.40) textural scores of IM

banana slices of the Nendran variety treated in sucrose solution compared to IM banana slices treated in honey of the variety Njalipoovan, which had lower (5.07) texture scores. According to Brochier *et al.* (2015), the osmotic agents that cause the most water losses are responsible for causing severe structural damage, which is consistent with the study's findings, where the osmotic solution that caused the most water loss, honey, resulted in textural loss, hence the low scores.

The intermediate-moisture banana slices from varieties Nendran, Pisang Lilin and Karpooravali immersed in sucrose+sorbitol also received the highest scores for texture, ranging from 6.73 to 7.20, and these high scores for texture were attributed to sorbitol's negative thermal impact, which causes a cold sensation in the mouth and gives the fruit a fresh, flavourful taste (Zhang *et al*., 2020). According to Hull (2010), sucrose has a high bulking effect when compared to other sugars like glucose, fructose, and sorbitol, and as a result, it adds texture to the food, which is consistent with the current study, which found highest (7.40) sensory scores for texture in IM banana slices immersed in sucrose solution for variety Nendran.

A banana's sweet taste is a desirable characteristic that determines its acceptability. The high (7.80) taste scores of IM banana slices of variety Nendran immersed in sucrose+sorbitol solution could be attributed to the sucrose (1.00) sweetness index, which could have been stabilized by sorbitol. Although honey has a high sweetness index (1.2) because fructose is its dominant sugar, the low (5.00) scores for the taste of IM banana slices immersed in honey for varieties Njalipoovan and Pisang Lilin could be attributed to the instability of the fructose sweetness index, which is more sensitive to conditions such as temperature, pH, and combination with other ingredients such as ascorbic acid and KMS (Hull, 2010).

IM banana fruit slices of banana varieties Nendran, Pisang Lilin, and Karpooravali immersed in sucrose+sorbitol solution showed the highest scores for overall acceptability of 7.67, 7.00, and 7.33, respectively. IM bananas of varieties of Njalipoovan

and Yangambi km5 had the highest overall acceptability of 7.60 and 7.00, respectively, when fruit slices were immersed in sucrose solution, while Grand Naine was the only variety where the highest scores of 7.33 for overall acceptability were observed when IM bananas were treated in glucose+sorbitol. As a result, the high overall acceptability of IM banana was revealed when fruit slices were immersed in sucrose solution or sucrose+sorbitol solution.

The browning effect of honey on IM banana slices, when compared to other osmotic agents, may have contributed to the product's low overall acceptability and colour, which was also observed with IM banana slices immersed in palm sugar. The viscid nature of honey may also have contributed to IM banana's low acceptability, making it sticky and difficult to handle.

Palm sugar is made by hydrolyzing sucrose, which yields reducing sugars, which are a substrate required for the Maillard reaction to occur, explaining its dark colour. Although IM banana slices immersed in palm sugar solution had a dark colour similar to honey-treated IM banana slices, its acceptability among all banana varieties were higher than 5.5 which may be due to its dinstinctive nutty flavour found in caramelized products such as palm sugar solution (Srikaeo *et al*., 2019).

Gomez *et al.* (2022) investigated different osmotic solutions for the development of intermediate moisture pineapple slices and discovered that the osmotic agent combination sucrose+sorbitol resulted in higher organoleptic scores, which is consistent with the current findings. Mahomud *et al.* (2015) suggested using a sucrose and honey solution to improve the sensory properties of osmoair dried bananas. Bawa and Gujral (2000) reported low sensory scores on appearance and overall acceptability for osmoair dried raisins when honey was used as an osmotic ageny and recommended combining this osmotic solution with sucrose to improve the appearance and flavour of the final product.

5.2.5 Effect of osmotic agents on the cost of production (Rs.) of Intermediate Moisture (IM) banana

The total cost of producing 100g of Intermediate Moisture (IM) bananas from the varieties ranged from Rs. 96.91 to Rs. 201.84, taking into account the cost of raw materials, labour charges, and other inputs. The cost of producing IM bananas was determined by the cost of the osmotic agent used as well as the price of bananas per kilogramme. Sucrose was found to be more costly (Rs. 940.94/kg), whereas palm sugar was almost ten times less costly (Rs. 90/kg). The cost of procuring variety Njalipoovan was higher (40/kg), whereas the varieties Pisang Lilin, Karpooravali, Grand Naine, and Yangambi (KM-5) were twice as cheap (15/kg) (Appendix 2). The current study's cost benefit ratio range of 0.35 to 0.72 suggests that lower cost alternatives, such as reusing osmotic agents or using other osmotic agents such as table sugar, may be acceptable for increasing returns.

Kiribhaga (2019) estimated the cost of making banana wine from 1000g of pulp from the varieties Grand Naine, Poovan, Karpooravalli, Yangambi km5 and Palayankodan to be between Rs. 129.00 and Rs. 144.00.The production cost of osmo air dried whole aonla was found to be Rs.155/kg by Saxena *et al.* (2017), due to the type of sugar they used as an osmotic agent, which was less costly than the osmotic agents used in the present study. Using sugar as an osmotic agent, Chavan *et al.* (2010) also estimated the cost of osmodried bananas at Rs. 65/kg.

5.2.6 Effect of vacuum drying and cabinet drying on the physical quality of Intermediate Moisture (IM) banana

Vacuum oven dried IM bananas showed superior quality in their physical characteristics compared to cabinet-dried IM bananas. Although the moisture content of IM bananas was high for vacuum oven dried fruit compared to cabinet drying, the fruit showed improved characteristics in terms of ease of transport, retained nutrients, and

improved shelf life as implicated by weight losses, solid gain, as well as water activity and ERH, respectively. The colour of vacuum dried IM banana was of superior quality with less browning and intense yellowness of the product as implicated by low a^* and high values of L^* and b^*.

Vacuum dehydrated IM banana slices outperformed cabinet dried IM bananas due to pressure reductions, which lower the boiling temperatures and deterioration rates associated with high-temperature drying. Despite the fact that the IM banana had lower water activity, the product's physical quality remained similar to the fruit's original state after vacuum drying (Plate 14).

Mitra *et al.* (2015) discovered improved qualitative parameters of vacuum drying of osmodehydrated onion slices compared to standard hot air drying practice in terms of colour preservation, less cell damage, and less shrinkage in tissues, which was consistent with the current study's findings. Junlakan *et al.* (2017) attribute the high browning (color value a^*) of cabinet dried fruits like bananas, pineapples, and apples to product oxidation because the fruits are exposed to air during dehydration. According to Ahmed *et al.* (2016), vacuum oven drying improves the state of dried fruit while decreasing water activity, which was also observed in the current study, where the vacuum dehydrated product had more solid gain and less browning.

5.2.7 Effect of vacuum drying and cabinet drying on the biochemical quality of Intermediate Moisture (IM) banana

When compared to IM banana slices dried with cabinet drier, vacuum-dried IM bananas had superior biochemical quality. The fruit was acidic, with less sugar and higher antioxidant levels like vitamin C, carotenoids, and total phenols. Low boiling temperatures of IM banana slices under vacuum avoided biochemical deteriorative reactions such as degradation of vitamin C and carotenoid, fat oxidation etc. which can be induced by high boiling temperatures in cabinet driers (Bonazzi and Dumoulin, 2011).

Cabinet-dried IM bananas had higher total sugars, including reducing and non-reducing sugars, than vacuum-dried IM bananas. The high sugars with cabinet drying may be associated with findings by Conrad (2005) who reported that the method of moisture removal from the food pieces determines its sugar content with high temperatures causing concentrations of both sugars and salts. This implies that the sugar content of cabinet dried IM bananas was concentrated at high temperatures, whereas low boiling temperatures under vacuum kept the sugar content of IM bananas similar to their "fresh like" state.

Ganachari *et al.* (2020) discovered that vacuum osmo-dried aonla slices outperformed osmo-tray dried aonla fruit in terms of biochemical content of vitamin C and titratable acidity, with values of 534.8-675.3 mg/100g and 0.23-0.22 per cent, respectively, which is consistent with the current study's findings. They did, however, reported an insignificant effect with the drying method on the total sugar content where values ranging from 80.2 to 82.2 percent, which were higher than those presented in the current study. Tewari *et al.* (2021) discovered that vacuum dried Indian gooseberry had the highest nutrient retention when compared to fresh fruit on nutrients such as ascorbic acid (99.33 %) and total phenol (99.45 %), which is consistent with the current study in which the ascorbic acid content of IM banana was not only preserved but increased almost threefold.

5.2.7 Effect of vacuum drying and cabinet drying on the microbiological quality of Intermediate Moisture (IM) banana

In both vacuum dehydrated and cabinet dried IM banana products, none of the microorganisms tested was detected. The role of hybrid dehydration using both osmotic dehydration and either vacuum or cabinet drier has been shown to be effective in the microbiological stability of IM bananas. The inactivation of microbes in the current study could also be attributed to the lower pH of the osmodehydration solution and the

water activity of IM products, both of which are critical process factors in the inactivation of microbes of public health significance in foods (Frazier and Westhoff, 2014).

Furthermore, the addition of ascorbic acid and potassium metabisulphite to osmotic solutions might have played a similar role in the inhibition of micro-organisms by interfering with their cell membranes, their enzyme activity, and their genetic mechanisms (Foster, 2020).

5.2.8 Effect of vacuum drying and cabinet drying on the organoleptic quality of Intermediate Moisture (IM) banana

Sensory attributes of dehydrated products are critical in determining the degree of their acceptance. It was observed that vacuum-dried IM bananas received the highest scores in all the sensory attributes tested compared to cabinet dried fruit, with the fruit exhibiting superior organoleptic qualities (Figure 7).

Tewari *et al.* (2021) discovered less cell rupture and more regular shaped cells in vacuum dried Indian gooseberry, implying minimal changes in the microstructure and textural attributes when compared to hot air dehydration, which resulted in tissue collapse and irregular shape. Their findings are consistent with the current study, in which cabinet dried IM bananas lost cell integrity and texture, resulting in low texture scores (6.33) compared to the high (7.67) textural scores of vacuum dried IM bananas.

Kumar and Sagar (2014) attributed the high sensory scores with osmovacuum dried fruits such as mango, guava, and aonla slices to the less degradation of sugar, acid, and carotenes, which was in line with the present findings for vacuum dried IM banana. According to Bonazzi and Dumoulin (2011), heating causes aroma and volatile compound evaporation during drying. The high boiling temperature of cabinet dried IM banana, which causes loss of aroma volatiles during dehydration, may explain the low

Cabinet dried IM banana

Vacuum dried IM banana

Plate 14: Effect cabinet drying and vacuum drying on the quality of IM banana

(6.80) scores of odour when compared to the lower boiling temperature of vacuum dried IM banana, which received a higher (6.67) odour score.

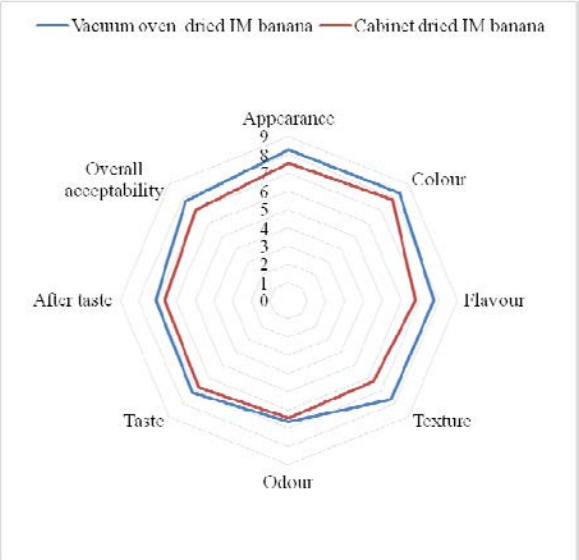


Figure 7: Effect of vacuum drying and cabinet drying on the organoleptic quality of intermediate moisture (IM) banana

5.2.9 Effect of vacuum drying and cabinet drying on the cost of production (Rs.) of 100g Intermediate Moisture (IM) banana

The cost of producing intermediate moisture bananas in vacuum and cabinet driers was comparable, they were both Rs. 198.68, which could be attributed to the same subsequent duration of dehydration of IM bananas, which was both done for two hours. According to Junlakan *et al.* (2017), while vacuum dryers can be more than twice as costly as cabinet driers, their benefits in retaining the physico-chemical qualities of dehydrated products make them a viable alternative for many food manufacturers. Similarly, Kumari and Samsher (2015); Srivastava and Kumar (2014) cited the reduced structural and biochemical damage with vacuum driers compared to cabinet driers which makes it best drying systems for the preparation of quality IM bananas.

5.3 Standardization of fruit to osmotic solution and duration of immersion on quality of Intermediate Moisture (IM) banana

5.3.1 Effect of fruit to osmotic solution and duration of immersion on the physical quality of Intermediate Moisture (IM) banana

5.3.1.1 Effect of fruit to osmotic solution and duration of immersion on the moisture content (%) of Intermediate Moisture (IM) banana

The influence of the fruit on the osmotic solution, as well as the duration of immersion, on the moisture content of IM bananas was studied (Figure 8). The moisture content of IM bananas decreased as the fruit to osmotic solution ratio increased, but after a fruit to osmotic solution ratio of 1:3, the moisture content reduction slowed. Duration of immersion that is beyond four hours led to increase in moisture content of IM banana.

The increase in fruit to osmotic solution ratio may be attributed to the increased driving force required for the removal of water from banana tissues by osmosis, thereby decreasing the moisture content of IM bananas. A minimum moisture loss beyond a fruit to osmotic solution ratio of 1:3 suggests that optimal osmotic dehydration is ineffective in moisture reductions of IM bananas beyond this point. The increase in moisture content with increasing duration of immersion may be attributed to lowered osmotic pressure due to osmotic solution dilution that results in the migration of water into the cell and decreases the effective removal of water from the cell walls in IM banana (Ahmed *et al.* 2016). Thus, the results suggest that to avoid osmotic solution dilution during osmotic pretreatment of IM bananas, the duration of immersion should not exceed four hours.

Tippanna *et al.* (2019) reported moisture content of osmodried pineapple slices at 56.82–61.91 per cent of osmodried pineapple slices when the fruits were immersed in an osmotic solution ratio of 1:2 and 18-hour duration. Mahomud *et al.* (2015) recommended an efficient fruit to osmotic solution of 1:7 and a three-hour duration to reduce moisture

levels to 14.6 per cent, while Singh and Gangwar (2020) observed effective moisture content reductions on carrot slices with a fruit to osmotic solution of 1:5 and a three-hour osmotic process duration. The moisture content range of the IM bananas in this study conforms to FAO (2003) specifications for intermediate moisture fruits with a moisture content range of 15 to 40 percent.

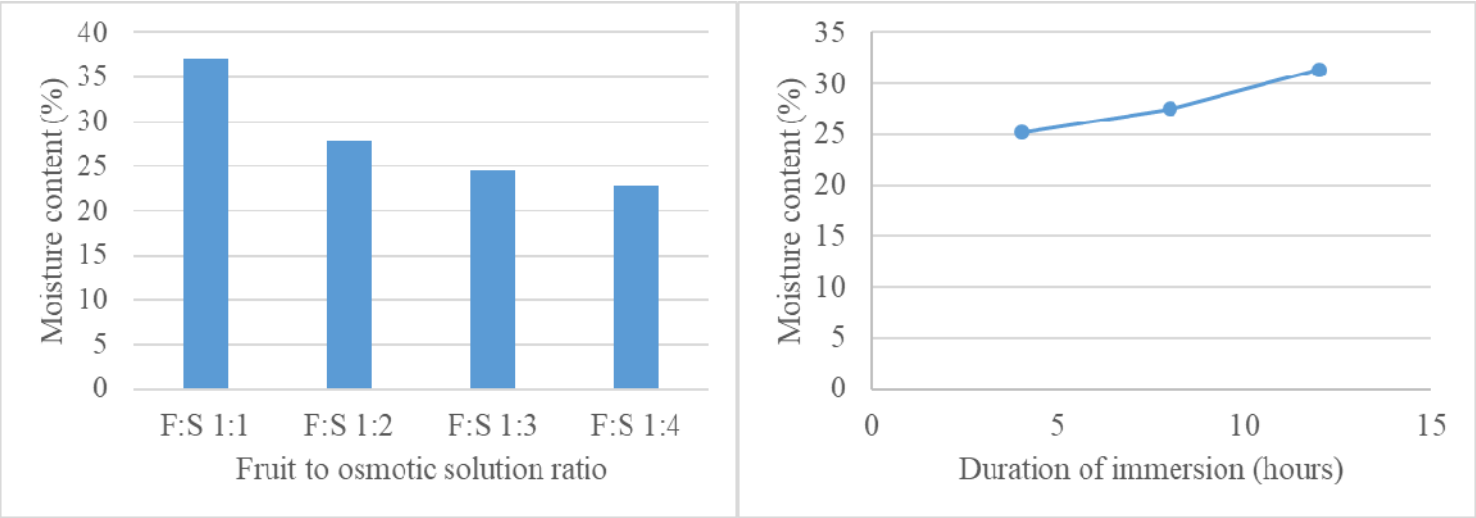


Figure 8: Effect of fruit: osmotic solution ratio and duration of immersion on moisture content (%) of intermediate moisture banana

5.3.1.2 Effect of fruit to osmotic solution and duration of immersion on the weight loss (%) of Intermediate Moisture (IM) banana

The influence of fruit on the osmotic solution ratio and duration of immersion of IM bananas was investigated (Figure 9). The weight loss of IM bananas increased with an increasing fruit to osmotic solution ratio and duration of immersion. The increased osmotic pressure gradient as well as improved contact of fruit pieces with osmotic solution with increasing fruit to osmotic solution ratio and duration of immersion, which dehydrated the protoplasm and resulted in cell shrinkage, may be responsible for the weight loss of IM banana.

A weight loss between 16.30 and 19.40 per cent was reported by Sagar and Suresh Kumar (2009) when fruit to osmotic solution of 1:4 and osmotic duration less than six hours. Renu *et al.* (2012) reported an efficient time of osmotic dehydration for weight loss when the fruit to osmotic solution ratio is 1:5 and the process duration is between 60 and 90 minutes on osmodehydrated banana. Kumari and Samsher (2015) found that increasing the fruit to osmotic solution ratio and 180 minutes of immersion time on osmoair dried banana slices resulted in weight losses of 8.23 and 21.72 per cent, which is consistent with the current findings.

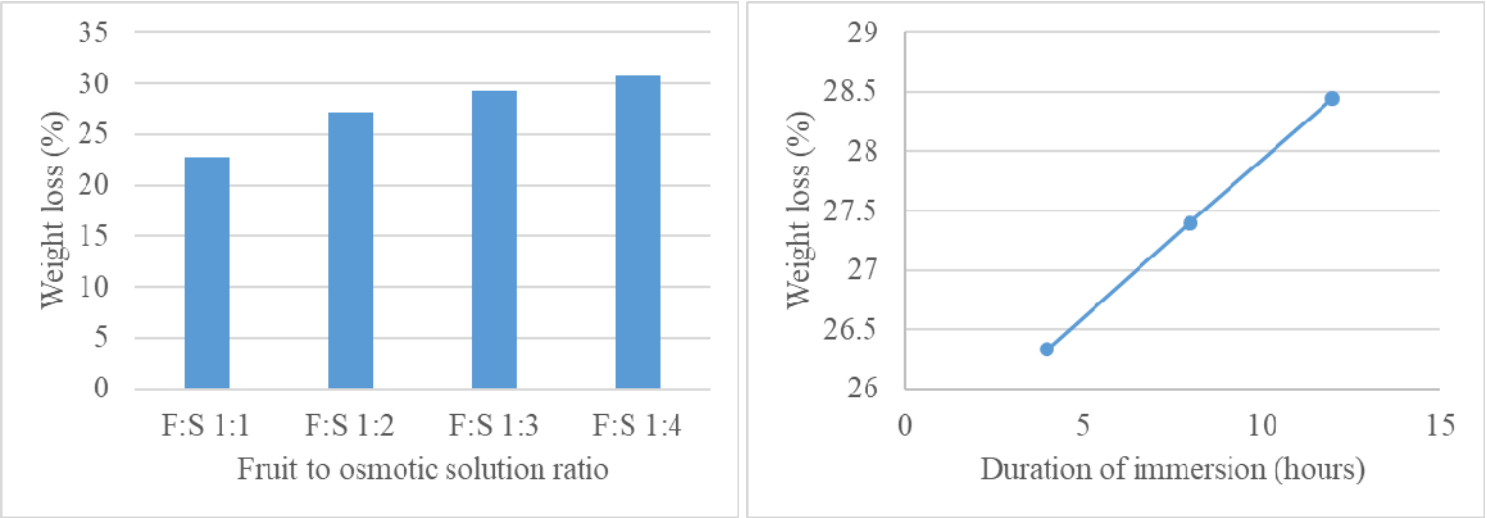


Figure 9: Effect of fruit: osmotic solution ratio and duration of immersion on weight loss (%) of intermediate moisture banana

5.3.1.3 Effect of fruit to osmotic solution and duration of immersion on the solid gain (%) of Intermediate Moisture (IM) banana

The solid gain of IM banana was observed regardless of the fruit to osmotic solution ratio or immersion time (Figure 10).The solid gain of IM banana was higher with lower fruit to osmotic solution ratio while a slight increase in the solid gain of IM banana was observed with increasing immersion time, which slowed after eight hours.The decrease in solid gain with increasing fruit to osmotic solution ratio may be due to an increase in osmotic solution viscosity, which accumulated sucrose in the thin sub-layer, resulting in tissue compaction and extra mass transport barrier (Tortoe, 2010).

According to Romero *et al.* (2022), low solid gain is desirable unless the goal is to enrich the product with bioactive compounds. The low solid gain was optimal when the fruit to osmotic solution ratio was 1:3, as increasing the fruit to osmotic solution ratio beyond this point resulted in a slight decrease in solid gain. The results also suggest that at eight hours, solid gain reduces as the state of equilibrium between cellular fluid and osmotic solution is approached. Therefore, longer duration of immersion beyond this point is ineffective (Ahmed *et al*., 2016; Sagar and Suresh Kumar, 2009).

Bera and Roy (2015) reported a rapid increase in solid gain during the first hours of osmotic duration, which then gradually decreased over time, with a maximum solid gain of 0.92g/g attained at three hours of osmotic duration. Solid gains of between 11.43 and 18.67 per cent of osmo-dried pineapple slices were reported by Tippanna *et al.* (2019) in a 1:2 fruit to syrup ratio, 18-hour immersion time osmotic treatment, which was comparable to the present study. In their study, Chavan *et al.* (2010) discovered a solid gain of between 3.8 and 13.1 per cent in osmodehydrated banana fruit slices when the fruit-to-osmotic ratio and duration of immersion were 1:2 and 16 hours, respectively.

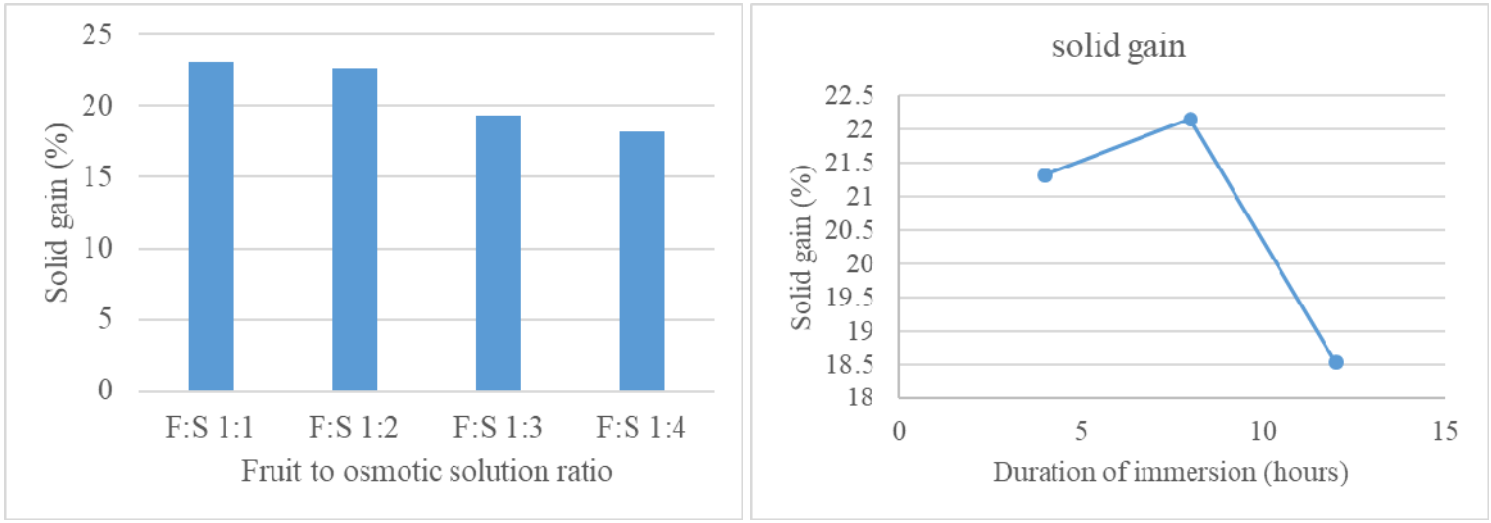


Figure 10: Effect of fruit: osmotic solution ratio and duration of immersion on solid gain (%) of intermediate moisture banana

5.3.1.4 Effect of fruit to osmotic solution and duration of immersion on the water loss (%) of Intermediate Moisture (IM) banana

Water loss was observed in IM banana regardless of the fruit-to-osmotic solution ratio or immersion time (Figure 11). There was an increase in water loss with an increase in fruit to osmotic solution ratio that slowed down beyond the fruit to osmotic solution ratio of 1:3 and eight-hour immersion time. The high water loss with an increase in fruit to osmotic solution ratio is attributed to the increased driving force due to the concentration gradient between the hypertonic solution and the cells of banana fruit for the removal of water from the food (Ahmed *et al*., 2016). The long duration of immersion beyond eight hours may have reduced the viscosity of the osmotic solution, making the solution dilute and reach the saturation point, which would not help in reducing more water during the osmodehydration pretreatment (Suresh Kumar and Devi, 2011).

Ghellam *et al.* (2021) reported maximum water loss during olive berry osmodehydration with a syrup-to-fruit ratio of 10:2 and shorter agitation runs during osmodehydration, as well as a lower solution volume with high mass transfer for lower drying costs, whereas Amiripour *et al.* (2015) reported 25.78 percent of water loss on osmotically dried pear fruit slices when a sample-to-osmotic-solution ratio and immersion time were 1:20 and 115 minutes, respectively. Pedapathi and Tiwari (2014) found water loss values of osmo-air dried guava fruits that were comparable to the present study to be in the range of 33.56 to 53.83 percent after maintaining a fruit to osmotic solution ratio of 1:2 and immersion duration of 24 hours.

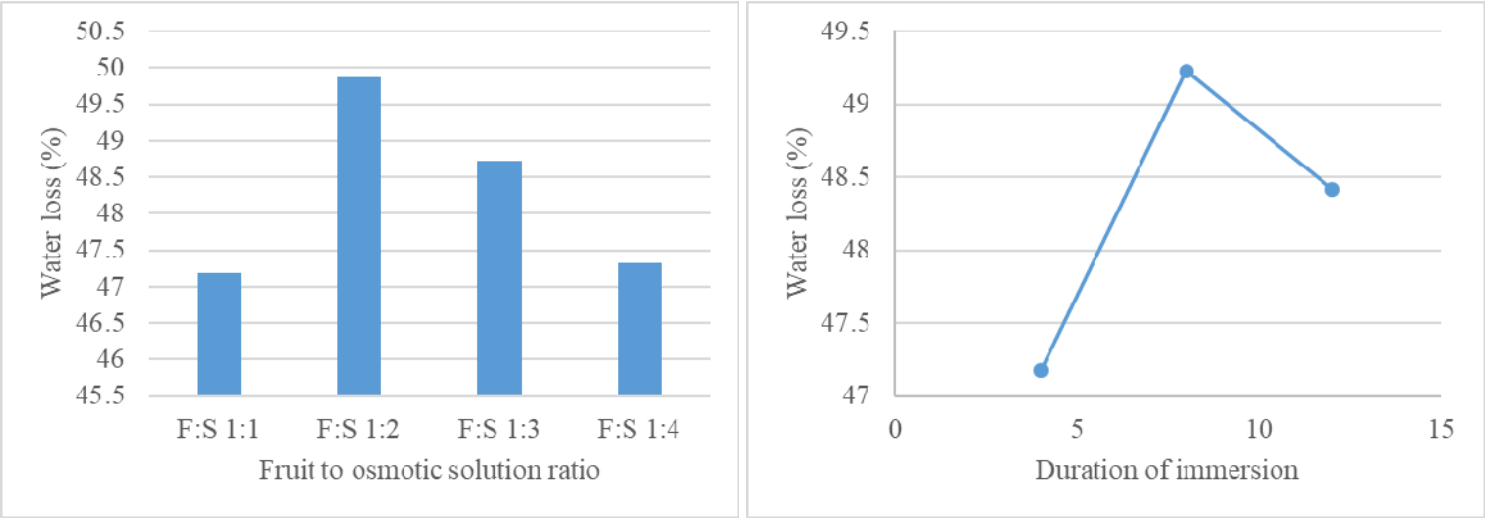


Figure 11: Effect of fruit: osmotic solution ratio and duration of immersion on the water loss (%) of intermediate moisture banana

5.3.1.5 Effect of fruit to osmotic solution and duration of immersion on the water activity and equilibrium relative humidity (ERH) (%) of Intermediate Moisture (IM) banana

The water activity and equilibrium relative humidity (ERH) of IM banana was investigated (Figure 12 and Figure 13). The water activity of IM banana decreased as the fruit-to-osmotic-solution ratio and immersion time increased. However, increasing the fruit to osmotic solution ratio beyond 1:3 slowed water activity reductions, whereas longer immersion duration decreased IM banana water activity. Increased fruit-to-osmotic-solution ratio and long duration imply that the gradient of chemical potential between solution and food was high, resulting in high water loss. Since a non-significant difference was observed in the immersion time, a shorter time of four hours was found to be appropriate for reduced process duration.

According to Rodriguez *et al.* (2015), increasing the fruit-to-osmotic-solution ratio from 1:4 to 1:10 resulted in a significant decrease in water activity from 0.97 to 0.44. Gomez *et al.* (2022) reported the water activity of intermediate moisture pineapple slices to be 0.67, whereas Singh and Mehta (2008) also found that a fruit-to-osmotic-solution ratio of 1:3 and duration of immersion not exceeding 180 minutes reduced water activity and ERH to 0.6 and 60 per cent respectively. Rai *et al.* (2004) reported the ideal ERH values for intermediate moisture papaya cheese to be less than 79.6 percent certifying the IM banana of the current study to be within the safe range of water activity and ERH values.

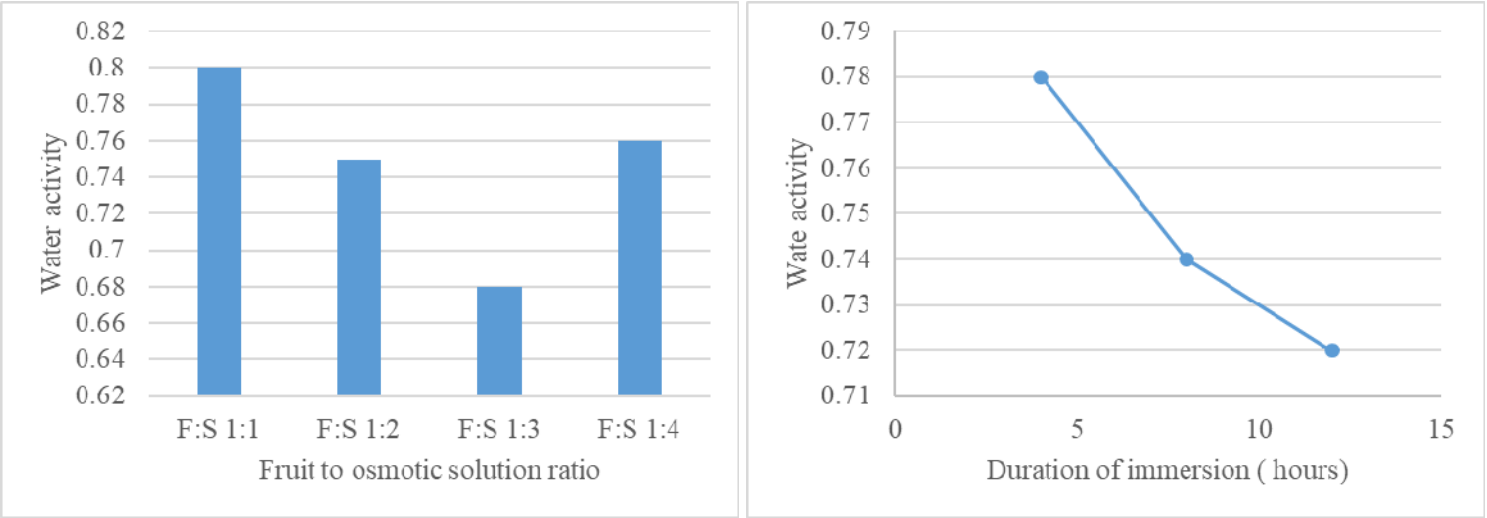


Figure 12: Effect of fruit: osmotic solution ratio and duration of immersion on the water activity of intermediate moisture banana

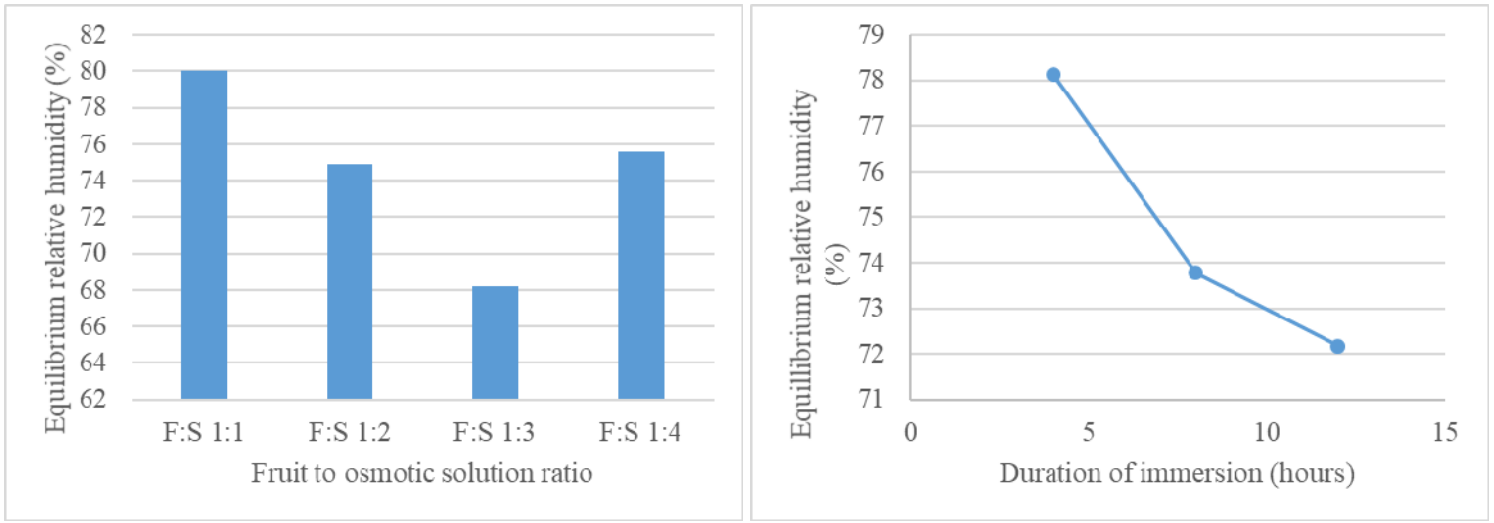


Figure 13: Effect of fruit: osmotic solution ratio and duration of immersion on the equilibrium relative humidity (%) of intermediate moisture banana

5.3.1.6 Effect of fruit to osmotic solution and duration of immersion on the colour values (*L*, a*, b**) of Intermediate Moisture (IM) banana

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the colour value *L** of IM banana was investigated (Figure 14.1.). When the fruit-to-osmotic-solution ratio was increased to 1:3, the colour value *L** (lightness) gradually increased, and it declined beyond this ratio. Similarly, increasing the osmotic duration up to eight hours increased the colour value of *L**, while increasing the osmotic duration beyond eight hours decreased the colour value of *L**.

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the colour value *a** of IM banana was investigated (Figure 14.2.). The increase in fruit-to-osmotic solution ratio gradually increased colour value *a** to a ratio of 1:2 and then declined as the fruit-to-osmotic ratio increased further. The colour value of *a** increased as the duration of immersion increased.

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the colour value *b** of IM banana was investigated (Figure 14.3.). As the fruit-to-osmotic solution ratio increased, the colour value *b** decreased. An increase in immersion time to eight hours reduced the colour value of *b**, but an increase in osmotic time increased the colour value of *b**.

The desirable colour values of IM bananas in the present study may be achieved with high *L** (lightness) and *b** (yellowness) values and a corresponding low *a** (redness/browning) value. Therefore, the fruit to osmotic solution ratio of 1:3 and duration of immersion of four hours may be optimum conditions for better colour retention during the development of IM banana.

The high *L** (lightness) and a corresponding low *a** value with increasing fruit to osmotic solution ratio might have been due to a provoked reduction in the activity of

polyphenol oxidase with increased contact of fruit pieces with osmotic solution, which avoided the degradation of colour of the IM banana slices (Chiralt and Talens, 2005). High colour values of a^* and b^* of IM banana may be associated with colour degradation of compounds such as carotenoids as well as tissue browning.

Cichowska *et al.* (2020) reported darkening of osmodehydrated apple slices when the drying process process was increased and recommended a short osmotic duration of 180 minutes and a syrup-to-fruit ratio of 2:1 for less browning. Similarly, Keerthisree *et al.* (2017) discovered that as the immersion time of osmoair dried banana slices increased from 44 to 71.07 minutes, the colour intensified. They reported the browning index ranges between 134.67 to 140.70 during the development of osmoair dried banana slices which was higher than the findings of the present study. The colour values found in this study agree with those found in intermediate moisture pineapple slices by Gomez *et al.* (2022) and Sethi and Kaur (2019).

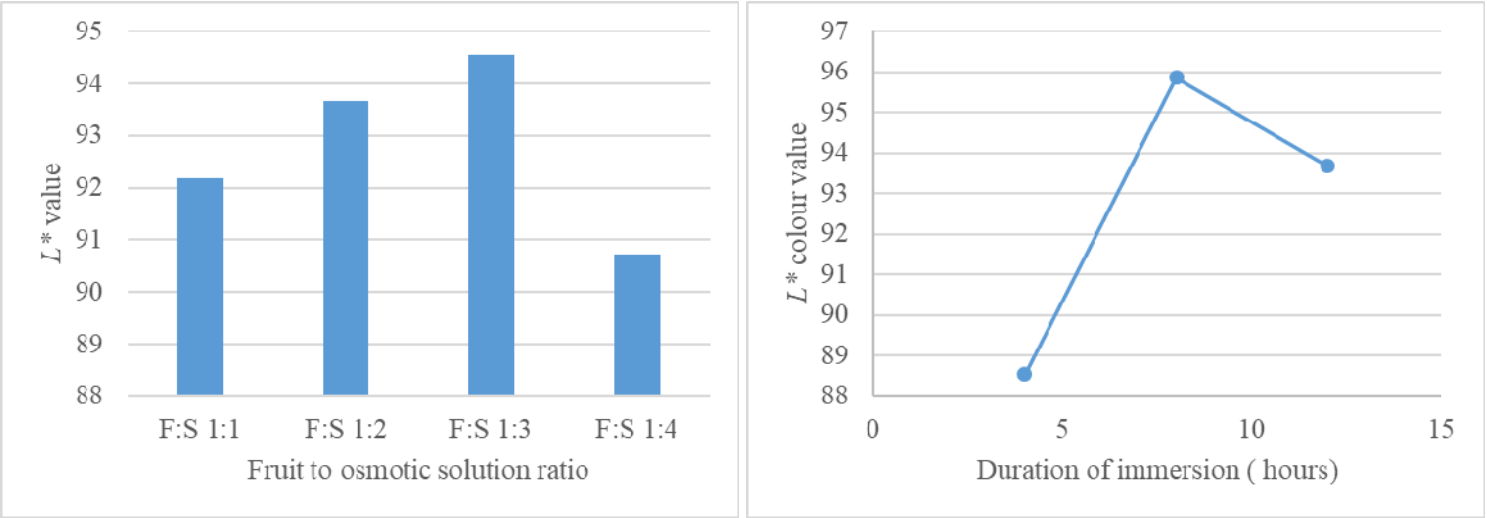


Figure 14.1. : Effect of fruit: osmotic solution ratio and duration of immersion on the colour value *L of intermediate moisture banana**

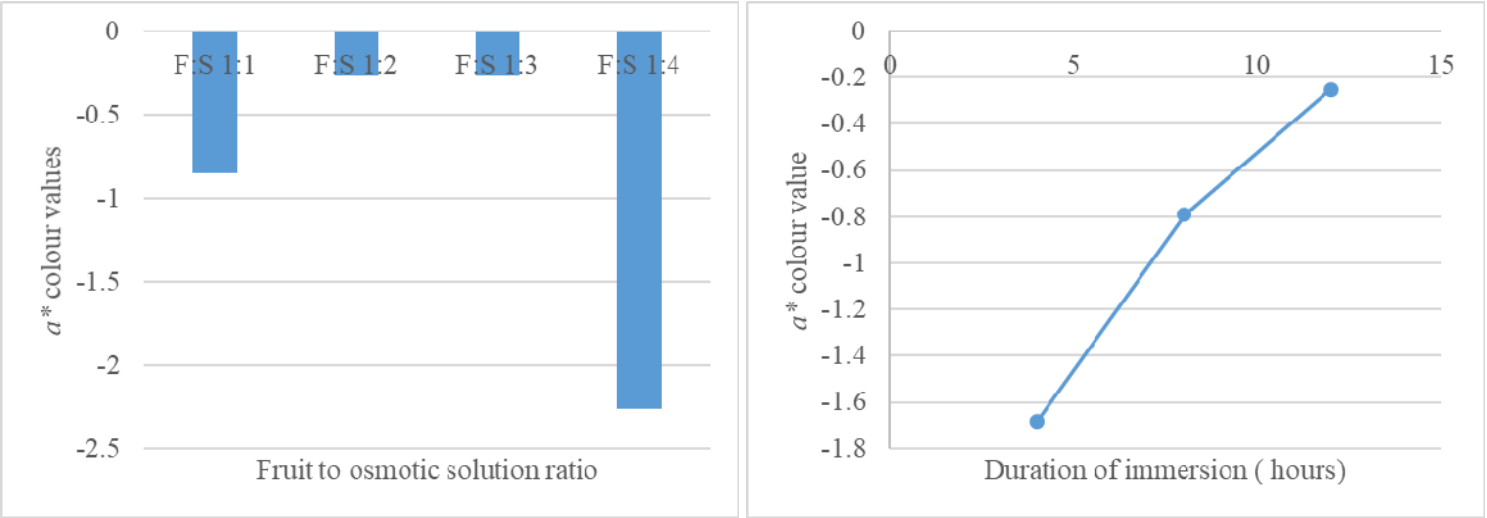


Figure 14.2. : Effect of fruit: osmotic solution ratio and duration of immersion on the colour value *a of intermediate moisture banana**

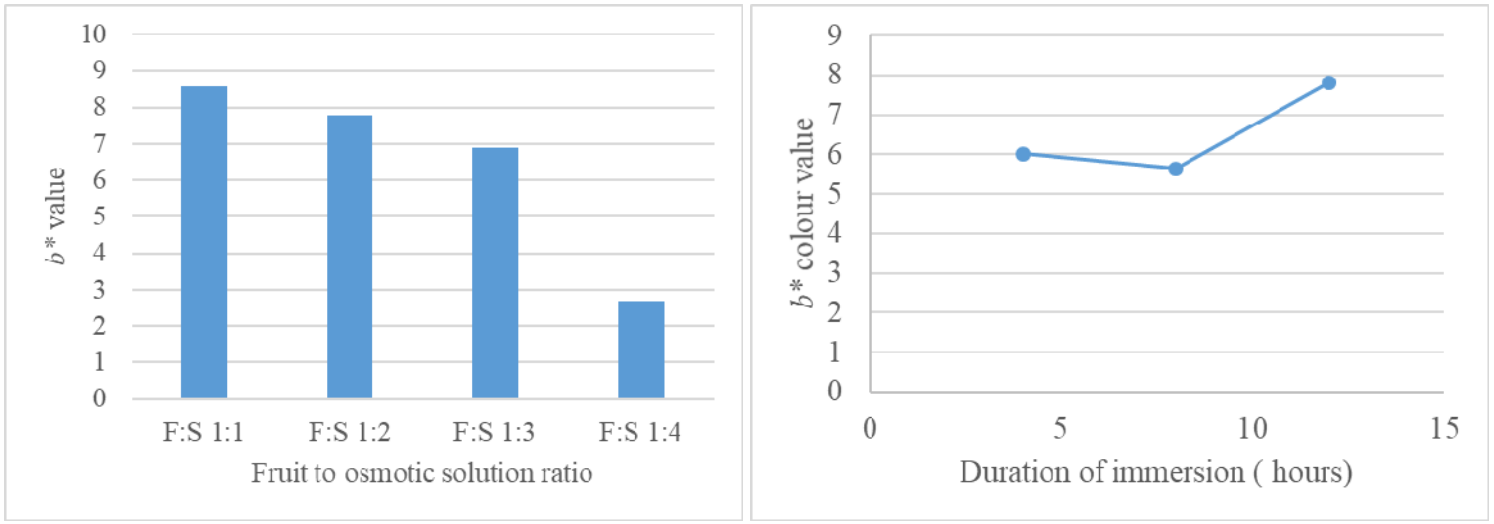


Figure 14.3. : Effect of fruit: osmotic solution ratio and duration of immersion on the colour value *b of intermediate moisture banana**

5.3.2 Effect of fruit to osmotic solution and duration of immersion on the biochemical quality of Intermediate Moisture (IM) banana

5.3.2.1 Effect of fruit to osmotic solution and duration of immersion on the total soluble solids (°Brix) of Intermediate Moisture (IM) banana

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the total soluble solids (TSS) of IM banana was investigated (Figure 15). Total soluble solids (TSS) of IM banana increased as the fruit to osmotic solution ratio was increased. However, a slight decline in TSS was observed when the fruit to osmotic solution was increased beyond 1:3. The TSS of IM banana increased irrespective of the duration of immersion, but a slight decline in TSS was observed at eight hours of immersion.

The increase in TSS of IM banana may be attributed to the sugar penetration when the fruit pieces are dipped into the hypertonic solution which reduces with increase in dip period when equilibrium between cellular fluid and osmotic solution is approached (Sagar and Suresh Kumar, 2009). Therefore, the fruit-to-osmotic-solution ratio of 1:3 and the four-hour immersion time were discovered to be a sustainable use of the osmotic agent used and the processing time for optimum TSS of IM banana.

Similarly, Togrul and Ispir (2008) discovered that a fruit-to-osmotic solution ratio greater than 1:4 decreased the total soluble solids of osmodehydrated apricot, whereas Tortoe (2010) discovered that the first three hours provide the greatest improvements in fruit pieces and thus recommend short processing time during osmodehydration. Aggarwal and Kaur (2014) associated moisture loss with a high total soluble solid content of 70°Brix on osmo-air dried kinnow mandarin, whereas Kudri *et al.* (2022) reported a TSS of muskmelon slices between 43-58°Brix, which was attributed to absorbed solutes from hypertonic solution during osmodehydration, which was consistent with the current study.

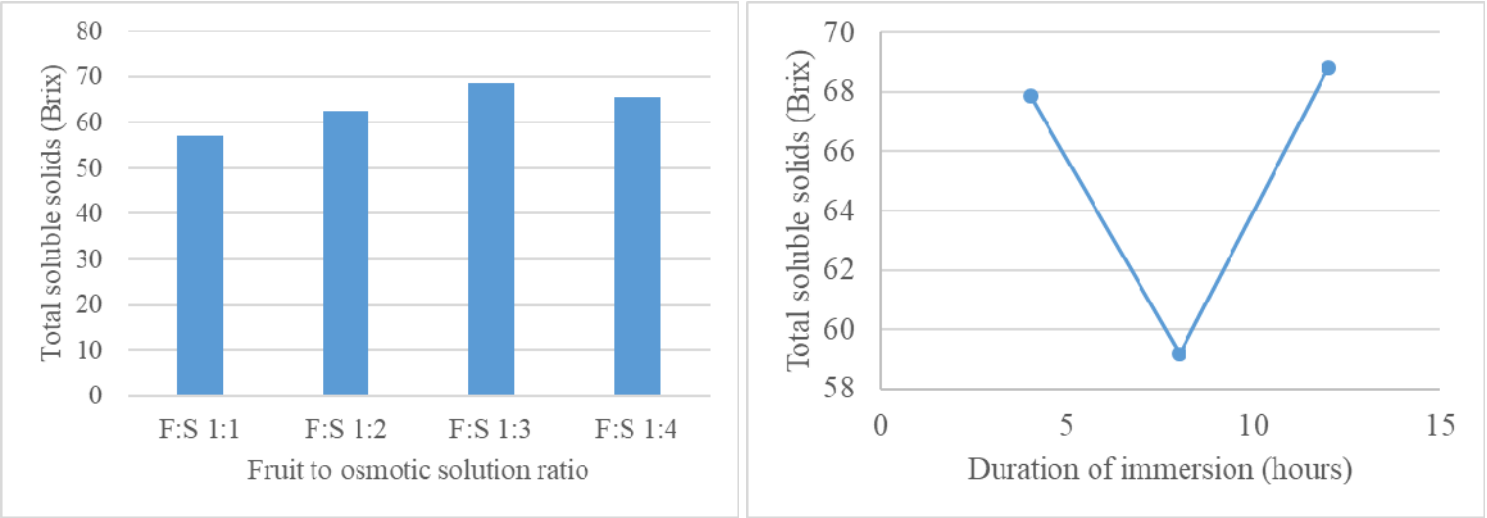


Figure 15: Effect of fruit: osmotic solution ratio and duration of immersion on the total soluble solids (°Brix) of intermediate moisture banana

5.3.2.2 Effect of fruit to osmotic solution and duration of immersion on the titratable acidity (%) of Intermediate Moisture (IM) banana

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the titratable acidity of IM banana was investigated (Figure 16). Increasing the fruit to osmotic solution ratio decreased the titratable acidity of IM banana. However, beyond a fruit to osmotic solution ratio of 1:3, the titratable acidity of IM banana increased. The titratable acidity of the IM banana decreased as immersion time increased. However, after eight hours of immersion, there was a slight increase in titratable acidity.

The influx of osmotic agent into the banana fruit slices during osmodehydration which accumulates the organic acids may be attributed to reduced titratable acidity of IM banana with increasing fruit to osmotic solution ratio while long immersion time leaches out the organic acids from the fruit into the hypertonic solution (Ahmed *et al.* 2016). To reduce organic acid leaching into the osmotic solution, a fruit-to-osmotic-solution ratio of 1:3 and an immersion time of no more than eight hours are sufficient to obtain a lower acidic fruit, which is a desirable characteristic of IM banana.

Phisut *et al.* (2013) observed a decrease in titratable acidity during the osmotic dehydration process on osmodried cantaloupe slices, ranging between 0.07 and 0.12 per cent. Renu *et al.* (2012) found an increase in the natural solutes of osmodried banana slices as the fruit to osmostic solution ratio increased, whereas Delgado *et al.* (2017) found a decrease in malic acid from 202 to 156 mg/100g as the osmotic time increased when a fruit to osmotic solution ratio of 1:10 was maintained during the osmodehydration pretreatment of chestnut slices.

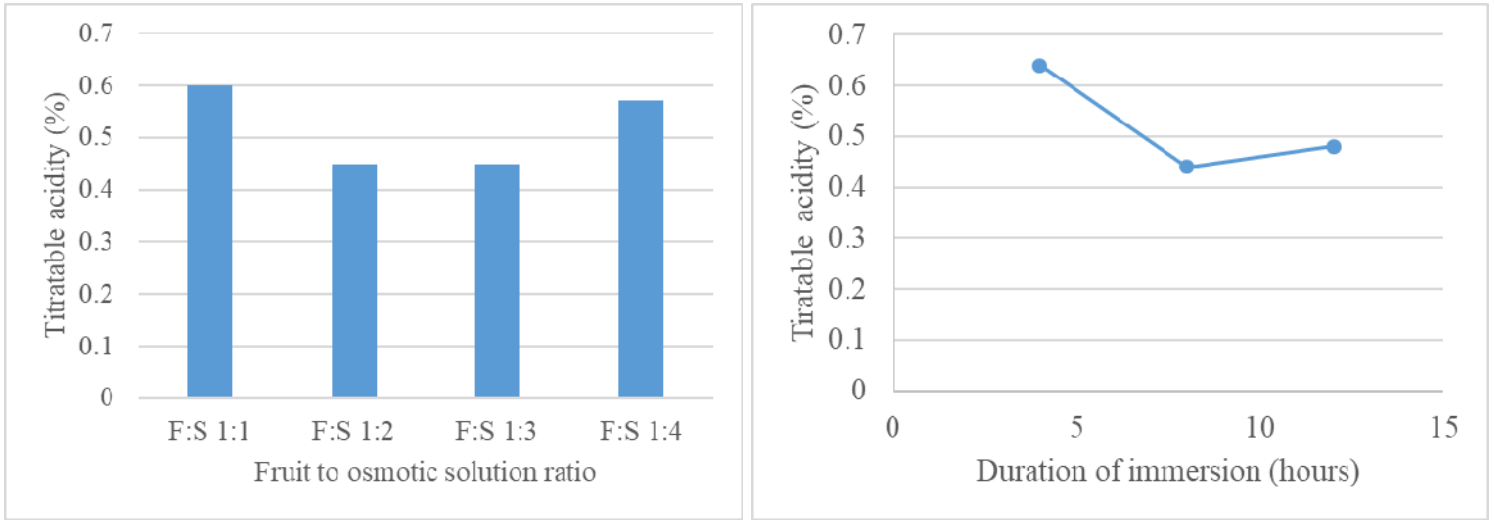


Figure 16: Effect of fruit: osmotic solution ratio and duration of immersion on the titratable acidity (%) of intermediate moisture banana

5.3.2.3 Effect of fruit to osmotic solution and duration of immersion on the total ash (%) of Intermediate Moisture (IM) banana

The total ash of IM bananas increased rapidly as the fruit to solution ratio increased, but it slowed once the fruit to osmotic solution ratio reached 1:3, whereas increasing immersion time resulted in a decrease in ash content (Figure 17). The decrease in total ash with increasing duration of immersion is due to nutrient degradation, which occurs due to the nutrients' high sensitivity to factors such as oxidation, pH, water, temperature, etc. There findings reveal that fruit to osmotic solution ratio exceeding 1:2 and a shorter immersion time are sufficient to retain maximum nutrients in IM banana.

Coimbra *et al.* (2022) measured the total ash retention of osmodehydrated sapota fruit at 0.45g/100g when the fruit to osmotic solution ratio was 1:20 and the immersion time was 165 minutes, which was comparable to 0.48 g/100g of fresh sapota fruit, demonstrating the retention of nutrients with a shorter immersion time. When the fruit to solution ratio was 1:3 and the immersion time was 24 hours, Priyanka *et al.* (2018) reported a lower total ash content of 1.49 per cent of osmodried banana. Singh *et al.* (2015) obtained a high ash content of 13.88–23.25 per cent on osmoair dehydrated papaya slices with a 1:4 fruit-to-solution ratio and a one-hour immersion time to avoid solution dilution, which was consistent with the current study's findings.

After observing total ash degradation with increasing fruit to osmotic solution and long immersion time of osmoair dried chayote squash cubes, Kumar *et al.* (2017) recommended fruit to osmotic solution 1:1 and 186.56 minutes of immersion time. Idah and Obajemihi (2014) reported a decrease in ash content from 2.79 to 2.38 percent with increased dehydration time and recommended a two-hour osmotic immersion and a fruit-to-osmotic solution ratio of 1:5 for nutrient retention in osmoair dried tomato slices.

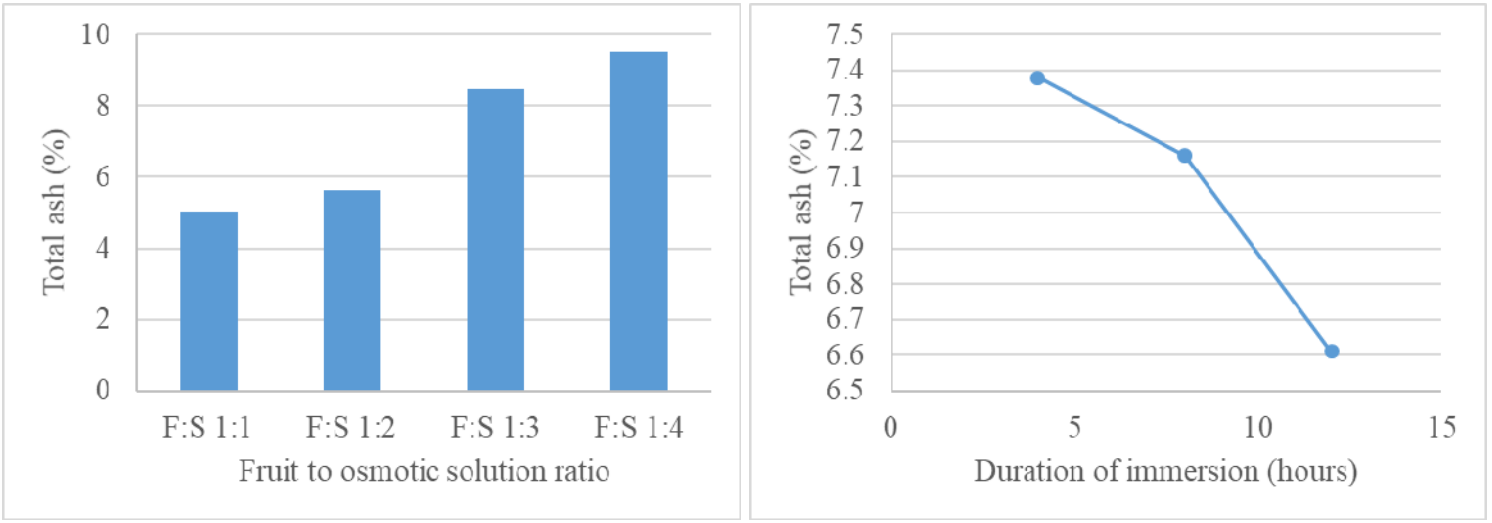


Figure 17: Effect of fruit: osmotic solution ratio and duration of immersion on the total ash (%) of intermediate moisture banana

5.3.2.4 Effect of fruit to osmotic solution and duration of immersion on the pH of Intermediate Moisture (IM) banana

The effect of fruit to osmotic solution and duration of immersion on the pH of Intermediate Moisture (IM) banana was studied (Figure 18). No significant effect was observed on the pH of IM banana when fruit to osmotic solution was increased, however, higher pH of IM banana was observed with fruit to osmotic solution ratio between 1:2 and 1:3. The pH stability of IM banana with increasing fruit to osmotic solution could be attributed to an acidulant (0.5 percent ascorbic acid) present in the osmotic solution that stabilizes the fruit's acid levels. The leaching of organic acids from the fruit cells into the osmotic solution and the degradation of the acidulant (0.5 percent ascorbic acid) of the osmotic agent over time due to its instable property in the presence of water may be responsible for the increase in pH of IM banana with increasing immersion time.

The most important factor causing pH changes in the IM banana was discovered to be the duration of immersion. As a result, shorter osmodehydration times were discovered to be sufficient for the IM banana's acidic, fruity nature. Similarly, Ganachari *et al.* (2020) on osmodried aonla reported a loss of acidic nature with prolonged osmodehydration and a fruit-to-syrup ratio of 1:3, while Jariyawaranugoon (2015) on osmotically dehydrated banana slices reported pH values of 4.4 to 4.6 when immersion time was four hours and the fruit-to-osmotic solution ratio was 1:2. Peiro *et al.* (2006) reported a stabilized pH after the third cycle of osmodehydration on grapefruit slices, with a pH value of 3.2, comparable to that IM banana in the present study.

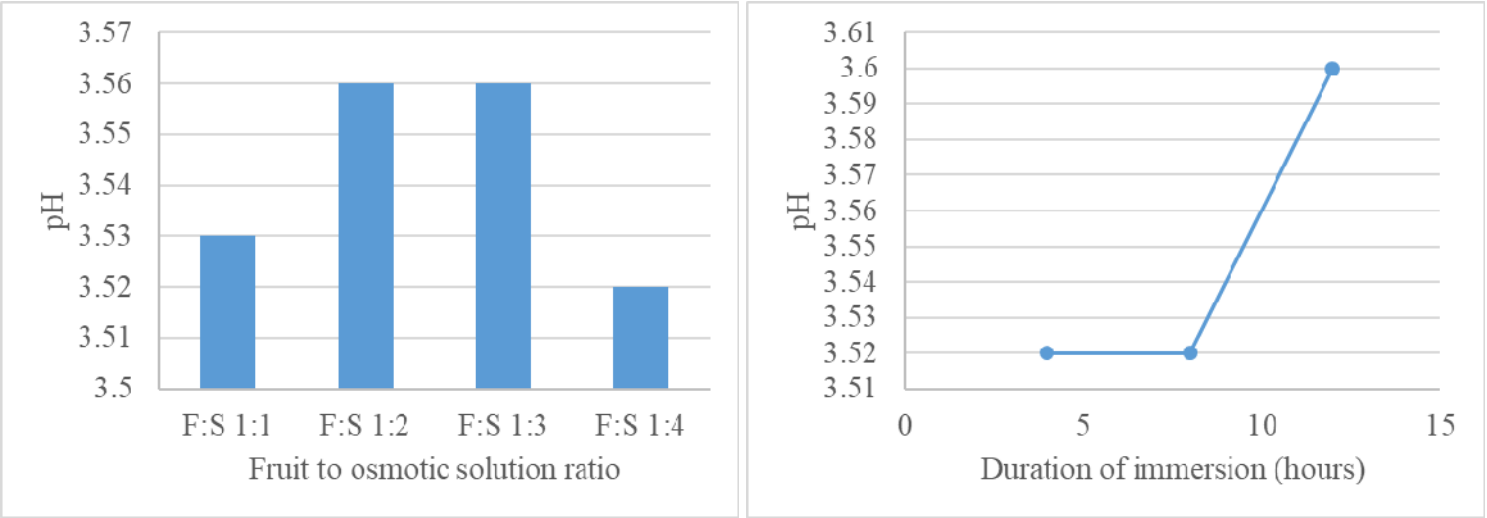


Figure 18: Effect of fruit: osmotic solution ratio and duration of immersion on the pH of intermediate moisture banana

5.3.2.4 Effect of fruit to osmotic solution and duration of immersion on the sugar content (reducing sugar, non reducing sugar, total sugar) of Intermediate Moisture (IM) banana

The effect of fruit to osmotic solution and duration of immersion on the sugars of Intermediate Moisture (IM) banana was studied (Figures 19, 20, and 21). There was no particular trend in the reducing sugars of IM banana with increasing fruit to osmotic solution ratio and duration of immersion. However, highest (13.44 %) mean for reducing sugars was recorded when fruit to osmotic solution ratio was at 1:3 while an increase in the duration of immersion to twelve hours recorded highest (15.12 %) mean for reducing sugars. The higher reducing sugars of IM banana with a fruit-to-osmotic solution ratio of 1:3 and a 12 hour immersion time could be attributed to sugar diffusion from the osmotic solution into the fruit cells via the existing pores and fruit spaces.

The non-reducing sugars of IM banana increased as the fruit to osmotic solution ratio increased, but after a fruit to osmotic solution ratio of 1:3, the non-reducing sugar of IM banana began to decline slowly. The slow decline in non-reducing sugar with increasing fruit to osmotic solution ratio could be attributed to the formation of a barrier with increased osmotic solution, which limits the entry of osmotic solution into the fruit cells during IM banana osmotic pretreatment. The non-reducing sugar decreased as immersion time increased, possibly due to the hydrolysis of sucrose into fructose and glucose over time in the presence of an acidic medium.

The total sugar content of IM banana increased as the fruit-osmotic solution ratio increased, but beyond a fruit-osmotic solution ratio of 1:3, the total sugar decreased. The total sugar of the IM banana was low after eight hours of osmotic time, after which there was a slight increase in total sugar. As a result, the current study reveals that a fruit to osmotic solution ratio of 1:3 and an immersion time of not more than 8 hours are required to produce an IM banana with a desirable sugar profile.

Kowalska *et al.* (2019) discovered high total sugars of 45 and 50 per cent in osmodried apple slices when the solution/fruit mass ratio was 4:1 during the development of osmoair dried apple slices. Phisut *et al.* (2013) reported comparable sugar values of 44.57 and 14.19 per cent for total and non-reducing sugars, respectively on osmo-dried cantaloupe slices with a fruit to osmotic solution ratio of 1:3 and short osmodehydration. Devic *et al.* (2010) used a high fruit to osmotic solution ratio of 1:20 and an osmotic solution time of no more than 180 minutes to achieve a 16-fold increase in total sugars of osmodried apple slices.The present study's IM banana was created with natural sweeteners, and the total sugars were found to be low, ranging between 13.97 and 39.13 per cent, indicating that the IM banana is a low glycemic index snack that can be incorporated into the diet as a healthy snack.

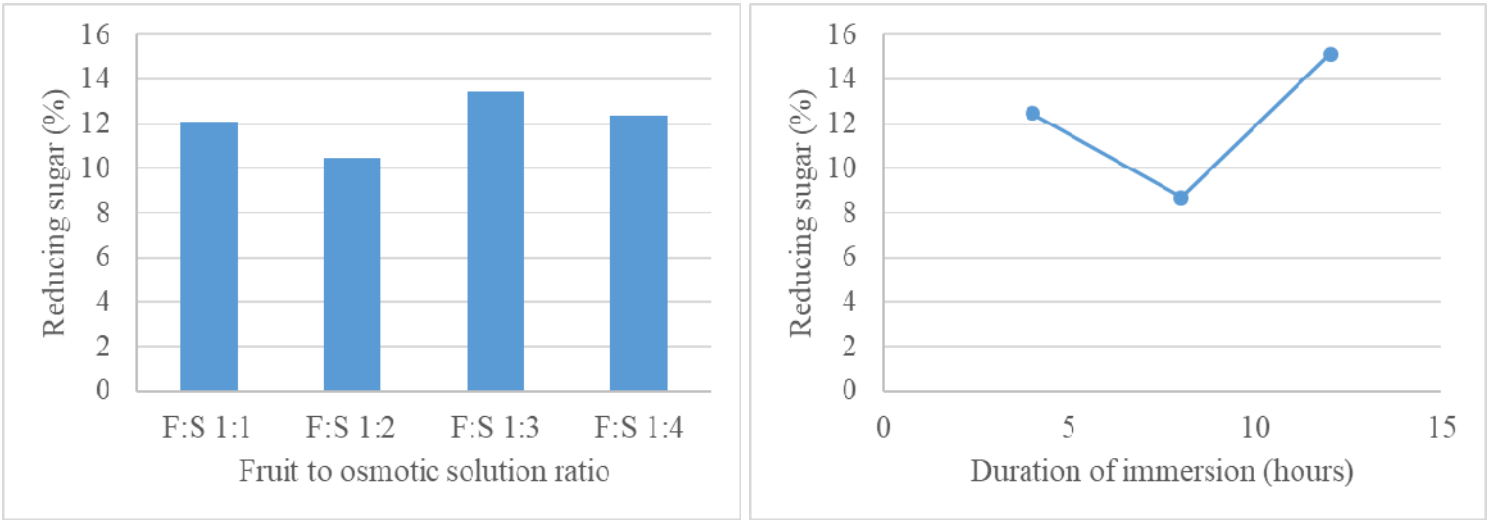


Figure 19: Effect of fruit: osmotic solution ratio and duration of immersion on the reducing sugars (%) of intermediate moisture banana

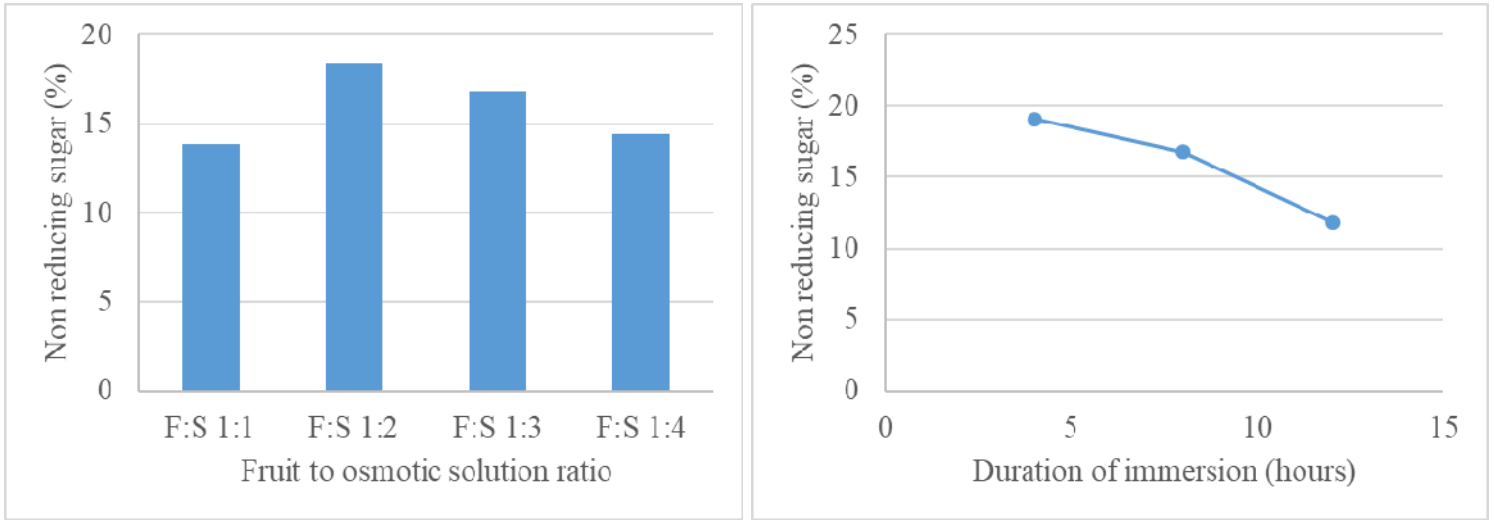


Figure 20: Effect of fruit: osmotic solution ratio and duration of immersion on the non-reducing sugars (%) of intermediate moisture banana

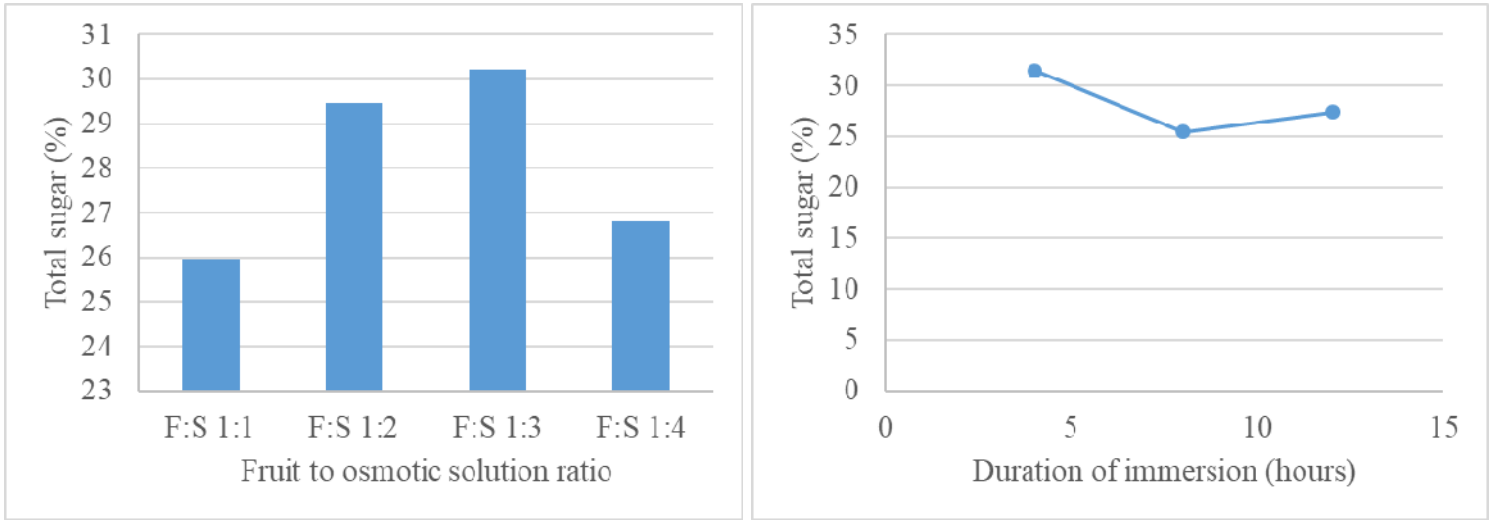


Figure 21: Effect of fruit: osmotic solution ratio and duration of immersion on the total sugars (%) of intermediate moisture banana

5.3.2.4 Effect of fruit to osmotic solution and duration of immersion on vitamin C content (mg/100g) of Intermediate Moisture (IM) banana

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the vitamin C content of IM banana was investigated (Figure 22). The vitamin C content of the IM banana increased as the fruit to osmotic solution ratio increased, but an increase beyond the fruit to osmotic solution of 1:3 resulted in a slight decrease in the vitamin C content of the IM banana. As the duration of immersion increased, so did the loss of vitamin C. The increase in vitamin C with increasing fruit to osmotic solution ratio could be attributed to the incorporation of sorbitol, an important intermediate of vitamin C, and antioxidant (0.5 % ascorbic acid) into the osmotic solution, which when absorbed by IM banana increased the vitamin C content of the dehydrated fruit. External resistance caused by a viscous solution with an increased fruit to osmotic solution ratio could explain the decrease in vitamin C content above the 1:3 fruit to osmotic solution ratio.

Santos and Silva (2000) confirmed the degradation of ascorbic acid with increasing immersion duration, reporting that prolonged osmotic solution increases dilutions of osmotic solution, thereby facilitating the reaction of oxidation and, consequently, vitamin C degradation. Islam *et al.* (2019) reported a vitamin C content range of 17.44 to 36.56 mg/100g in osmoair dried papaya slices when the fruit to osmotic solution ratio was 1:4 and four immersion durations, which was comparable to the current study's findings.

Jariyawaranugoon (2015) discovered a decrease in ascorbic acid as drying times of osmotically dehydrated banana slices increased up to six hours. They did, however, report the vitamin C content of osmotically dehydrated bananas as 1.65-1.68 mg/100g, which was lower than the current study. After observing a loss of 6 mg/100g vitamin C in the eighth hour of osmotic treatment, Peiro *et al.* (2006) recommended an osmotic time of less than eight hours during the development of osmotically dehydrated grapefruit slices.

A fruit-to-osmotic-solution ratio of 1:3 and a maximum immersion time of four hours were found to be optimal for retaining adequate vitamin C content in IM banana. The product was found to be able to supply 15.54 percent of adults' daily vitamin C requirements, which is important in imparting antioxidant functions (Abobaker *et al.* 2020).

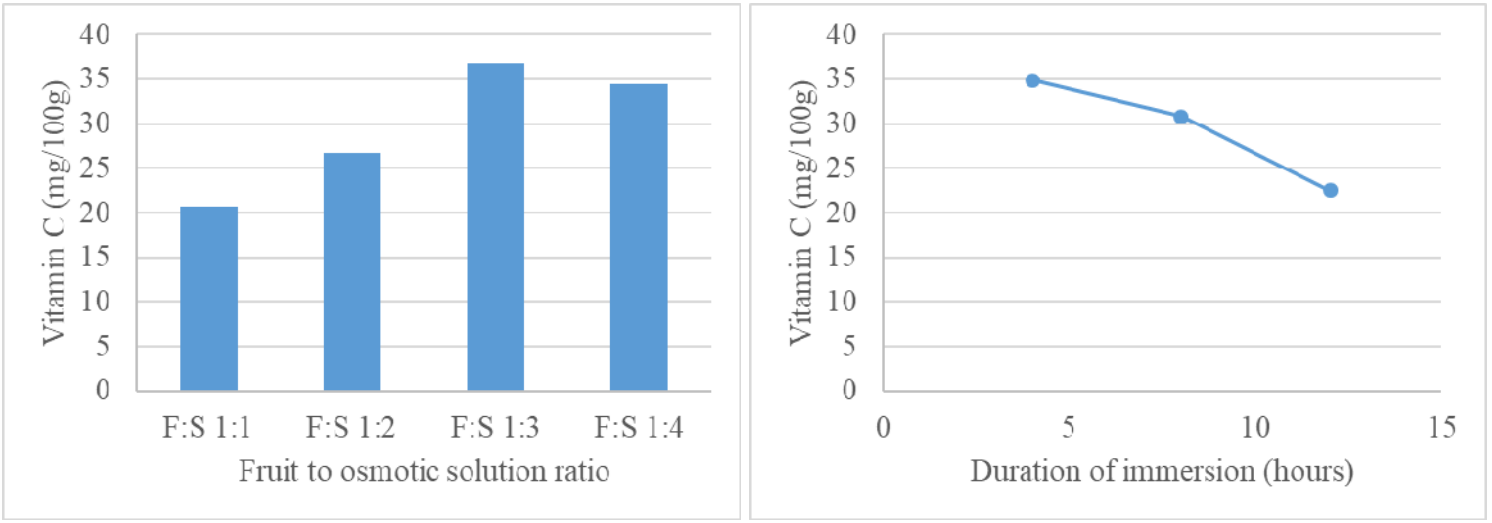


Figure 22: Effect of fruit: osmotic solution ratio and duration of immersion on the vitamin C content (mg/100g) of intermediate moisture banana

5.3.2.5 Effect of fruit to osmotic solution and duration of immersion on total carotenoids (µg/100g) of Intermediate Moisture (IM) banana

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the total carotenoid content of IM banana was investigated (Figure 23). The total carotenoid content of the IM banana increased as the fruit to osmotic solution ratio was increased to 1:3, after which total carotenoids decreased. Increasing duration of immersion reduced total carotenoids of IM banana The high carotenoids content of IM banana could be attributed to blanching of banana slices prior to osmodehydration and high pressure gradient with an increasing fruit to osmotic solution ratio that disrupts cell organelles, allowing carotenoids to be liberated from cell matrices (Landim *et al.* 2016; Chiralt and Talens, 2005).

The decrease in total carotenoid content beyond the fruit to osmotic solution ratio of 1:3 and eight-hour duration of immersion is most likely due dense solute-barrier layer formed at the surface of the food material with a high fruit to osmotic solution ratio, which obstructs osmotic impregnation to the fruit, whereas with prolonged immersion, the carotenoids may have diffused into the osmotic solution, resulting in a reduction in total carotenoid.

Ramakrishnan (2014) obtained a comparatively higher carotenoid content of 1089 and 5463g/100g on osmodehydrated mango at a fruit-to-solution ratio of 1:2 and an osmotic duration of 12 hours. Mishra *et al.* (2015) reported the optimum carotenoid content of intermediate moisture papaya cubes with a four-hour dehydration time, at 1010 and 3720g/100g, which was consistent with the current study.

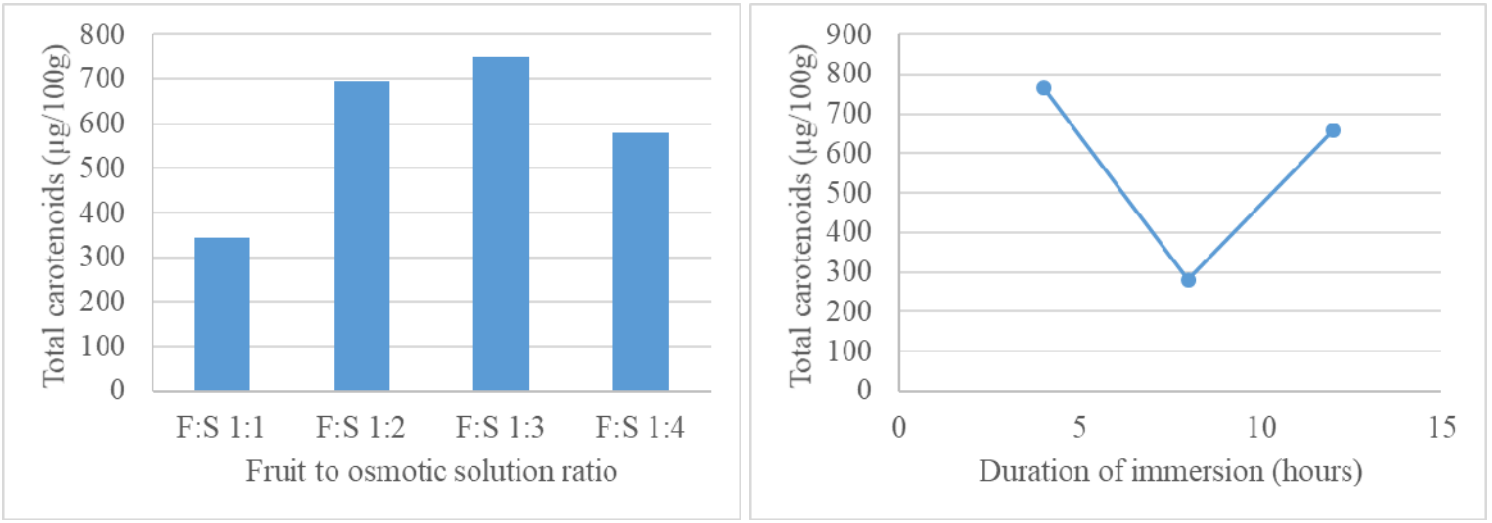


Figure 23: Effect of fruit: osmotic solution ratio and duration of immersion on the total carotenoids content (µg/100g) of intermediate moisture banana

5.3.2.6 Effect of fruit to osmotic solution and duration of immersion on total phenols (mg/100g) of Intermediate Moisture (IM) banana

The total phenol content of the IM banana increased as the fruit to osmotic solution ratio increased, whereas it decreased as the duration of immersion increased (Figure 24). The release of bound phenolic acids or bound phenolic compounds in tissues under high pressures may have caused the increased total phenols of IM banana with increasing fruit to osmotic solution ratio (Rozek *et al.,* 2010). The softening of banana slices with long period of osmotic treatment may have caused phenolic compounds to seep into the osmotic solution, could explain the low total phenol content with increasing duration of immersion (Renu *et al.* 2012).

Nowicka *et al.* (2015) discovered a reduction in total phenol content from 1470.51 mg/100 g to 1157.21 mg/100 g within the first 30 minutes of osmodehydration of sour cherries, while Kucner *et al.* (2013) observed between 14.60 and 20.40 per cent loss of phenolic content in every hour of dehydration of blueberries, which was consistent with the total phenol reduction found with IM banana.

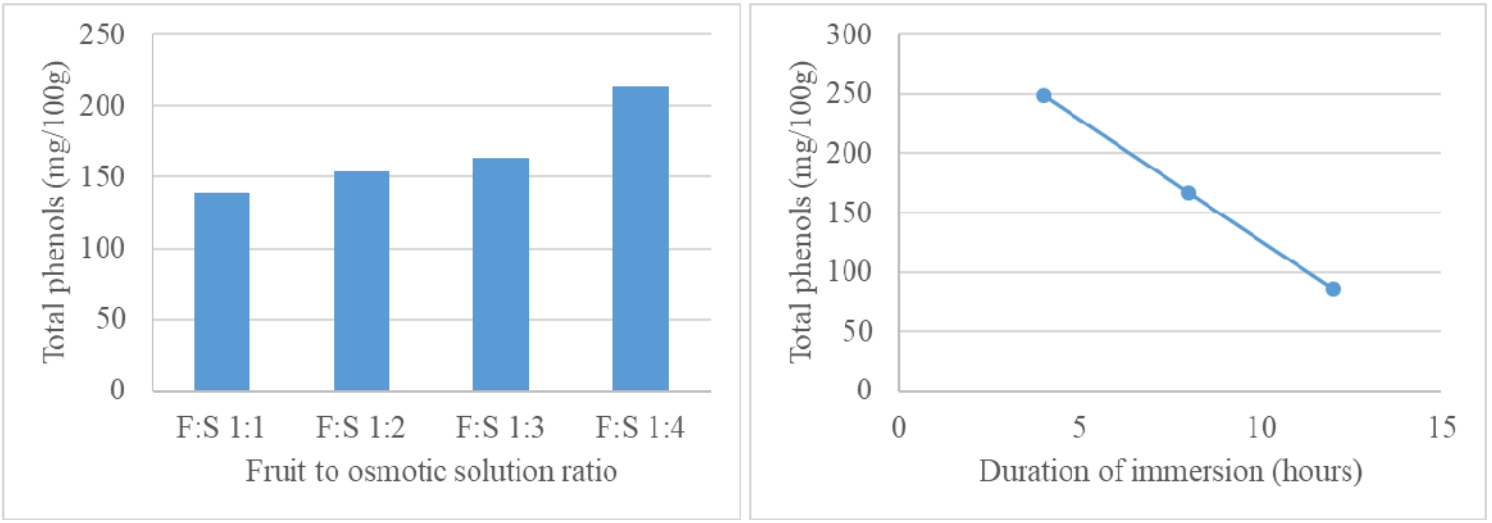


Figure 24: Effect of fruit: osmotic solution ratio and duration of immersion on the total phenol content (mg/100g) of intermediate moisture banana

5.3.2.6 Effect of fruit to osmotic solution and duration of immersion on non enzymatic browning of Intermediate Moisture (IM) banana

The effect of fruit-to-osmotic-solution ratio and duration of immersion on the non enzymatic browning of IM banana was investigated (Figure 25). As the fruit-to-osmotic-solution ratio increased, the non-enzymatic browning (NEB) of IM bananas decreased. However, above a fruit to osmotic solution ratio of 1:3, there was an increase in NEB of IM bananas. The non-enzymatic browning of the IM banana decreased as the immersion time increased.

Devic *et al.* (2010) discovered a decrease in oxygen availability in fully submerged apple slices in osmotic solution, which decreased polyphenol oxidase activity and subsequent browning as the fruit-to-osmotic-solution ratio and soaking time increased, which could explain the current findings' reduced browning. The high NEB of IM bananas subjected to a fruit-to-osmotic-solution ratio greater than 1:3 may, however, are explained by the resumption of browning reactions that occur when food is exposed to glass transition factors such as shrinkage and structural damage (Croguennec, 2016).

Suresh Kumar and Sagar (2016) and Suresh Kumar and Sagar (2008) reported optical density values for NEB of 0.06 and 0.15 on osmovacuum dried guava slices and osmovacuum dried mango slices, respectively, when a fruit to osmotic solution ratio of 1:4 and a six-hour immersion time were used. According to Chauhan *et al.* (2011), a two-hour osmotic dipping of apple slices at a fruit to osmotic solution ratio of 1:2 inhibited browning, with the low colour *a** value responsible for browning reported to be between -1.18 and 5.85.

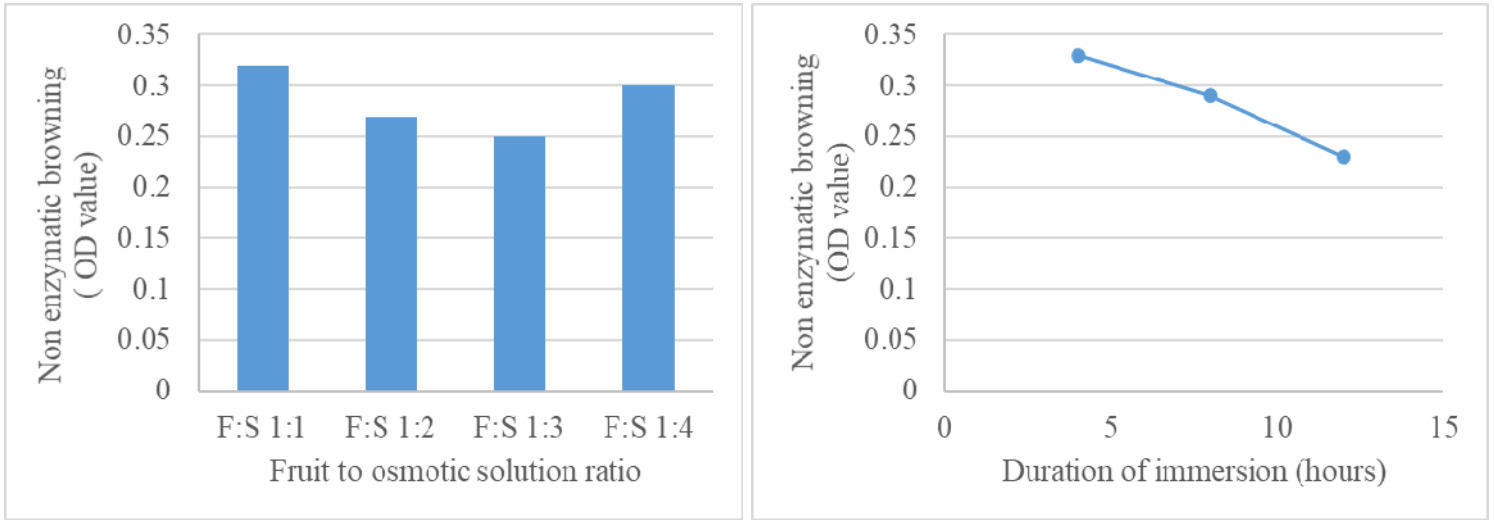


Figure 25: Effect of fruit: osmotic solution ratio and duration of immersion on the non-enzymatic browning (OD value) of intermediate moisture banana

5.3.2.6 Effect of fruit to osmotic solution and duration of immersion on bacteria, *Escherichia coli*, fungi and yeast of Intermediate Moisture (IM) banana

Bacterial, fungi, and yeast population on IM banana slices was observed when the fruit slices were exposed to a fruit-to-osmotic solution ratio of 1:1. Both fungal (0.10×10^{-3} cfu/g) and yeast (3.67×10^{-4} cfu/g) populations were detected on the IM banana after four hours. Bacteria (0.33×10^{-3} cfu/g) population on IM banana slices was detected after eight hours of immersion. The undetected microbial population with increasing fruit to osmotic solution could be attributed to the increased pressure created, which creates an unsuitable environment for microorganism growth (Hull, 2010). Extending the immersion time during IM banana development to eight hours may have resulted in osmotic solution dilution and a reduction in the effectiveness of the antimicrobial (0.25 % KMS) in the osmotic solution, thereby providing a suitable medium for microbial growth.

Although the water activity was reduced to less than 0.93, where most pathogenic bacteria are suppressed, Azoubel *et al.* (2009) reported that one specific pathogenic bacteria, *Staphylococcus aureus*, grows aerobically at a_w values as low as 0.86 and thrives in low acidic foods, which may explain the current study, in which minimal contact of the banana fruit slices with the osmotic solution may have allowed a favourable environment for the growth of bacteria. The current study demonstrates that by increasing the fruit to osmotic solution ratio, which allows banana slices to be fully immersed in osmotic solution, food-borne microbes are reduced. Long immersion times have also been found to promote microbial growth on IM banana.

Gurumeenakshi and Varadharaju (2019) found no microbial contamination for bacteria, yeast, and fungi in osmodried mango slices with a lower fruit slice to osmotic agent ratio of 1:1 and an osmotic immersion time of 18 hours. Dermesonlouoglou *et al.* (2016) discovered an undetectable microbial load (≤10 cfu/g) of yeasts, molds, and aerobic mesophiles in osmodehydrated strawberries with a higher fruit-to-osmotic solution ratio of 1:5 and shorter immersion duration of five hours which was consistent to the present findings. Kaushalya and Weerasooriya (2017) found no microbiological

counts for bacteria, yeast, or molds in osmoair dehydrated cashew apples after an eight-hour immersion time and a fruit-to-syrup ratio of 1:4.

5.3.2.7 Effect of fruit to osmotic solution and duration of immersion on the organoleptic quality of Intermediate Moisture (IM) banana

Increasing the fruit to osmotic solution ratio improved the sensory attributes of the IM banana, but increasing the fruit to osmotic solution ratio to 1:3 resulted in the highest IM banana scores. During osmodehydration pretretment, the sensory properties of the IM banana decreased as the duration of immersion increased.

The high scores of IM banana with a fruit to osmotic solution ratio of 1:3 are attributed to the improvement of banana characteristics in their natural state, including appearance (8.13), colour (7.93), texture (7.53), odour (6.87), taste (8.13), and overall acceptability (8.20). The low scores of IM bananas with osmotic durations greater than four hours could be attributed to undesirable fruit softening caused by pectin degradation in the cell wall and structural collapse of bananas, as reported by Renu *et al*. (2012), who also maintained that IM bananas should have a firm texture.

Suresh Kumar and Sagar (2011) reported high sensory attribute scores due to better solid gain and water loss at high osmotic pressure when the fruit to osmotic solution ratio of pineapple slices was 1:4 and the immersion time was six hours, resulting in the volatile retention of compounds such as furanones and pyranones. Archana and Lekshmi (2019) discovered that a lower fruit-to-osmotic solution ratio of 1:1 and a three-hour immersion time were ideal for the osmodehydration of banana slices while retaining desirable organoleptic properties.

Jariyawaranugoon (2015) discovered that longer dehydration times beyond three hours resulted in reduced sweetness, which they confirmed was the most sensorial attribute that influenced the taste and product preference of osmodried banana slices and was in agreement with the present findings. Keerthishree *et al.* (2017) found that

increasing immersion time of up to 80 minutes in 15mm Nendran banana slices resulted in an increase in colour and textural properties.

5.3.2.8 Effect of fruit to osmotic solution and duration of immersion on the cost of production of Intermediate Moisture (IM) banana

The cost of producing IM bananas increased proportionally to the fruit-to-osmotic-solution ratio and immersion time with a range between Rs. 168.98 and Rs. 378.92. The cost of producing IM bananas was determined by the quantity of raw materials used and the duration of immersion, with fewer quantities of raw materials used and a shorter duration of osmotic pretreatment resulting in a lower cost of production. However, for effective IM banana development, the dehydration process should have maximum water loss and nutrient retention, which was achieved with a high fruit to osmotic solution ratio of 1:3 and a four-hour immersion time which was estimated at Rs. 277.47 (Appendix 6).

On osmodehydration of apricots, Togrul and Ispir (2008) reported that a fruit: solution ratio of no more than 1:10 is the most important factor that can reduce process costs. Similarly, Suresh Kumar and Devi (2011) found that increasing the driving force of an osmotic solution was nearly equal to increasing the final water loss, lowering the dehydration process costs.

5.3.3 Effect of sucrose+sorbitol solution and liquid glucose on quality of Intermediate Moisture (IM) banana

5.3.3.1 Effect of sucrose+sorbitol solution and liquid glucose on the physical quality of Intermediate Moisture (IM) banana

When compared to IM bananas treated with glucose syrup, IM bananas immersed in sucrose+sorbitol osmotic solution showed superior physical qualities such as low moisture (21.31 %), water activity (0.70), ERH (69.83 %), and weight loss (27.17 %). The solid gain of IM banana slices treated with a sucrose+sorbitol solution was higher,

and the color values were better. The superior physical properties of IM banana using sucrose+sorbitol solution can be attributed to the multiple properties that the osmotic agent exhibits from both sucrose and sorbitol agents when compared to glucose syrup alone.

The low hygroscopicity and stability of sorbitol, as well as the osmotic pressure of sucrose, which doubles when inverted, may have resulted in improved physical properties of IM banana, such as lower moisture content, weight gain, water activity, and ERH, as well as higher solids and water loss. As a result, IM banana made from sucrose+sorbitol solution had higher retention of solids and storability than glucose syrup treated samples.

Rodriguez *et al.* (2017) observed better mass transfer kinetics during osmodehydration of plums when osmotic agents with sorbitol were compared to those treated with glucose solutions. Naknean *et al.* (2013) also found that the use of sorbitol-based osmotic agents gave better physical properties such as water loss (42.00 %) and solid gain (16%) of the osmodried cantaloupe slices while Togrul and Ispir (2008) discovered that a sucrose-based osmotic agent mixture was more effective in mass transfer kinetics characteristics such as water loss and solid gain compared to glucose osmotic agent, which was consistent to the findings of the present study.

The low (-0.49) a^* value and high (8.00) b^* value of IM bananas immersed in glucose syrup indicate that they have better colour values than IM banana slices immersed in sucrose+sorbitol solution, which had a^* and b^* values of -0.21 and 3.74, respectively. According to Hull (2010), commercially available glucose syrups can contain up to 400 mg/kg of sulphur dioxide, which prevents proteins from forming colored compounds by blocking the aldehyde reactive sites in the syrup. The antioxidants already present in glucose syrup, as well as the ascorbic acid (0.5 %) added to the osmotic agent during the development of IM banana, may explain why IM banana treated with glucose syrup has better color values. The current study's high L^* values of IM

banana slices treated with sucrose+sorbitol compared to glucose treated samples are consistent with the findings of Chauhan *et al*. (2011) on osmodehydrated apple slices, which they attributed to the preservation of lightness with sucrose impregnation.

5.3.3.2 Effect of sucrose+sorbitol solution and liquid glucose on the biochemical quality of Intermediate Moisture (IM) banana

When compared to IM bananas treated with glucose syrup, intermediate moisture (IM) bananas immersed in sucrose+sorbitol osmotic solution showed superior biochemical quality characters such as total soluble solids, total ash, pH etc. Pattanapa *et al.* (2010) discovered that sucrose has the ability to retain nutrients, stabilize pigment, and prevent oxygen entry for reduced browning during the development of osmo-air dried mandarin slices, which was consistent with the current study on IM banana development, where sucrose-based osmotic agents demonstrated better nutrient retention and less browning than glucose syrup-treated samples.

The browning of glucose syrup may be explained by its low molecular weight, which influences its reactivity for participating in browning reactions when compared to sucrose-containing osmotic solution, which has a higher molecular weight and is less reactive to browning reactions (Croguennec, 2016).

Leite *et al.* (2007) reported that the participation of glucose in the Maillard reaction reduced the ash content of bananas by 25% during dehydration, which explains the high nutrient loss such as total ash and vitamin C of IM bananas treated with glucose syrup compared to sucrose+sorbitol solution.

Cichowska *et al.* (2019) discovered that during osmo-dehydration of apple slices, sorbitol is preferentially converted into fructose, which has low glycemic index of 25 when compared to 100 of pure glucose solution. This preferential conversion of sorbitol to fructose may explain the high total sugar content of IM bananas treated with glucose

syrup compared to fruit pieces pretreated with sucrose+sorbitol solution. IM banana slices treated with sucrose+sorbitol solution may thus be an alternative healthy snack that maintains nutritional quality and sweet flavour while containing fewer calories, making it ideal for consumers seeking a healthy lifestyle free of obesity, which is a global public health concern.

5.3.3.3 Effect of sucrose+sorbitol solution and glucose syrup on the Intermediate Moisture (IM) banana on bacteria, *Eschechia coli*, fungi, and yeast population

Bacteria, *Escherichia coli*, fungi, and yeast did not grow on IM banana fruits immersed in sucrose+sorbitol solution or glucose syrup. No microorganisms were detected in any of the samples immediately following IM banana development. This could be due to the osmotic pressure applied to the IM banana slices during osmodehydration, as well as the addition of antimicrobials, which inhibited microorganism growth during the manufacturing process.

According to Deng *et al*. (2019), steam blanching prior to osmodehydration not only inactivates the enzymes but also destroys the microorganisms, which may explain the absence of tested microorganisms since the banana slices were subjected to 2 minutes prior to osmodehydration during the manufacturing of IM banana.

Kaushalya and Weerasooriya (2017) found no bacterial count, yeast count, or mold count immediately after the development of the osmo-air dehydrated cashew apple, which is consistent with the current study. Similarly, bacteria and fungi were not found on osmodried banana slices prepared by Chavan *et al.* (2010), where zero values were recorded and the product was found to be microbiologically sound.

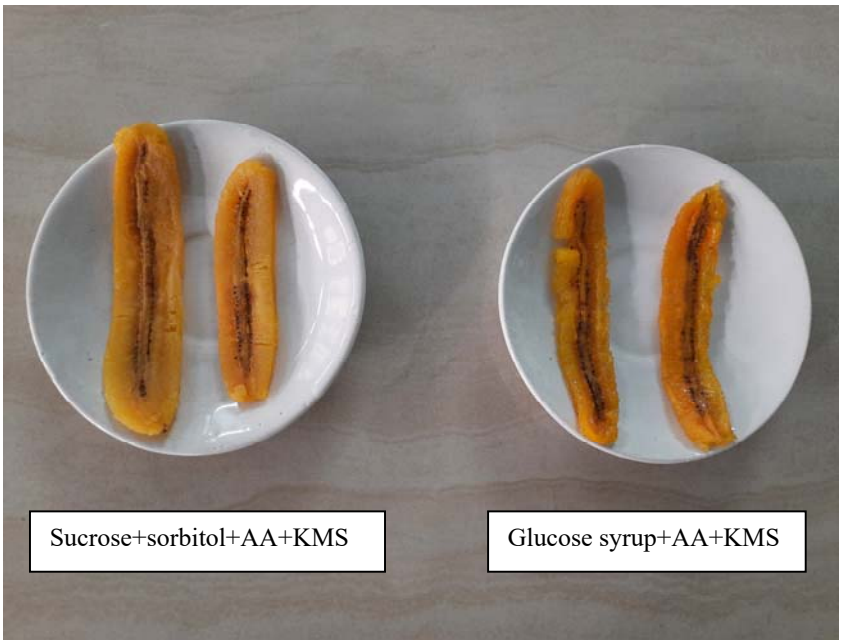


Plate 15. Intermediate Moisture (IM) banana slices treated with sucrose+ sorbitol solution and glucose syrup [AA=0.5% ascorbic acid, KMS=0.25% potassium metabisulphite]

5.3.3.4 Effect of sucrose+sorbitol solution and glucose syrup on the organoleptic characteristics of Intermediate Moisture (IM) banana

Intermediate Moisture (IM) banana immersed in sucrose+sorbitol showed superior sensory attributes in terms of the appearance, colour, flavour, texture, odour, taste, after taste and overall taste compared to IM banana slices immersed in glucose syrup (Figure 26).

Tippanna *et al*. (2019) reported that the improved sensory properties of osmodehydrated pineapple slices are due to solid gain during osmodehydration, which improves the dried product's colour, texture, and sugar acid ratio. This was consistent with the IM banana in the current study, where the IM banana immersed in sucrose+sorbitol solution had a higher solid gain than the fruit samples treated with glucose syrup. Suresh Kumar and Devi (2011) found that osmodehydrated pineapple slices had a high overall acceptability with less enzymatic and oxidative browning, which is consistent with the current findings. Hussain *et al.* (2004) found that osmodehydrated banana slices treated with glucose had lower overall acceptability than those treated with sucrose. According to Landim *et al.* (2016), high solid gain increases cell integrity, resulting in improved fruit texture, whereas a high viscous osmotic agent has the disadvantage of stickiness, which was also observed with IM bananas treated with glucose syrup, resulting in low acceptability (Plate 15).

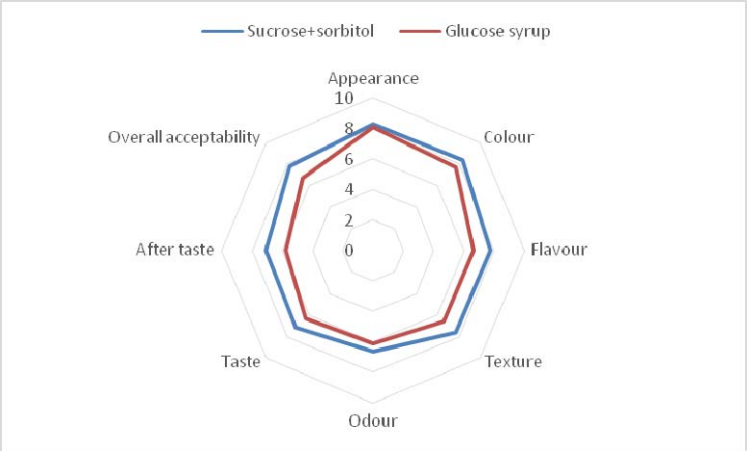


Figure 26. Effect of sucrose+sorbitol solution and glucose syrup on the organoleptic characteristics of Intermediate Moisture (IM) banana

5.3.3.4 Effect of sucrose+sorbitol solution and glucose syrup on the cost of production of Intermediate Moisture (IM) banana

The cost of production of IM banana slices immersed in sucrose+sorbitol was Rs. 277.74 while for samples immersed in glycose syrup was Rs. 269.76 which differed with a margin which was less than 3 per cent indicating an insignificant difference between the costs of production between the two osmotic solutions.

5.4 Study on packaging materials and storage temperature on quality of IM banana

5.4.1 Physical characteristics

5.4.1.1 Study on packaging materials and storage temperature on moisture content (%) of IM banana

The moisture content of intermediate moisture (IM) bananas increased slightly during the first month of storage; thereafter, the moisture content of IM bananas declined throughout storage irrespective of storage condition. However, IM bananas held in polyethylene-laminated aluminium pouches and stored at low temperatures retained their high (28.70 %) moisture content throughout storage. IM bananas held in LDPE (200 gauge) and kept at room temperature showed low (17.29 %) moisture content after three months of storage. High moisture loss of IM bananas held in LDPE (200 gauge) and stored at room temperature could be attributed to evaporation of water in the form of vapour from the product, which accounts for high moisture loss of product stored at ambient conditions. The high permeability of the LPDE package material to vapour may also account for moisture loss within the package, while ambient temperature may have accelerated IM banana moisture losses.

Gomez *et al.* (2022) found a similar decreasing trend in the moisture content of intermediate moisture (IM) pineapple slices, with moisture content ranging from 19–23.09 per cent and low temperatures retaining more moisture than room temperature.Similarly, Ibrahim and Hamzah (2019) reported a decrease from 49.85 per cent to 38.07 percent in the moisture content of date palm fruits during three months of

storage, and they recommended laminated polyethylene containers for reduced moisture loss. Suresh Kumar and Sagar (2016) also observed that coextruded film with nitrogen or aluminium laminated polyethylene and low temperature has minimal moisture losses of osmo-vacuum dehydrated guava slices during storage, which is consistent with the current study.

5.4.1.2 Study on packaging materials and storage temperature on water activity of IM banana

A constant water activity does not only influence the shelf life of a product but it also maintains proper physical and nutritional stability of the product, such as product structure, texture, vitamins etc. The initial water activity (a_w) value of IM bananas was 0.71 and it showed an increasing trend irrespective of storage condition. The IM banana held in LDPE (200 gauge) and kept at ambient conditions showed a high (0.85) a_w compared to the IM banana held in polyethylene laminated aluminium pouches and kept under low conditions where low (0.80) a_w values were recorded after three months of storage. The minimal alterations in the water activity values of IM banana were observed when samples were kept in polyethylene laminated aluminum pouches compared to IM banana kept in LDPE (200 gauge). In terms of the storage conditions, low temperature storage retained a low a_w compared to ambient conditions.

Din *et al.* (2019) produced similar results where intermediate moisture muskmelon chunks kept for three-month storage showed a slight pickup of moisture during storage, resulting in increased water activity from 0.4 to 0.7, which is consistent with the current study. Likewise, Gomez *et al.* (2022) also discovered that intermediate-moisture pineapple stored at room temperature had higher water activity than intermediate-moisture pineapple stored at low temperature, with values ranging between 0.66–0.77 and 0.65–0.66, respectively. Water activity ranging between 0.71 and 0.75 was recorded in intermediate moisture aonla segments by Panwar *et al.* (2013), during six months of storage.

5.4.1.3 Study on packaging materials and storage temperature on colour values (*L, a, b*) of IM banana

Vacuum packaging can prevent the colour degradation of intermediate moisture fruits during storage by preventing the fruits from coming into contact with atmospheric oxygen, lowering respiration rates, which can degrade the quality of dried fruits during storage. The initial *L** (lightness), *a** (redness/browning), and *b** (yellowness) values of IM bananas were 95.48, -0.28, and 5.52, respectively. IM bananas held in polyethylene-laminated aluminium pouches and kept at a low temperature showed minimal changes in *L** (95.78) and *a** (-0.26) values compared to the initially prepared sample, while IM bananas held in LDPE (200 gauge) and kept at ambient conditions showed major changes in *L** (92.72) and *a** (0.42) values.

Lowest (2.27) *b** value of IM banana were observed when temperature conditions were low, while highest (7.70) *b** value was observed at ambient conditions. The high *L** and low *a** values of IM bananas held in polyethylene-laminated aluminium pouches and kept at a low temperature reveal better colour retention while IM bananas held in LDPE (200 gauge) and kept at ambient conditions darken with storage. It was also discovered that low temperature storage reduces the yellowness of IM bananas, whereas ambient conditions increase it.

The difference in colour values *L**, *a**, and *b** of IM bananas in the initially developed product is due to a series of chemical reactions during dehydration and storage related to pigment decomposition, ascorbic acid browning, and non-enzymatic browning Maillard reaction. In comparison to the samples vacuum packed in LDPE (200 gauge), where the package was more permeable, the polyethylene laminated aluminum pouches could have prevented direct contact of IM bananas with atmospheric oxygen, which is required for oxidation of polyphenols and subsequent colour destruction. Low temperature storage may have delayed the deterioration of the IM banana colour by retaining its lightness and inhibiting the formation of o-quinones and other intermediate complexes involved in the formation of brown colour pigments, whereas ambient temperature exacerbated the browning effects.

Gomez *et al.* (2022) reported similar findings during storage of intermediate moisture pineapple slices, colour degradation was found to be higher with ambient temperature storage compared to samples kept at lower temperature. During ambient temperature storage of osmo-dried pineapple cuboids, Saini and Sharma (2016) discovered an increase in browning as indicated by an increase in the value of *a** from 2.02 to 10.93. When osmo-air dried guava slices were kept at room temperature, Duangmal and Khachonsakmetee (2009) observed a decrease in lightness and a slight increase in *a** and *b**, which is consistent with the current study.

5.4.1.4 Study on packaging materials and storage temperature on equilibrium relative humidity (%) of IM banana

The initial equilibrium relative humidity of IM bananas was 71 per cent and it showed an increasing trend irrespective of storage condition. The IM banana held in LDPE (200 gauge) and kept at ambient conditions showed a highest (85.00 %) equilibrium relative humidity compared to the IM banana held in polyethylene laminated aluminium pouches and kept under low conditions where lowest (80.00 %) equilibrium relative humidity was recorded after three months of storage.

The high permeability of the IM banana held in LDPE (200 gauge) and kept at room temperature may have favoured moisture condensation, allowing the IM banana to pick up moisture from the surrounding environment and increase its ERH compared to samples packed in polyethylene laminated aluminium pouches and kept at a low temperature (Saraswathy *et al.*2019). Therefore, conditions where IM banana is held in LDPE (200 gauge) and kept at room temperature are not ideal since they may promote microbial growth and decay of the product.

Suresh Kumar and Sagar (2016) reported a relative humidity of 60 per cent to be ideal for longer storage of osmo vacuum dehydrated guava slices which was lower than those observed in the present study. Similarly, Rai *et al.* (2004) observed an increase in ERH during storage from 11.1 to 79.61 per cent, causing deterioration of osmotically dehydrated papaya cubes where mould growth was observed. Sharma *et al.* (2000) also

reported that laminated pouches retained ERH stability when stored at room temperature compared to polyethylene pouches and glass jars, with the product becoming susceptible to mould growth when relative humidity exceeded 80 per cent.

5.4.1.5 Study on packaging materials and storage temperature on critical moisture content of IM banana

Critical moisture content of dried food products occurs when moisture is picked up by a sample that was initially attractive and crispy in texture and transforms into a dark, soft, and mouldy product as relative humidity rises. The isotherm relationship was determined from the data collected and followed the sigmoid pattern (Figure 27). The isotherm study of IM banana shows a danger point where the product starts to show a slight change in colour when the relative humidity was 80 per cent with a moisture content of 32.00 per cent, while a severely affected product was when the relative humidity was at 89.60 per cent with a moisture content of 39.20 per cent.

Suresh Kumar and Sagar (2016) attributed the colour changes and collapse of tissues of osmo-vacuum dried guava which facilitated fungal growth to the product's moisture pick-up, which was similarly observed with the present study where high moisture and relative humidity accelerated the product’s deterioration. However, they reported lower critical moisture point of osmo-vacuum dried guava of 16.60 per cent and relative humidity 80 per cent. According to Yan *et al*. (2008), the critical moisture content of intermediate moisture bananas stored at 40 ^{o}C in airtight containers has thresholds for moisture content and relative humidity of 13.5 per cent and 59 per cent, respectively, which is lower than in the current study. The differences between Yan *et al.* (2008) and the current study could be attributed to different storage temperatures and pretreatments. They developed IM bananas that received partial dehydration without osmotic dehydration pretreatment, while for the present study, osmodehydration followed by vacuum oven dehydration was used to lower the water activities to desired levels.

Rai *et al*. (2004) found that the critical moisture content of papaya cheese was 21.4 and the relative humidity was 79.60 per cent after 34 days of storage, which was

consistent with our findings. Sharma *et al*. (2000) attributed the accelerated browning of polyethylene packed osmodried apricot slices to the oxidation of ascorbic acid to dehydro ascorbic acid and a non-enzymatic browning reaction. They reported that after 19 days of storage of osmoair dried apricot slices at a temperature of 25 ^{o}C, the critical moisture point of 12.5 per cent and humidity of 60 per cent were reached, which was in agreement with our findings.

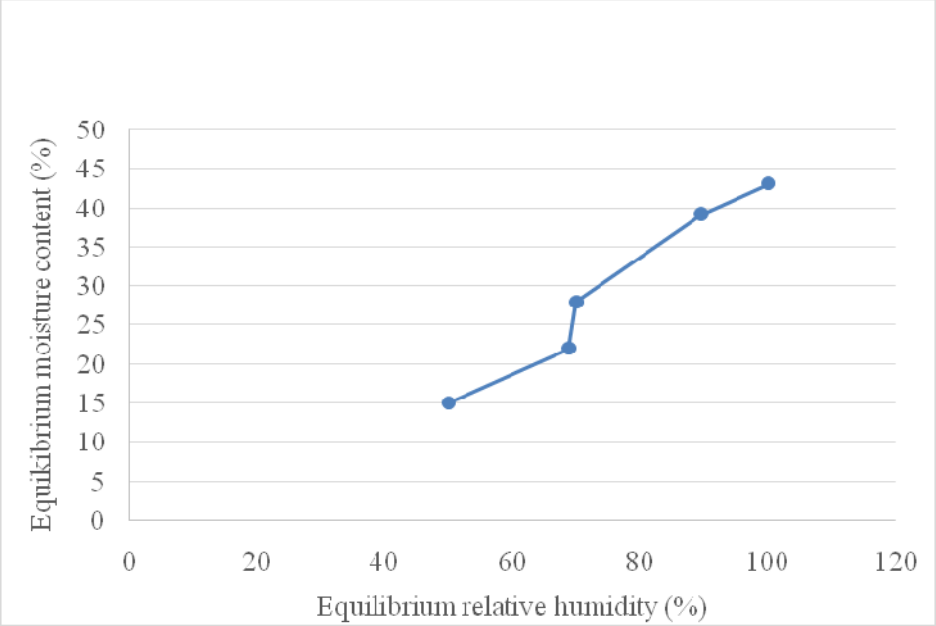


Figure 27. Pattern of equilibrium relative humidity (%) on IM banana

5.4.2 Study on packaging materials and storage temperature on the biochemical characteristics of IM banana

5.4.2.1 Effect of package material and temperature on total soluble solids of IM banana

The presence of high total soluble solids (TSS) in fruit products is directly related to sweetness, which the majority of consumers prefer. TSS decreased during storage regardless of package material or temperature. The initial TSS of IM banana was 69.50 ^{o}Brix, which declined during storage irrespective of package material and storage temperature. After three months of storage, IM banana stored in LDPE (200 gauge)

pouches at low temperature had the lowest (40.67 ºBrix), whereas IM banana stored in polyethylene laminated aluminium pouches at ambient temperature retained the highest (69.00 ºBrix) TSS that was comparable to the initially prepared sample. The present study reveals that high retention of TSS during storage of IM bananas was obtained when samples were kept in polyethylene laminated aluminium pouches and kept at ambient conditions.

The high TSS reduction of IM bananas vacuum packaged in LDPE (200 gauge) and stored at low temperature may be attributed to the permeability of the package material and the hygroscopic nature of IM bananas in cool storage, which may have allowed moisture across the wall of the package material and led to sweetness dilution when compared to IM bananas vacuum packaged in polyethylene laminated aluminum and stored at ambient temperature (Saraswathy *et al.,* 2019).

Similarly, to the data pertaining to the storage stability of IM bananas after three months of storage, Din *et al.* (2019) revealed a TSS decrease from 56.53 ºBrix to 53.28 ºBrix of intermediate moisture musk melon chunks packaged in high density polyethylene bags and stored at ambient temperatures. Atri *et al.* (2016) also reported a total soluble solid reduction from 46.8 ºBrix to 45.5 ºBrix during six months of ambient temperature storage in intermediate moisture papaya. Sharma *et al*. (2000) discovered that osmoair dried apricots packed in laminated (200 gauge) pouches retained more total soluble solids than samples packed in polyethylene (150 gauge) pouches during storage, which was consistent with the current study.

5.4.2.2 Effect of package material and temperature on titratable acidity (%) of IM banana

Titratable acidity is essential for all fruits' shelf life and inhibits the growth of microorganisms in foods. The titratable acidity of freshly prepared IM banana was 0.62 per cent, which declined to 0.54 per cent during storage with IM banana vacuum packed in LDPE (200 gauge) and kept at ambient temperature. IM bananas held in polyethylene laminated aluminium pouches and kept at low temperature showed a slight increase in the

titratable acidity from 0.62 to 0.63 per cent during the first month of storage, but it remained stable throughout the remaining months of storage.

During the storage of dehydrated fruits, acids are used for the hydrolysis of polysaccharides and non-reducing sugars into hexose sugars, which may explain the decrease in titratable acidity of IM bananas (Suresh Kumar and Sagar, 2016).On the other hand, polyethylene laminated aluminium pouches may have reduced the rate of metabolic and enzyme-catalyzed deterioration of IM bananas through oxygen exclusion during storage and stabilised the titratable acidity (Saraswathy *et al.* 2019; Sharma *et al*. 2000).

Similarly, Gomez *et al.* (2022) observed the steady decline of acidity of intermediate moisture pineapple slices over a three-month storage period, with the highest acidity of 1.03 per cent retained at low temperatures and in polyethylene laminated aluminium pouches. Alajil *et al.* (2020) discovered a decrease in the titratable acidity of osmodehydrated apricots due to moisture gain and organic acid decomposition during 6 months of storage from 0.33 to 0.22 per cent, which was more retained in ALPE and HDPE pouches than shrink wrapping. Priyanka *et al.* (2018) found that osmo-solar dried banana figs packed in aluminium pouches had a more stable acidity than samples stored in polypropylene pouches over a six-month period. The values reported in this study were also found to be consistent with those reported in osmodried mango slices by Gurumeenakshi and Varadharaju (2019).

5.4.2.3 Effect of package material and temperature on total ash (%) of IM banana

Dehydration helps to preserve food by extending its shelf life. However, minimally processed foods continue to perform metabolic activities such as nutritional losses during storage, albeit at a slower rate, which can eventually reduce food quality. The nutritional status of IM bananas, represented by the ash content, declined with storage irrespective of package material and storage temperature, from 8.12 per cent to a range of 5.72 and 7.33 per cent. IM bananas held in polyethylene laminated aluminium pouches and kept at a low temperature retained more total ash content than when IM bananas were held in LDPE (200 gauge) and kept at ambient conditions.

The protective role against total ash degradation of IM banana held in polyethylene laminated aluminum pouches and kept at a low temperature compared to IM banana held in LDPE (200 gauge) and kept at ambient temperature may be attributed to the impermeable property of the laminate package material against the ingress of gases and vapour, while low temperatures reduce the metabolic reactions that can lead to nutritional loss of IM banana (Saraswathy *et al.* 2019). As a result, vacuum packaging of IM bananas held in polyethylene-laminated aluminum pouches and kept at low temperature are found to be ideal conditions for minimizing total ash degradation of the dehydrated product.

Chaudhary *et al.* (2020) observed a decreasing trend in the total ash content of osmoair dried pineapple slices packed in HDPE bags after 90 days of storage, while Kumar *et al.* (2016) also reported total ash degradation in bittergourd chips packed in polypropylene bags (200 gauge) with the advancement of three months of storage, which was consistent with the current study.

5.4.2.4 Effect of package material and temperature on pH of IM banana

A decreasing trend on the pH of IM banana was observed irrespective of packaging material and temperature condition. Intermediate Moisture (IM) banana kept in LDPE (200 gauge) showed a rapid decreasing trend in pH which from 3.57 to range of between 3.36 and 3.45 during storage. On the other hand, IM banana kept in polyethylene laminated aluminum pouches maintained constant pH throughout storage which ranged between 3.54 and 3.57 by the end of three month storage. The temperature conditions had no effect on the pH of IM banana, but samples kept at room temperature had a lower pH than those kept at low temperature. The use of acids on non-reducing sugars and non-enzymatic browning may account for the decrease in pH of IM banana during storage (Saraswathy *et al.,* 2019; Sharma *et al*., 2000).

Malik *et al.* (2022) discovered decreasing pH on lemon cordial beverage during a three month storage from 2.46 to 2.35, which they claimed was due to the accumulation of lactic acid and acetic acid by microbes with storage. Falah *et al.* (2015) linked the

decrease in pH during storage to the permeability of the package material and high temperatures, which promotes the use of organic acids and increases respiration, as well as the senescence of minimally processed melon and papaya. Therefore a drop in pH of IM banana vacuum packaged in LDPE (200 gauge) and kept at ambient temperature may have indicated its susceptibility to a shorter shelf life when compared to samples packaged in polyethylene laminated aluminum pouches and kept at low temperature.

Din *et al.* (2019) reported a slight decrease in pH of intermediate moisture musk melon chunks from 5.19 to 4.98 in response to temperature as in situ acid production in the product. Aggarwal and Kaur (2014) confirmed the effect of package and temperature on the pH of intermediate moisture carrot pulp, reporting pH values of 4.12 in polyethylene pouches at room temperature and lower pH values of 4.10 in laminate pouches under refrigeration conditions. Kamran *et al.* (2008) measured the pH of osmodried mango after six months of storage, which was between 4.0 and 4.10, which was within the range of the current study.

5.4.2.5 Effect of package material and temperature on the reducing sugars (%) of IM banana

The initial reducing sugars of IM banana was 14.55 per cent, which declined during storage irrespective of package material and storage temperature. IM banana held in LDPE (200 gauge) and kept at ambient conditions showed lower (9.29 %) reducing sugars compared to IM banana held in polyethylene laminated aluminium pouches and kept at a low temperature, where higher (15.35 %) reducing sugars were retained.

According to Djaoudene and Louaileche (2016), metabolic activities such as non-enzymatic browning and hydroxymethylfurfural (HMF) are responsible for decreasing the reducing sugar of intermediate moisture products. The permeability of package material and high temperature conditions may have increased respiration rates of IM banana held in LDPE (200 gauge) and kept at ambient conditions, resulting in high metabolic activity and a more rapid decline of reducing sugars.

Suresh Kumar and Sagar (2016) similarly observed high retention of reducing sugars when osmo-vacuum dried guava was packed in coextruded and aluminium laminated films with nitrogen flushing. Kamran *et al.* (2008) reported reducing sugar of 61.14 per cent for osmodried mango slices after six months of storage, while Chavan *et al.* (2010) reported lower reducing sugars of 11.8 per cent for osmodried banana slices packed in polypropylene bags (200 gauge) and stored at room temperature for six months. Ahmed *et al*. (2016) reported reducing sugars in osmoair dried peach slices from 38.08 to 39.38 per cent over 145 days when the sample was packaged in polythene pouches and stored at room temperature, which was consistent with the current study.

5.4.2.6 Effect of package material and temperature on non reducing sugars (%) and total sugars (%) of IM banana

The initial non-reducing sugars and total sugars of IM banana were 25.03 and 39.58 per cent, respectively, and decreased with storage regardless of package material or temperature condition. IM bananas held in polyethylene laminated aluminum pouches and kept at ambient temperature showed lower (3.50 %) retention of non-reducing sugars, while higher (7.97 %) retention of non-reducing sugars was found with IM bananas kept in polyethylene laminated aluminum pouches and kept at a low temperature. Similarly, IM bananas stored in polyethylene laminated aluminum pouches at low temperature retained higher (23.39 %) total sugars, whereas IM bananas stored in LDPE (200 gauge) packages at ambient conditions retained lower (17.08 %) total sugars. The present results show that reducing sugars and total sugars of IM bananas kept in polyethylene-laminated aluminum pouches are well retained, whereas ambient temperature may have accelerated the decomposition of non-reducing sugars into reducing sugars and the subsequent deterioration of total sugars.

The low non-reducing sugars with the progression of storage was reported by Suresh Kumar and Sagar (2016) on osmovacuum dehydrated guava slices when the sample was kept in HPDE (200 gauge), which they attributed to its inversion into reducing sugars. Sharma *et al.* (2000) observed maximum deterioration of total sugars of osmodried apricot slices kept in polyethylene pouches compared to those kept in

laminated pouches and attributed this decline to the utilization of sugars in non-enzymatic browning during storage. Djaoudene and Louaileche (2016) also found that a storage temperature of 35ºC has degrading effects on both the non-reducing and total sugar in commercial orange jam, which was in line with the findings of the current study.

Suresh Kumar and Sagar (2008) observed total sugar content of osmovacuum dried mango in ranges between 77.11 to 79.64 per cent, with higher values retained in samples kept in coextruded film and ALPE (260 gauge) compared to HDPE (200 gauge) packages. Chenlo *et al.* (2010) similarly found a threefold decline in non-reducing sugars of chestnut fruits kept in polyamide/polyethylene compared to samples kept in polyethylene laminated aluminum pouches. However, an increase in non-reducing and total sugars of osmo-air dried apricots during storage regardless of package material was reported by Alajil *et al.* (2020), which contradicts the findings of the current study.

5.4.2.6 Effect of package material and temperature on vitamin C (mg/100g) of IM banana

Vitamin C has been linked to a variety of health benefits, including its ability to act as an antioxidant, anti-carcinogenic, treatment of pneumonia and the management of covid-19 (Abobaker *et al.* 2020). However, ascorbic acid is an unstable compound under certain storage conditions, such as high temperatures and exposure to air and light (Deng *et al.,* 2019). Vitamin C of IM banana declined during storage irrespective of package material and temperature condition. The vitamin C content of the initially prepared IM banana was 48.02 mg/100g, which declined to 6.93 mg/100g in IM banana held in an LDPE (200 gauge) package and kept at ambient conditions. IM bananas held in polyethylene-laminated aluminum pouches and kept at a low temperature retained higher vitamin C content (42.63 mg/100g) during the three-month duration of storage.

The results also reveal that IM bananas held in polyethylene-laminated aluminum pouches retained better vitamin C content compared to LDPE (200 gauge) packages and vitamin C deterioration occurs faster in ambient conditions than at low temperatures. The high ascorbic acid losses of IM banana during storage packaged with LDPE (200 gauge)

and ambient temperature may be attributed to packaging material's permeability to ascorbic acid oxidation and increased rates for metabolic reactions with every 10 ºC increase in temperature (Sharma, 2010).

Suresh Kumar and Sagar (2016) discovered a high vitamin C content of osmovacuum dehydrated guava in the range of 481.4 to 864.5 mg/100g with better retention in packages that prevented oxygen and light exposure, such as coextruded film and aluminium laminated polyethylene pouches, as well as low temperature during a six-month storage period. According to Falah *et al.* (2015), refrigerated storage preserved the ascorbic acid content of melon and papaya slices longer than room temperature storage because higher temperatures favour senescence conditions that accelerate the respiration process and ascorbic acid oxidation to L-dehydroascorbic and L-diketogulonase. Similarly, Paul *et al.* (2014) reported more than 50 per cent decrease in ascorbic acid of osmovacuum dried pineapple slices stored in HDPE after six months, which was consistent with the current study's findings, which showed that more than half of the vitamin C content was lost in IM bananas stored in LDPE (200 gauge) packages. Sharma *et al.* (2000) discovered that after six months of storage, the vitamin C content of osmodried apricots ranged from 8.84 to 11.67 mg/100g, with polyethylene pouches and higher temperatures, degrading faster than laminated pouches and lower temperatures, which is consistent with the current study.

5.4.2.7 Effect of package material and temperature on the total carotenoids (µg/100g) of IM banana

IM banana had initial total carotenoids content of 1492.67 µg/100g which declined to range of 1012.00 and 1338.67 µg/100g. The total carotenoid content of IM banana decreased rapidly when the samples were held in LDPE (200 gauge) and kept at ambient conditions, while IM banana held in polyethylene laminated aluminum pouches and stored at a low temperature showed a low decline in the total carotenoid content. The higher retention of total carotenoids content of IM banana held in polyethylene-laminated aluminum pouches and kept at low temperature may be attributed to lamination barrier of the package material that may have prevented entry of respiratory gases such as oxygen

that promotes enzymatic activity such as peroxidase and lipoxidase reactions, which can lead to pigment degradation and the development of off-flavors during storage (Saraswathy *et al.,* 2019).

Gomez *et al*. (2022) reported total carotenoids in intermediate moisture pineapple slices ranging between 0.22 and 0.81 mg/100g, which were rapidly lost when intermediate moisture pineapple slices were stored at room temperature versus samples kept in the refrigerator, which was consistent with the current findings. The carotenoid content of osmodried mango slices was found to be between 982 and 1580 µg/100 g, compared to the initial amount of 1225 to 1652 µg/100 g, as reported by Gurumeenakshi and Varadharaju (2019). A decline in total carotenoids was similarly reported by Atri *et al.* (2016) on intermediate moisture food products, *viz*. osmotically treated papaya slices and candy during storage with reported mean values of 1190 and 1178 µg/100g while Suresh Kumar *et al.* (2008) observed better retention of the total carotenoids in osmovacuum dehydrated mango slices packaged in coextruded film pouches and kept at low temperature, which was in line with the findings of the present study.

5.4.2.7 Effect of package material and temperature on the total phenols (mg/100g) of IM banana

The total phenol content of IM bananas increased during storage regardless of package material or storage temperature. The total phenol content of IM banana was found to be between 281.00 to 311.67 mg/100g compared to the initial amount of 251.67 mg/100 g. Higher (311.67 mg/100g) total phenols was retained in IM banana held in polyethylene laminated aluminium pouches and kept at low temperatures while the IM banana held in LDPE (200 gauge) and kept at ambient conditions retained lower (281.00 mg/100g) total phenols. The increase in total phenols might be explained by the disintegration of fruit tissue and loss of fruit texture which has been linked with aging and has been found to release phenolic compounds bound in cell membrane/ cell walls (Soto-Hernandez *et al.,* 2017). IM banana held in polyethylene laminated aluminium pouches and low temperature condition may have aided in the retention of these released compounds compared to IM banana held in LDPE (200 gauge) and kept at ambient

temperature. Saraswathy *et al.* (2019) confirmed that LDPE package material is permeable to phenolic and volatile aromatic compounds during storage of dehydrated products, whereas polyethylene laminated aluminum pouches retain them.

Gomez *et al*. (2022) discovered a similar increasing trend of total phenols during storage of intermediate moisture pineapple, with values ranging from 150 to 220 mg/100 g, which they attributed to migration of ascorbic acid and potassium metabisulphite infusion from osmotic solution into the fruit tissue during processing, which aided in the retention of total phenol degradation throughout storage, which is consistent with the current study. According to Zoric *et al.* (2015), the maximum retention of 262.18 mg/100g total phenols in freeze-dried sour cherry was kept in laminated materials and metalized films made of polyethylene and stored at low temperature, which is in agreement with the current study's findings.

5.4.2.7 Effect of package material and temperature on the non enzymatic browning of IM banana

Non-enzymatic browning caused by the Maillard reaction not only reduces nutritional quality but also produces potentially toxic compounds such as melanoidins, carbonyl compounds, and heterocyclic amines, among others, which can cause allergenic reactions (Croguennec, 2016). The optical density of IM bananas, which is an index of browning, increased with storage regardless of package material or storage conditions from the inital amount of 0.12 to a range of 0.17 and 0.86. IM bananas held in LDPE (200 gauge) and kept at ambient temperature had highest (0.86) browning, while lowest (0.12) browning was observed when IM bananas were held in polyethylene laminated aluminium pouches and kept at low temperatures.

According to Saraswathy *et al.* (2019), LDPE has good chemical and water vapour resistance but poor oxygen resistance. As a result, browning when IM banana was held in an LDPE (200 gauge) package could have resulted from the oxidation of phenolases into orthophenolic substances to form the coloured quinone compounds (Croguennec, 2016). Furthermore, browning could also be caused by ascorbic acid

decomposition, which was favoured at room temperature, resulting in the accumulation of furaldehyde and 5-hydroxymethyl-furaldehyde (5-HMF) and subsequent browning colouration of IM bananas (Suresh Kumar and Sagar, 2016; Da Silva *et al.,* 2015).

Suresh Kumar *et al.* (2008) also reported that after six months of storage, non-enzymatic browning on osmo-vacuum dehydrated mango slices increased from 0.15 to a range between 0.33 and 0.50. They also discovered that low temperature storage and laminated packages resulted in less browning of osmo-vacuum dehydrated mango slices when compared to samples packaged in HDPE (200 gauge) and stored at room temperature, which was consistent with the current study. Suresh Kumar and Sagar (2016) found that during six months of storage of osmo-vacuum dehydrated guava slices, non-enzymatic browning increased from 0.06 to 0.08, which was less in coextruded film with nitrogen packages at a low temperature compared to HDPE (200 gauge) and room temperature. Djaoudene and Louaileche (2016) observed a 157 percent increase in 5-HMF from a starting concentration of 1.8 mg/100 g at room temperature and reported that browning is temperature dependent.

5.4.2.8 Effect of package material and temperature on the shelf life (days) of IM banana

The vacuum package is designed to remove air from the package material and keep the environment around the product oxygen-deficient from oxidation that may create off-flavors and slow down the growth of microorganisms that require oxygen to grow. Intermediate moisture (IM) banana like any other dehydrated food product, is physicochemically and biologically active therefore the level of its quality is reduced over time. IM banana held in LDPE (200 gauge) and kept at ambient conditions showed most of physicochemical deterioration as indicated by the aforementioned characteristics such as browning, nutrient degradation etc within one month of storage followed by IM banana held in LDPE (200 gauge) and kept at low temperature (Plate 16). The IM bananas packaged in polyethylene laminated aluminum pouches showed high retention of physico chemical quality throughout the three month storage with the low temperature storage showing a more retained characteristics such as nutrients, colour, less browning

etc. The low physicochemical characteristics with LDPE (200 gauge) package and ambient condition may be due to permeability of the package and accelerated enzymatic and respiratory activity which result in the quality degradation of IM banana.

Chavan *et al.* (2010) reported the shelf life of osmoair dried banana slices packed in polypropylene bags (200 gauge) and stored under ambient condition to have a shelf life up to six months, which was higher the one presented in the current study. Saini and Sharma (2016) observed that when dehydrated pineapple slices were in less contact with oxygen gas in aluminum foil laminated with colourless low density polyethylene (LDPE), the product could be stored up to 18 months which agrees with the present findings where prolonged shelf life was observed in a package that excludes both oxygen and light. Sharma *et al.* (2000) attributed the short shelf life of osmoair dried apricot slices stored at 25 ºC to chemical composition changes, which were reduced when samples were packed in polyethylene pouches versus samples packed in laminated pouches, which is consistent with the current study's findings.

Plate 16. Storage changes in vacuum packaged intermediate moisture bananas [1= polyethylene laminated aluminium pouches+ ambient temperature, 2= LDPE (200 gauge)+ ambient temperature, 3= polyethylene laminated aluminium pouches+low temperature, 4=LDPE (200 gauge)+low temperature]

5.4.2.8 Effect of package material and temperature on the microbiological quality of IM banana

Despite the fact that vacuum packaging limits microorganism access to the product, the microbial population increased with storage in intermediate moisture (IM) banana held in LDPE (200 gauge) with high contamination found in samples kept at ambient temperature followed by low temperature. In the second month of storage, fungal population (0.67×10^{-3} cfu/g) was discovered in intermediate moisture (IM) banana held in LDPE (200 gauge) kept at room temperature, and by the third month of storage, both bacteria (1.00×10^{-5} cfu/g) and yeast (0.33×10^{-4} cfu/g) populations were identified in the sample. During the third month of storage, fungal (0.67×10^{-3} cfu/g) population was detected in IM banana held in LDPE (200 gauge) and kept at a low temperature. Regardless of temperature, none of the micro organisms tested was found on IM banana held in polyethylene laminated aluminum pouches, indicating their safety for consumption throughout storage.

Mitra *et al*. (2015) noticed that with increasing water activities to ranges between 0.85 and 0.86 there was increase in pathogenic microorganisnms of dried banana powder packaged in LDPE pouches at higher temperature condition. They further confirmed that since LDPE pouches and ambient temperature showed the total plate counts more than HDPE pouches at the end of 60 days storage, which indicated that such conditions are not ideal for long term storage period of dried banana powder. Their findings are consistent with the present study where LDPE (200 gauge) package was found to support the survival of microbes for food spoilage with high microbial load was found in higher temperature condition.

A higher microbial load on intermediate moisture pineapple was reported by Gomez *et al.* (2022) who also observed similar microbes of bacteria (2.5×10^{-5} cfu/g) and yeast (15.0×10^{-4} cfu/g) after three months of storage. Suresh Kumar and Sagar (2016) observed a direct relationship between microbial proliferation and an increase in relative

humidity and moisture pick up of osmovacuum dried guava slices, which was also observed in the current study, particularly when IM banana was held in LDPE (200 gauge) and kept at ambient temperature. Ramakrishnan (2014) discovered that the polyethylene (200 gauge) had the highest population of bacteria, yeast, and fungi over a three-month storage period, while the aluminium foil laminated cover had the lowest microbiological proliferation, which is in agreement with the present study.

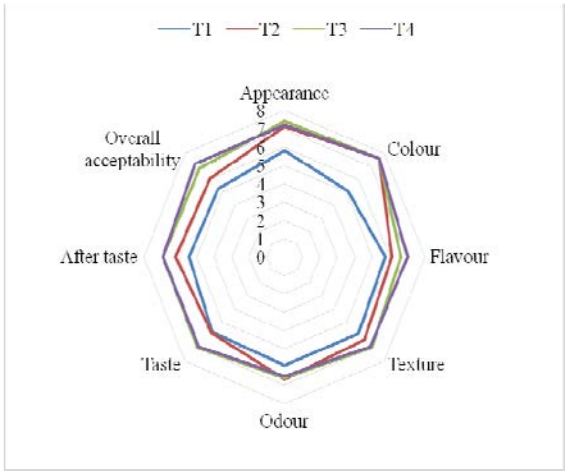
5.4.2.9 Effect of packaging material and temperature on the organoleptic quality of IM banana

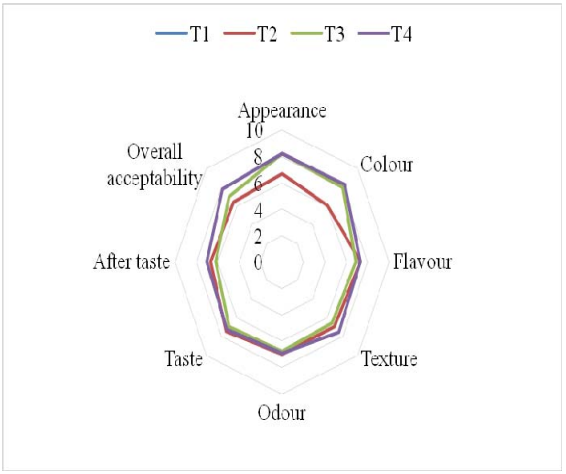
The effect of fruit-to-osmotic-solution ratio and duration of immersion on the organoleptic quality of IM banana was investigated (Figure 28). The sensory scores of samples held in LDPE (200 gauge) and kept at ambient temperature deteriorated over time by losing their colour, texture, and becoming unmarketable by the second month. IM banana products held in polyethylene laminated aluminum pouches received higher sensory scores than samples held in LDPE (200 gauge) with samples kept at low temperature maintaining higher sensory attributes throughout storage.

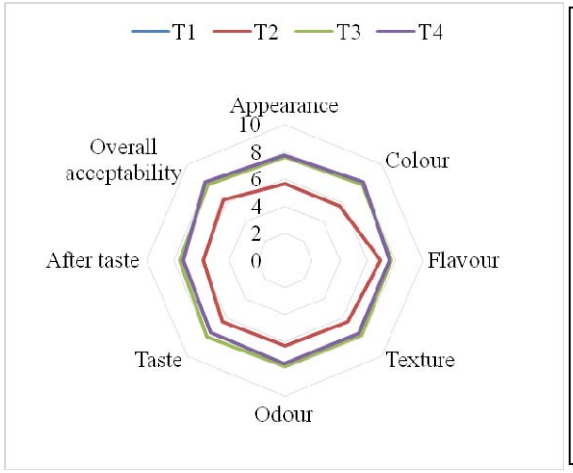
Reduced sensory attributes of IM banana held in LDPE (200 gauge) kept at ambient conditions could be attributed to several physiological activities that double with every 10^{o}C temperature increase, resulting in deterioration of quality attributes such as appearance, colour, flavor, etc. Suresh Kumar and Sagar (2008) attributed the high sensory scores of osmovacuum dried mango slices packed in coextruded films and nitrogen over six-month storage duration to low gas permeability and reduced physiological activity with low temperature, which was consistent with the current study.

Pervin *et al.* (2021) attributed the high overall acceptability of osmodehydrated plums to better retention of sensory attributes, particularly colour, due to the sample's pre-treatment with potassium metabisulphite, whereas Alajil *et al.* (2020) recommended ALPE (250 gauge) for osmodehydrated apricot storage to retain high sensory attributes. Ibrahim and Hamzah (2019) recommended low-density polyethylene and refrigerated

conditions for intermediate moisture date palms for storage duration up to three months for retention of sensory attributes. Gurumeenakshi and Varadharaju (2019) discovered that a brown tint and soggy texture of osmodried mango slices reduced overall acceptability during storage, which is consistent with the current study's findings.







T1 for vacuum packaging in LDPE 200 gauge (32-34 ºC).

T2 for vacuum packaging in LDPE 200 gauge (5-7 ºC).

T3 for vacuum packaging in polyethylene laminated pouches (32-34 ºC).

T4 for vacuum packaging in polyethylene laminated pouches (5-7 ºC).

Figure 28. Effect of packaging material and storage temperature on the organoleptic quality of IM banana

5.4.2.9 Effect of packaging material and temperature on the cost of production of IM banana

An insignificant (Rs. 4.50) cost difference was found between 100g of IM bananas held in polyethylene laminated aluminium pouches and IM banana held in LDPE (200 gauge). Although polyethylene laminated aluminium pouches were found to have a higher (Rs. 6.00/pack) cost, while LDPE (200 gauge) had the lowest (Rs. 1.50/pack) cost, they had the advantage of retaining product quality for longer periods. The cost-benefit ratio of IM banana kept in both LDPE (200 gauge) and polyethylene laminated aluminium pouches was 0.25, indicating that lower cost alternatives such as the use of cane sugar to replace sucrose by small-scale food processors, conducting osmotic pretreatment at room temperature, and reuse of the osmotic solution by recycling may be opted to reduce the cost of production of IM banana.

According to Srilakshmi (2018), proper packaging materials and storage conditions of intermediate moisture foods are those that can prevent product deterioration without a need for refrigerated storage. Gurumeenakshi and Varadharaju (2019) estimated the unit cost of producing 10g of osmo dried mango slices packed in metallised of polypropylene packs at Rs. 1.85 while Saxena *et al.* (2017) reported cost of production for osmodehydrated aonla slices packed in HDPE pouches (200 gauge) at Rs. 155/kg.

SUMMARY

6. SUMMARY

The main objectives of the present study, titled "Evaluation of banana (*Musa* spp.*)* varieties for the development of Intermediate Moisture Fruit (IMF)", were to evaluate and explore banana varieties for their suitability in the development of Intermediate Moisture (IM) fruit, evaluate different osmotic agents on the quality of IM banana, standardize the fruit to osmotic solution ratio and duration of immersion for IM banana, and observe the changes in quality of IM banana during three months of storage. The experiment was carried out in the Department of Post Harvest Technology, College of Agriculture, Vellanikkara between the years 2018 and 2022.

Fruits of six varieties of banana of different genomic groups *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA) were collected from the Banana Research Station, Kannara in the Thrissur district of Kerala where they were grown under uniform conditions as per Package of Practices recommendations of the Kerala Agricultural University. Nedunendran banana of the variety Nendran variety was used in the present study. In the first experiment, banana varieties were characterized based on horticultural and biochemical traits. Variety Nendran (AAB), had superior morphological and horticultural characteristics such as fruit length (22.07 cm), fruit pedicel length (28.54 mm), fruit pedicel width (11.56 mm), peel thickness (3.10 mm), and fruit pulp weight (89.20 g) compared to other banana varieties, whereas variety Karpooravalli (ABB) had less superior horticultural traits but a larger fruit to pulp weight ratio (4.81). The banana variety Nendran (AAB) had the most desirable biochemical characteristics in terms of titratable acidity (0.34 %), total soluble solids (23.90^{o}Brix), total carbohydrates (37.51 %), total ash (14.89 %), and crude fibre content (0.90 %), whereas minerals such as calcium (168.90 mg/100g) and potassium (406.60 mg/100g) were more abundant in Yangambi km5 (AAA). Substantial morphological variations among banana varieties of different genomic groups were revealed, even within varieties of the same genomic group. The morphological and biochemical characteristics of Nendran (AAB) revealed its superiority in the development of IM bananas because of its larger and firmer fruit as well as its higher nutritional content compared to other banana varieties under investigation in the present study.

The second experiment was to evaluate the osmotic agents on the quality of the Intermediate Moisture (IM) banana. The osmotic agents were evaluated by immersing longitudinal fruit slices of ripe banana from the six varieties Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA), and Yangambi km5 (AAA) collected from the Banana Research Station in various osmotic solution combinations containing ascorbic acid (AA) (antioxidant) and potassium metabisulphite (KMS) (antimicrobial), namely sucrose + AA + KMS, glucose + AA + KMS, sucrose+ sorbitol + AA+ KMS, palm sugar + AA+ KMS, honey + AA + KMS and sucrose + NaCl+ KMS for preparation of IM banana. The fruit slices of 8 mm thickness were immersed in the aforementioned different osmotic agents for 8 hours, and subsequently dehydrated in a cabinet drier or in a vacuum drier at 55-60^{o}C to constant moisture. A significant variation in the type of osmotic agent used for the development of IM banana was revealed, with the IM banana conforming to the properties of the types of osmotic agents used, whether used singly or as a combination of osmotic agents. Honey was able to reduce the water activity to below 0.80 in all the banana varieties, but it had the consequence of browning IM bananas, which was also observed with banana slices immersed in palm sugar solution. The sucrose+sorbitol solution retained higher total carotenoids (233.87µg/100g), total phenols (335.00 mg/100g), and lowest values of non enzymatic browning (0.13 OD value) in the Nendran banana variety. Based on the organoleptic qualities of IM banana, a sucrose+sorbitol solution was discovered to be the best osmotic solution for varieties Nendran, Pisang Lilin, and Karpooravalli, with the highest overall acceptability scores of 7.67, 7.00, and 7.33, respectively. Sucrose solution was found to be the best osmotic solution in varieties Njalipoovan and Yangambi km5, with overall acceptability scores of 7.60 and 7.00, respectively, while glucose+sorbitol solution yielded a score of 7.33 in variety Grand Naine. IM banana developed was found to be microbiologically safe in all the osmotic agents used, but samples treated with glucose solution were found to serve as a good medium for the growth of microbial growth, particularly in banana varieties of Pisang Lilin and Yangambi km5 where bacteria, fungi, and yeast populations of 0.67×10^{-5}, 0.33×10^{-3} and 0.33×10^{-4} cfu/g were recorded, respectively.

The cost of IM banana was dependent on the initial cost of raw materials, such as the type of osmotic solution used, the cost of raw materials, etc. The cost of producing 100 g of IM banana when the osmotic solution was kept at room temperature and sucrose solution was used as an osmotic agent was the highest (Rs. 201.84), while palm sugar solution was the lowest (Rs. 97.34), with cost benefit ratios of 0.35 and 0.72, respectively. Variations on the subsequent dehydration using the best treatment with osmotic agent of sucrose+sorbitol solution were revealed between the vacuum drier and the cabinet drier. Vacuum drying of the osmodehydrated banana treated with sucrose+sorbitol solution was found to retain superior quality of IM banana compared to cabinet drier in reduction of water activity (0.79) while maintaining better nutritional qualities such as vitamin C (34.67 mg/100g), total carotenoids (502.48 µg/100g), total phenols (290.00 mg/100g) and less browning (0.25). The osmodehydrated fruit slices that were subsequently dehydrated in a vacuum dryer had superior physical, biochemical, microbiological, and organoleptic qualities, and the cost of producing 100g was the same for both dehydrators, which was estimated at Rs. 198.86.

The third experiment was to standardize the fruit to osmotic solution ratio and duration of immersion on the quality of IM banana. Fruit slices of the Nendran banana variety were immersed in sucrose+sorbitol solution, with the osmotic solution temperature maintained at 40ºC and the fruit to osmotic solution ratios of 1:1, 1:2, 1:3, and 1:4 and immersed for 4, 8, and 12 hours before being dried to a constant moisture in a vacuum drier. The physical, biochemical, microbiological, and organoleptic qualities of IM banana as well as the cost of producing 100g of IM banana were determined when osmotic solution temperature and osmotic concentration were kept constant at 40 ºC and 60 ºBrix, respectively. IM banana subjected to a fruit to osmotic solution ratio of 1:3 and kept for a duration of 4 hours was found to be the best treatment with the highest total soluble solids (69.50 ºBrix), non-reducing sugar (25.03 %), total sugars (38.87 %), vitamin C (48.17 mg/100g) and total carotenoids (1149.58 µg/100g). High organoleptic scores such as appearance (8.13), colour (7.93), flavour (7.93), texture (6.60), taste (8.13), and overall acceptability of IM banana were found when the process conditions during osmotic pretreatment were at a fruit to osmotic solution ratio of 1:3 and kept for the 4 hour

duration of immersion. The low fruit to osmotic solution of 1:1 and a four-hour duration of immersion of immersion recorded high microbial populations of fungi and yeast, which were 0.10×10^{-3} cfu/g and 3.67×10^{-4} cfu/g, respectively, while a bacteria population of 0.33×10^{-5} cfu/g was recorded in the same fruit to osmotic solution ratio of 1:1 but at an eight-hour duration of immersion. The process conditions beyond fruit to osmotic solution ratio of 1:3 and four-hour duration of immersion were found to be ineffective in maintaining the desirable quality of IM banana as well as not sustainable in the utilization of raw materials and energy.

In the fourth experiment, the best treatment obtained from the third experiment was kept for storage studies on packaging materials and storage temperature to evaluate the quality changes during storage on banana variety Nendran. IM bananas were held in various packaging materials (200 gauge LPDE cover and polyethylene laminated aluminum pouches) and stored under two storage conditions (32-34ºC ambient and 5-7 ºC low temperature), and the quality during storage was evaluated monthly over a three-month period. The quality of IM banana deteriorated during storage irrespective of package material and storage temperature, with IM banana kept in LDPE (200 gauge) package material and kept at ambient (32–34ºC) temperature showing the maximum decline in the physical, biochemical, organoleptic, and microbiological qualities throughout the three month storage period. IM banana held in polyethylene laminated aluminum pouches and stored at a low (5-7ºC) temperature maintained the best physical quality, nutritional content, microbiological safety, and organoleptic quality throughout storage. At the end of three months of storage, better physicochemical qualities such as a stable water activity value (0.80), titratable acidity (0.63 %), total ash (7.33 %), pH (3.54), reducing sugars (15.35 %), non-reducing sugars (7.97 %), total sugars (23.39 %), vitamin C (42.63 mg/100g), total carotenoids (1338 µg/100g), total phenols (311.67 mg/100g) and the least value for non-enzymatic browning (0.17) were retained in IM bananas held in polyethylene laminated aluminum pouches and kept at a low temperature. IM banana held in LDPE (200 gauge) packaging material and kept at ambient (32-34ºC) temperature was found to be unmarketable with with the highest population for both bacteria (1.00×10^{-5} cfu/g) and yeast (0.33×10^{-4} cfu/g) identified in the sample by the end of three months of storage. IM bananas held in polyethylene

laminated aluminum pouches and kept at a low temperature had better quality retention, while samples held in LDPE (200 gauge) packaging material and kept at ambient temperature showed the highest quality deterioration during storage. The cost of production of 100g of IM bananas held in both LDPE (200 gauge) and polyethylene laminated aluminum pouches ranged between Rs. 283.74 and Rs. 279.24 with a cost benefit ratio of 0.25, indicating that lower cost alternatives are acceptable.

The IM banana developed was a healthy snack of low calorific value similar to the fresh banana fruit, and it is enriched with vitamin C and total carotenoids. The variety Nendran proved to be the best banana variety for the development of IM banana due to its large size and firm texture. The IM banana developed using sucrose+sorbitol solution was found to retain better biochemical qualities of IM banana such as vitamin C, total carotenoids, and total phenols as well as high sensory attributes like appearance, colour, flavour, texture, odour, taste, after taste, and overall acceptability of IM banana. The best standard procedures for developing IM bananas with an osmotic solution temperature of 40^{o}C and an osmotic solution concentration of 60^{o}Brix as well as a fruit to osmotic solution ratio of 1:3 and a four-hour immersion duration. Vacuum packaging of IM bananas in polyethylene laminated aluminum pouches and keeping them at a low temperature were found to be the best storage conditions for the developed product, which retained their physicochemical quality and kept them microbiologically safe throughout the three months of storage.

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7. REFERENCES

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APPENDICES

APPENDIX

1.0 Score card for organoleptic evaluation of Intermediate Moisture (IM) banana

Name of the judge:

Date:

Characteristic				
	T1	***T2***	***T3***	***T4***
Appearance				
Colour				
Flavour				
Texture				
Odour				
Taste				
After taste				
Overall acceptability				

9 point hedonic scale

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

APPENDIX

Appendix 1.1: Mean rank scores for the effect of osmotic agents and varieties on the appearance of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	4.14	5.10	2.33	5.40	5.60	4.50
T2	3.82	4.30	2.90	4.73	2.33	4.07
T3	5.46	4.33	5.03	3.90	3.97	5.13
T4	4.43	3.53	3.63	4.40	4.97	4.07
T5	2.89	3.73	3.77	3.40	3.10	3.00
T6	2.39	2.67	5.43	1.53	3.10	3.07
T7	4.86)	4.33	4.90	4.63	4.93	4.17
KW	0.32**	0.17^{NS}	0.33**	0.43**	0.37**	0.15^{NS}

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)
* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively

Appendix 1.2: Mean rank scores for the effect of osmotic agents and varieties on the colour of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	4.63	5.17	3.63	5.87	5.07	4.60
T2	3.83	4.37	3.37	4.00	3.13	4.23
T3	5.27	4.20	5.47	4.73	4.10	5.00
T4	4.33	3.63	4.27	4.20	4.87	4.60
T5	3.10	3.50	3.20	3.07	3.37	2.47
T6	2.73	2.73	3.37	1.87	3.07	2.80
T7	4.1	4.40	4.70	4.27	4.40	4.30
KW	0.21**	0.18^{NS}	0.18^{NS}	0.40**	0.18^{NS}	0.24**

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)
*, **, NS. Significant at 0.05, 0.01 and non- significant respectively.

Appendix 1.3: Mean rank scores for the effect of osmotic agents and varieties on the flavour of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	5.60	4.60	3.43	5.17	3.53	4.37
T2	3.13	4.03	2.43	3.83	3.43	3.87
T3	3.97	6.00	4.63	5.23	4.80	5.63
T4	3.40	4.33	4.00	3.73	4.87	3.83
T5	3.30	3.33	4.03	3.17	3.47	3.43
T6	4.10	2.60	4.30	2.73	3.47	2.53
T7	4.50	3.10	5.17	4.13	4.43	4.33
KW	0.22*	0.31**	0.24**	0.25**	0.13^{NS}	0.25**

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)
*, **, NS. Significant at 0.05, 0.01 and non- significant respectively

Appendix 1.4: Mean rank scores for the effect of osmotic agents and varieties on the texture of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	5.07	4.33	2.93	4.93	4.37	3.80
T2	4.17	3.37	2.93	2.87	2.77	3.10
T3	3.93	5.43	4.60	5.57	4.83	4.20
T4	3.07	4.93	3.87	4.70	4.83	4.43
T5	3.07	3.27	3.60	2.67	3.80	4.50
T6	4.13	3.23	5.53	2.90	3.47	3.23
T7	6.67	3.43	4.53	4.37	3.93	4.73
KW	0.14^{NS}	0.20^{NS}	0.26**	0.35**	0.18^{NS}	0.11^{NS}

T1: Sucrose (60^{o}Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60^{o}Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60^{o}Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60^{o}Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60^{o}Brix), Sodium chloride (0.5%), KMS (0.25%)
*, **, NS. Significant at 0.05, 0.01 and non- significant respectively.

Appendix 1.5: Mean rank scores for the effect of osmotic agents and varieties on the odour of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	5.40	4.63	3.00	4.67	3.93	4.67
T2	3.27	3.67	2.77	4.57	3.90	3.37
T3	4.03	4.87	4.23	5.37	4.80	3.83
T4	3.53	4.53	3.37	3.77	4.77	4.70
T5	4.73	3.50	4.43	2.97	3.77	3.50
T6	3.47	3.50	5.47	2.60	3.27	2.77
T7	3.57	3.33	4.73	4.07	3.57	5.17
KW	0.19^{NS}	0.11^{NS}	0.36**	0.27**	0.10^{NS}	0.21*

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)
*, **, NS. Significant at 0.05, 0.01 and non- significant respectively

Appendix 1.6: Mean rank scores for the effect of osmotic agents and varieties on the taste of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	4.37	4.43	2.57	5.90	4.00	4.53
T2	3.73	4.17	2.53	4.53	2.70	3.13
T3	5.07	5.53	4.83	5.23	4.53	4.63
T4	3.80	4.63	3.47	3.17	4.53	4.33
T5	4.47	3.33	4.03	2.43	3.83	3.97
T6	2.80	2.77	5.77	2.60	3.67	2.23
T7	3.77	3.13	4.80	4.13	4.73	5.17
KW	0.16^{NS}	0.24*	0.36**	0.40**	0.13^{NS}	0.25**

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)
*, **, NS. Significant at 0.05, 0.01 and non- significant respectively

Appendix 1.7: Mean rank scores effect of osmotic agents and varieties on the after taste of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	4.10	4.63	2.27	4.87	4.60	4.60
T2	2.73	3.63	3.13	4.20	2.67	2.33
T3	4.70	5.20	3.90	5.07	4.70	4.03
T4	4.00	3.97	3.83	3.73	4.40	4.20
T5	4.60	3.47	4.37	3.20	3.43	4.13
T6	3.90	3.33	5.37	2.63	3.67	3.07
T7	3.97	3.77	5.13	4.30	4.53	5.63
KW	0.13^{NS}	0.12^{NS}	0.30**	0.21*	0.15^{NS}	0.31**

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)
*, **, NS. Significant at 0.05, 0.01 and non- significant respectively

Appendix 1.8: Mean rank scores for the effect of osmotic agents and varieties on the overall acceptability of IM banana

Treatment	Nendran (AAB)	Pisang Lilin (AA)	Karpooravalli (ABB)	Njalipoovan (AB)	Grand Naine (AAA)	Yangambi (KM-5) (AAA)
T1	4.03	4.97	2.33	5.93	4.23	4.93
T2	2.70	4.07	2.90	4.00	2.47	2.87
T3	4.63	5.63	5.03	4.93	4.47	4.73
T4	4.17	4.13	3.63	4.00	5.07	3.83
T5	4.20	3.13	3.77	3.07	3.83	3.27
T6	3.57	3.03	5.43	2.10	3.60	3.20
T7	4.70	3.03	4.90	3.97	4.33	5.17
KW	0.13^{NS}	0.26**	0.33**	0.36**	0.17*	0.21**

T1: Sucrose (60°Brix), Ascorbic acid (AA) (0.5%), Potassium metabisulphite (KMS) (0.25%)
T2: Glucose (60°Brix) AA (0.5%) KMS (0.25%)
T3: Sucrose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T4: Glucose+ sorbitol (50:50 ratio) (60°Brix), AA (0.5%). KMS (0.25%)
T5: Palm sugar (60°Brix), AA (0.5%), KMS (0.25%)
T6: Honey, AA (0.5%), KMS (0.25%)
T7: Sucrose (60°Brix), Sodium chloride (0.5%), KMS (0.25%)
*, **, NS. Significant at 0.05, 0.01 and non- significant respectively

Appendix 2: The cost of production for 100g of IM bananas using different osmotic agents

1.0 Cost of production for IM banana of Nendran variety

1. Cost of production for IM banana developed using 60ºBrix sucrose solution

Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00 g	2069.56/100g	2.10
Cost of KMS	0.50 g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Cost of lime	15g	40/kg	0.60
Water cost	80ml	NA	0.00
Labour cost	1hr	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			200.34

2. Cost of production for IM banana developed using 60ºBrix glucose solution

Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	120g	2240.82/5kg	53.76
Water costs	80ml	NA	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hr	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			141.30

3. Cost of production for IM banana developed using 60ºBrix sucrose: sorbitol (50:50) solution

Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.5
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml	NA	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			198.86

4. Cost of production for IM banana developed using 60ºBrix glucose: sorbitol (50:50) solution

Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.5
Cost of ascorbic acid	1.00g	2069.56/100g	2.10

Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	60g	2240.82/5kg	26.88
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			169.34
5. Cost of production for IM banana using 60°Brix palm sugar solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of palm solution	120g	90/kg	10.80
Water costs	80ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			98.34
6. Cost of production for IM banana using honey solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of honey	200g	440/kg	88.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			175.54
7. Cost of production for IM banana using 60°Brix sucrose and sodium chloride (NaCl) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Water costs	80ml	0	0.00
Cost of sodium chloride (NaCl)	1.00g	60/500gm	0.12
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			198.36

2.0 Cost of production for IM banana using Pisang Lilin variety

1. Cost of production of IM banana developed using developed using 60°Brix sucrose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Cost of lime	15ml	40/kg	0.60
Cost of water	80ml	0	0.00
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost	68.22 per cent		199.34
2. Cost of production of IM banana developed using developed using 60°Brix glucose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	120g	2240.82/5kg	53.76
Cost of water	80ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	70.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			139.30
3. Cost of production for IM banana developed using 60°Brix sucrose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.5
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Cost of water	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			198.86
4. Cost of production for IM banana developed using 60°Brix glucose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15kg	1.50
Cost of ascorbic acid	1.00 g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	60g	2240.82/5kg	26.88
Cost of sorbitol	60g	457.72/500g	54.92

Cost of water	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			168.34
5. Cost of production for IM banana developed using 60°Brix palm sugar solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of palm solution	120g	90/kg	10.8
Cost of water	80ml		0.00
Cost of lime	15ml	40/kg	0.60
Labour cost	1hour	630/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			97.34
6. Cost of production for IM banana developed using honey solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of honey	200g	440/kg	88.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			174.54
7. Cost of production for IM banana developed using 60°Brix sucrose and sodium chloride (NaCl) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	1.50
Cost of KMS	0.50 per cent	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Cost of water	80ml		0.00
Cost of sodium chloride (NaCl)	1.00g	60/500g	0.12
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			197.36
3.0 Cost of production for IM banana using Karpooravalli variety			
1. Cost of production for IM banana developed using 60°Brix sucrose solution			
Particulars	Quantity	Amount per unit	Total amount (Rs.)

		price	
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Water cost	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			199.34

2. Cost of production for IM banana developed using 60ºBrix glucose solution

Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	120g	2240.82/5kg	53.76
Water costs	80ml		0.00
Cost of lime	15ml	40/kg	0.60
Labour cost	1 hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			140.30

3. Cost of production for IM banana developed using 60ºBrix sucrose: sorbitol (50:50) solution

Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	0.5 per cent	2069.56/100g	2.10
Cost of KMS	0.25 per cent	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.80
Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1 hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			197.74

4. Cost of production for IM banana developed using 60ºBrix glucose: sorbitol (50:50) solution

Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	60g	2240.82/5kg	26.88
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00

Electricity cost	2 hours	5.50Kwh	11.00
Total cost			168.34
5. Cost of production for IM banana using 60ºBrix palm sugar solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of palm solution	120g	90/kg	10.8
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			97.34
6. Cost of production for IM banana using honey solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of honey	200g	440/kg	88.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			174.54
7. Cost of production for IM banana using 60ºBrix sucrose and sodium chloride (NaCl) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Water costs	80ml		0.00
Cost of sodium chloride (NaCl)	1.0g	60/500g	0.12
Cost of lime		40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			197.36
4.0 Cost of production for IM banana using Njalipoovan variety			
1. Cost of production for IM banana developed using 60ºBrix sucrose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	40/kg	4.00
Cost of ascorbic acid	1.00g	2069.56/100g	2.10

Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Water cost	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			201.84
2. Cost of production for IM banana developed using 60°Brix glucose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	40/kg	4.00
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	120g	2240.82/5kg	53.76
Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			142.80
3. Cost of production for IM banana developed using 60°Brix sucrose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	40/kg	4.00
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			200.36
4. Cost of production for IM banana developed using 60°Brix glucose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	40/kg	4.00
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	60g	2240.82/5kg	26.88
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			170.84

5. Cost of production for IM banana using 60°Brix palm sugar solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	40/kg	4.00
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of palm solution	120g	90/kg	10.80
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.17
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			99.41
6. Cost of production for IM banana using honey solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	40/kg	4.00
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of honey	200g	440/kg	88.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			177.04
7. Cost of production for IM banana using 60°Brix sucrose and sodium chloride (NaCl) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	40/kg	4.00
Cost of KMS	0.50 per cent	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Water costs	80ml		0.00
Cost of sodium chloride (NaCl)	1.0g	60/500g	0.12
Cost of lime		40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			199.86
5.0 Cost of production for IM banana using Grand Naine variety			
1. Cost of production for IM banana developed using 60°Brix sucrose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80

Water cost	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			199.34
2. Cost of production for IM banana developed using 60°Brix glucose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	120g	2240.82/5kg	53.76
Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			140.30
3. Cost of production for IM banana developed using 60°Brix sucrose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	0.5 per cent	2069.56/100g	2.10
Cost of KMS	0.25 per cent	341.72/500g	0.34
Cost of sucrose	30°Brix	940.94/kg	56.40
Cost of sorbitol	30 °Brix	457.72/500g	54.92
Water costs	40ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			197.86
4. Cost of production for IM banana developed using 60°Brix glucose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	60g	2240.82/5kg	26.88
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			168.34
5. Cost of production for IM banana using 60°Brix palm sugar solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)

Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of palm solution	120g	90/kg	10.80
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			97.34
6. Cost of production for IM banana using honey solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.5g	341.72/500g	0.34
Cost of honey	200g	440/kg	88.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			174.54
7. Cost of production for IM banana using 60^{o}Brix sucrose and sodium chloride (NaCl) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of KMS	0.25 per cent	341.72/500g	0.34
Cost of sucrose	60^{o}Brix	940.94/kg	112.80
Water costs	80ml	0	0.00
Cost of sodium chloride (NaCl)	1.00g	60/500g	0.12
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			197.36
6.0 Cost of production for IM banana using Yangambi km5 variety			
1. Cost of production for IM banana developed using 60^{o}Brix sucrose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	120g	940.94/kg	112.80
Water cost	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00

Total cost			199.34
2. Cost of production for IM banana developed using 60°Brix glucose solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	120g	2240.82/5kg	53.76
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			140.30
3. Cost of production for IM banana developed using 60°Brix sucrose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	0.5 per cent	2069.56/100g	2.10
Cost of KMS	0.25 per cent	341.72/500g	0.34
Cost of sucrose	30°Brix	940.94/kg	56.40
Cost of sorbitol	30 °Brix	457.72/500g	54.92
Water costs	40ml		0.00
Cost of lime		40/kg	0.60
Labour cost		600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			197.86
4. Cost of production for IM banana developed using 60°Brix glucose: sorbitol (50:50) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of glucose	60g	2240.82/5kg	26.88
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			168.34
5. Cost of production for IM banana using 60°Brix palm sugar solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of palm solution	120g	90/kg	10.80

Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			97.34
6. Cost of production for IM banana using honey solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of honey	200g	440/kg	88.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			174.54
7. Cost of production for IM banana using 60^{o}Brix sucrose and sodium chloride (NaCl) solution			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	15/kg	1.50
Cost of KMS	0.50g	341.72/500g	0.17
Cost of sucrose	120g	940.94/kg	112.80
Water costs	80ml	0.00	0.00
Cost of sodium chloride (NaCl)	1.00g	60/500g	0.12
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			197.36

NB: Water costs excluded as the first 3,000 litres of water is free to all consumers while for the consumers below the poverty line (BPL) the limit is up to 10,000 litres.

Appendix 3: Mean ratings of the effect of vacuum drying and cabinet drying on organoleptic quality of intermediate moisture (IM) banana

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
Vacuum oven dried IM banana	1.77	1.77	1.83	1.80	1.50	1.70	1.73	1.73
Cabinet dried IM banana	1.23	1.23	1.17	1.20	1.50	1.30	1.27	1.23
Kendal's W test	0.53*	0.53*	0.68*	0.60*	0.00^{NS}	0.20*	0.47*	0.53*

*, **. Significant at 0.05 and 0.01

Appendix 4: Effect of vacuum drying and cabinet drying on the cost of production of IM banana

Cost of production for IM banana developed using 60°Brix sucrose: sorbitol (50:50) solution and subsequently dried using vacuum drier			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			198.86
Cost of production for IM banana developed using 60°Brix sucrose: sorbitol (50:50) solution and subsequently dried using cabinet drier			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml		0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	2 hours	5.50Kwh	11.00
Total cost			198.86

Appendix 5: Mean rankings on the effect of fruit osmotic solution ratio and duration of immersion on organoleptic attributes of IM banana

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	8.67	6.70	6.63	7.17	6.83	5.50	4.50	4.03
T2	5.70	5.73	5.70	5.03	8.37	7.63	6.97	7.47
T3	9.67	9.03	8.97	9.43	7.77	11.33	8.53	11.20
T4	5.37	9.07	9.37	6.83	7.23	5.87	5.83	6.43
T5	4.87	3.97	3.93	4.83	7.50	5.40	7.00	5.00
T6	8.43	4.13	4.30	5.30	6.30	7.00	6.07	6.27
T7	8.43	7.70	7.67	9.30	8.03	9.50	9.83	8.83
T8	2.50	7.13	7.10	7.90	5.03	5.47	6.73	5.07
T9	8.07	5.97	5.93	7.17	7.50	9.73	9.13	7.93
T10	3.10	5.77	5.73	5.90	5.43	3.33	2.80	5.00
T11	7.07	6.77	6.67	4.17	3.30	3.83	4.00	4.47
T12	6.13	6.03	6.00	4.97	4.70	3.40	6.60	6.30
Kendal's W test	0.48**	0.26**	0.26**	0.28**	0.24**	0.60**	0.38**	0.40**

**Significant at 1%

T1 for osmotic ratio of 1:1 and duration of immersion of four hours
T2 for osmotic ratio of 1:2 and duration of immersion of four hours
T3 for osmotic ratio of 1:3 and duration of immersion of four hours
T4 for osmotic ratio of 1:2 and duration of immersion of four hours
T5 for osmotic ratio of 1:1 and duration of immersion of eight hours
T6 for osmotic ratio of 1:2 and duration of immersion of eight hours
T7 for osmotic ratio of 1:3 and duration of immersion of eight hours
T8 for osmotic ratio of 1:4 and duration of immersion of eight hours
T9 for osmotic ratio of 1:1 and duration of immersion of twelve hours
T10 for osmotic ratio of 1:2 and duration of immersion of twelve hours
T11 for osmotic ratio of 1:3 and duration of immersion of twelve hours
T12 for osmotic ratio of 1:4 and duration of immersion of twelve hours

Appendix 6: Cost of production of IM banana at different fruit: osmotic ratio and different duration of immersion

1.0 Cost of production of IM banana at 1:1 ratio and different duration of immersion

1. Osmotic solution 1:1 and duration of immersion at 4 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	0.5 per cent	2069.56/100g	1.05
Cost of KMS	0.25 per cent	341.72/500g	0.17
Cost of sucrose	30°Brix	940.94/kg	28.20
Cost of sorbitol	30 °Brix	457.72/500g	27.46
Water costs	40ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6hours	5.50Kwh	33.00
Total cost			163.98
2. Osmotic solution 1:1 and duration of immersion at 8 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	0.5 per cent	2069.56/100g	1.05
Cost of KMS	0.25 per cent	341.72/500g	0.17
Cost of sucrose	30°Brix	940.94/kg	28.20
Cost of sorbitol	30 °Brix	457.72/500g	27.46
Water costs	40ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	10hours	5.50Kwh	55.00
Total cost			185.98
3. Osmotic solution 1:1 and duration of immersion at 12 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	0.5 per cent	2069.56/100g	1.05
Cost of KMS	0.25 per cent	341.72/500g	0.17
Cost of sucrose	30°Brix	940.94/kg	28.20
Cost of sorbitol	30 °Brix	457.72/500g	27.46
Water costs	40ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	14hours	5.50Kwh	77.00
Total cost			207.98

2.0 Cost of production of IM banana at 1:2 ratio and different duration of immersion

1. Osmotic solution 1:2 and immersion of duration at 4 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6 hours	5.50Kwh	33.00
Total cost			220.86
2. Osmotic solution 1:2 and immersion of duration at 8 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	10 hours	5.50Kwh	55.00
Total cost			242.86
3. Osmotic solution 1:2 and immersion of duration at 12 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.00g	2069.56/100g	2.10
Cost of KMS	0.50g	341.72/500g	0.34
Cost of sucrose	60g	940.94/kg	56.40
Cost of sorbitol	60g	457.72/500g	54.92
Water costs	80ml	0.00	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	14 hours	5.50Kwh	77.00
Total cost			264.86

3.0 Cost of production of IM banana at 1:3 ratio and different duration of immersion

1. Osmotic solution 1:3 and duration of immersion at 4 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.5g	2069.56/100g	3.15
Cost of KMS	0.75 per cent	341.72/500g	0.51
Cost of sucrose	90g	940.94/kg	84.60
Cost of sorbitol	90g	457.72/500g	82.38
Water costs	120ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6hours	5.50Kwh	33.00
Total cost			277.74
2. Osmotic solution 1:3 and duration of immersion at 8 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.5g	2069.56/100g	3.15
Cost of KMS	0.75 per cent	341.72/500g	0.51
Cost of sucrose	90g	940.94/kg	84.60
Cost of sorbitol	90g	457.72/500g	82.38
Water costs	120ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	10hours	5.50Kwh	55.00
Total cost			299.74
3. Osmotic solution 1:3 and duration of immersion at 12 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.5g	2069.56/100g	3.15
Cost of KMS	0.75 per cent	341.72/500g	0.51
Cost of sucrose	90g	940.94/kg	84.60
Cost of sorbitol	90g	457.72/500g	82.38
Water costs	120ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	14hours	5.50Kwh	77.00
Total cost			321.74

4.0 Cost of production of IM banana at 1:4 ratio and different duration of immersion

1. Osmotic solution 1:4 and duration of immersion at 4 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.60g	2069.56/100g	4.20
Cost of KMS	1.00g	341.72/500g	0.68
Cost of sucrose	120g	940.94/kg	112.80
Cost of sorbitol	120g	457.72/500g	109.84
Water costs	160ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6hours	5.50Kwh	33.00
Total cost			334.62
2. Osmotic solution 1: 4 and duration of immersion at 8 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.60g	2069.56/100g	4.20
Cost of KMS	1.00g	341.72/500g	0.68
Cost of sucrose	120g	940.94/kg	112.80
Cost of sorbitol	120g	457.72/500g	109.84
Water costs	160ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	10hours	5.50Kwh	55.00
Total cost			356.52
3. Osmotic solution 1: 4 and duration of immersion at 12 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.60g	2069.56/100g	4.20
Cost of KMS	1.00g	341.72/500g	0.68
Cost of sucrose	120g	940.94/kg	112.80
Cost of sorbitol	120g	457.72/500g	109.84
Water costs	160ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	14hours	5.50Kwh	77.00
Total cost			378.62

Appendix 7: Effect of sucrose+sorbitol solution and glucose syrup on the organoleptic characteristics of Intermediate Moisture (IM) banana

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
Sucrose+sorbitol	1.60	1.73	1.90	1.73	1.63	1.80	1.90	1.80
Glucose syrup	1.40	1.27	1.10	1.27	1.37	1.20	1.10	1.20
Kendal's W test	0.08^{NS}	0.30^{*}	0.80**	0.47^{NS}	0.11^{NS}	0.36*	0.80**	0.49**

*, **, NS. Significant at 0.05, 0.01 and non- significant respectively

Appendix 8: Cost of production of Intermediate Moisture (IM) banana with sucrose+sorbitol solution and glucose syrup

Osmotic solution 1:3 and duration of immersion at 4 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.5g	2069.56/100g	3.15
Cost of KMS	0.75 per cent	341.72/500g	0.51
Cost of sucrose	90g	940.94/kg	84.60
Cost of sorbitol	90g	457.72/500g	82.38
Water costs	120ml	0	0.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6hours	5.50Kwh	33.00
Total cost			277.74
Osmotic solution 1:3 and duration of immersion at 8 hours			
Particulars	Quantity	Amount per unit price	Total amount (Rs.)
Ripe banana	100g	25/kg	2.50
Cost of ascorbic acid	1.5g	2069.56/100g	3.15
Cost of KMS	0.75 per cent	341.72/500g	0.51
Glucose syrup	300g	265/500g	159.00
Cost of lime	15g	40/kg	0.60
Labour cost	1hour	600/day	71.00
Electricity cost	6hours	5.50Kwh	33.00
Total cost			269.76

Appendix 9.1: Effect of package material and temperature on organoleptic attributes of IM banana (1MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	2.05	1.75	2.20	2.15	2.20	2.00	1.85	1.80
T2	2.40	2.75	2.10	2.05	2.75	1.90	2.20	2.00
T3	3.00	2.95	2.75	2.95	2.60	3.20	3.00	2.95
T4	2.55	2.75	2.95	2.85	2.45	2.90	2.95	3.25
Kendal's W test	0.12^{NS}	0.21^{NS}	0.12^{NS}	0.17^{NS}	0.05^{NS}	0.31*	0.23^{NS}	0.33*

Table 9.2: Effect of package material and temperature on organoleptic attributes of IM banana (2MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	UM	UM	UM	UM	UM	UM	UM	UM
T2	1.35	1.00	2.20	2.05	2.15	2.20	2.35	1.75
T3	2.35	2.25	1.60	1.60	1.85	1.60	1.40	1.70
T4	2.30	2.65	2.20	2.35	2.00	2.20	2.25	2.55
Kendal's W test	0.41*	0.84**	0.20^{NS}	0.18^{NS}	0.04^{NS}	0.14^{NS}	0.35*	0.27^{NS}

Table 9.3: Effect of package material and temperature on organoleptic attributes of IM banana (3MAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T1	UM	UM	UM	UM	UM	UM	UM	UM
T2	1.00	1.05	1.60	1.30	1.20	1.10	1.20	1.20
T3	2.45	2.40	2.25	2.50	2.50	2.70	2.45	2.30
T4	2.55	2.55	2.15	2.20	2.30	2.20	2.35	2.50
Kendal's W test	0.00**	0.00**	0.33*	0.65**	0.75**	0.84**	0.67**	0.75**

* ,** , NS . Significant at 0.05, 0.01 and non- significant respectively.

T1 for vacuum packaging in LDPE 200gauge (32-34^{o}C)

T2 for vacuum packaging in LDPE 200 gauge (5-7^{o}C)

T3 for vacuum packaging in polyethylene laminate pouches (32-34^{o}C)

T4 vacuum packaging in polyethylene laminate pouches (5-7^{o}C)

ABSTRACT

EVALUATION OF BANANA (*Musa* spp.) VARIETIES FOR THE DEVELOPMENT OF INTERMEDIATE MOISTURE FRUIT (IMF)

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ABSTRACT OF THE THESIS

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ABSTRACT

The study on 'Evaluation of banana (*Musa* spp.) varieties for the development of Intermediate Moisture Fruit (IMF)' was undertaken at the Department of Post Harvest Technology, College of Agriculture, Vellanikkara between the years 2018 and 2022, using varieties of different genomic groups *viz.* Nendran (AAB), Pisang Lilin (AA), Karpooravalli (ABB), Njalipoovan (AB), Grand Naine (AAA) and Yangambi km5 (AAA), which were collected from the Banana Research Station, Kannara. Nedunendran banana of the variety Nendran variety was used in the present study. The main objectives of the study were to characterize banana varieties and to explore their suitability for the development of Intermediate Moisture Fruit (IMF).

Horticultural characteristics of banana variety Nendran (AAB) were found to be superior in terms of the fruit length (22.07cm), fruit pedicel length (28.54 mm), fruit pedicel width (11.56 mm), peel thickness (3.10 mm), and fruit pulp weight (89.20 g) compared to other banana varieties, whereas variety Karpooravalli (ABB) had inferior horticultural traits but a higher fruit to pulp weight ratio (4.81). Nendran (AAB) and Karpooravalli (ABB) varieties were firm, with fruit flesh firmness of 0.08 and 0.09 cm^2kg^{-1}, respectively. The banana variety Nendran (AAB) had the most desirable biochemical characteristics in terms of titratable acidity (0.34 %), total soluble solids (23.90^{o}Brix), total carbohydrates (37.51 %), total ash (14.89 %), and crude fibre content (0.90 %), whereas minerals such as calcium (168.90 mg/100g) and potassium (406.60 mg/100g) were more abundant in Yangambi km5 (AAA). The horticultural and biochemical characteristics of Nendran (AAB) revealed its superiority in the development of IM bananas.

Variation in the quality of IM banana was revealed when 8mm longitudinal fruit slices of ripe banana from the six varieties were immersed in osmotic solution combinations containing ascorbic acid (AA) (antioxidant) and potassium metabisulphite (KMS) (antimicrobial), namely sucrose + AA + KMS, glucose + AA + KMS, sucrose + sorbitol + AA+ KMS, glucose + sorbitol + AA + KMS, palm sugar + AA + KMS, honey + AA + KMS and sucrose + NaCl + KMS for preparation of IM banana. The variety Nendran treated with sucrose+sorbitol solution was found to be the best treatment during the development of IM banana, which retained highest total carotenoids (233.87µg/100g), total phenols (335.00 mg/100g), lowest values of non

enzymatic browning (0.13 OD values) and highest scores for the overall acceptability (7.67). IM banana of the variety Pisang Lilin recorded fungal colonies of 0.33×10^{-3} cfu/g when fruit slices were immersed in glucose solution, while bacterial colonies of 0.67×10^{-5} cfu/g were recorded in variety Yangambi km5 in both sucrose and glucose solutions. Yeast colonies of 0.33×10^{-4} cfu/g were recorded in glucose solution in the variety Yangambi km5. However, the IM banana developed was found to be microbiologically safe in all the osmotic agents used. Vacuum drying of the osmodehydrated banana slices treated with sucrose+sorbitol solution was found to be superior in the reduction of water activity (0.79) while retaining better nutritional qualities such as vitamin C (34.67 mg/100g), total carotenoids (502.48 µg/100g), total phenols (290.00 mg/100g) and less browning (0.25 OD value).

Fruit to osmotic solution ratio of 1:3 and a duration of immersion of 4 hours were found to be the best treatments when osmotic solution temperature and osmotic concentration were kept constant at 40ºC and 60ºBrix, respectively, during the development of IM banana. The product had a reduced water activity (0.73) and optimum biochemical quality such as total soluble solids (69.50ºBrix), non-reducing sugars (25.03 %), total sugars (38.87 %), vitamin C (48.17 mg/100g) and total carotenoids (1149.58 µg/100g). Highest organoleptic scores such as appearance (8.13), colour (7.93), flavour (7.93), texture (7.53), taste (8.13), and overall acceptability (8.20) of IM banana were also recorded with fruit to osmotic solution ratio of 1:3 and the 4 hour duration of immersion.

IM banana held in polyethylene laminated aluminum pouches and kept at low temperature (5-7ºC) retained a lower water activity (0.80) throughout the three month storage. It also retained better biochemical qualities in terms of titratable acidity (0.63 %), total ash (7.33 %), pH (3.54), reducing sugars (15.35%), non-reducing sugars (7.97 %), total sugars (23.39 %), vitamin C (42.63 mg/100g), total carotenoids (1338.67 µg/100g), total phenols (311.67 mg/100g), non-enzymatic browning (0.17 OD value), and highest scores for overall acceptability (8.10) that were comparable to the initially prepared product. The product was found to be microbiologically safe throughout storage with the longest shelf life.

സംഗ്രഹം

വാഴപ്പഴത്തിൽ നിന്നും (മൂസ സ്പീഷീസ്), ഇൻറർമീഡിയറ്റ് മോയിസ്ചർ ഫ്രൂട്ട് (ഐഎംഎഫ്) വികസനത്തിനായുള്ള ഇനങ്ങളെക്കുറിച്ചുള്ള പഠനം ഡിപ്പാർട്മെൻറ് ഓഫ് പോസ്റ്റ് ഹാർവെസ്റ്റ് ടെക്നോളജി, കോളേജ് ഓഫ് അഗ്രികൾച്ചർ, വെള്ളാനിക്കരയിൽ 2018 മുതൽ 2022 വരെ നടത്തി. വാഴ ഗവേഷണ കേന്ദ്രം, കണ്ണാറയിൽ നിന്ന് ശേഖരിച്ച വിവിധ ജീനോമിക് ഗ്രൂപ്പുകളുടെ ഇനങ്ങളായ നേന്ത്രൻ (AAB), പിസാങ്ങ് ലിലിൻ (AA), കർപൂരവല്ലി (ABB), ഞാലിപൂവൻ (AB), ഗ്രാൻഡ് നൈൻ (AAA), യാംഗമ്പി km5 (AAA) എന്നിവയാണ് ഈ പഠനത്തിന് വേണ്ടി ഉപയോഗിച്ചിരിക്കുന്നത്. പഠനത്തിന്റെ പ്രധാന ലക്ഷ്യം ഇന്റർമീഡിയറ്റ് മോയിസ്ചർ ഫ്രൂട്ട് (IMF) വികസിപ്പിക്കുന്നതിനുള്ള ഇവയുടെ അനുയോജ്യത നിർണ്ണയിക്കുന്നതായിരുന്നു.

നേന്ത്രപ്പഴത്തിന്റെ (AAB) ഹോർട്ടികൾച്ചറൽ സവിശേഷതകൾ പരിശോധിച്ചപ്പോൾ പഴത്തിന്റെ നീളം (22.07cm), പഴത്തണ്ടിന്റെ നീളം (28.54 mm) പഴത്തിന്റെ പൂങ്കുലയുടെ വീതി (11.56 മില്ലിമീറ്റർ), തൊലി കനം (3.10 മില്ലിമീറ്റർ), പഴത്തിന്റെ പൾപ്പ് ഭാരം (89.20 ഗ്രാം) എന്നിവയെല്ലാം മറ്റ് വാഴ ഇനങ്ങളെ അപേക്ഷിച്ച് വളരെ ഉയർന്നതാണെന്ന് കണ്ടെത്തി. കൂട്ടത്തിൽ കർപൂരവല്ലി (ABB) ഇനത്തിനായിരുന്നു IMF വികസിപ്പിക്കാൻ അനുയോജ്യമല്ലാത്ത ഹോർട്ടികൾച്ചറൽ സ്വഭാവസവിശേഷതകൾ കണ്ടതെങ്കിലും പഴത്തിന്റെയും പൾപ്പ് ഭാരത്തിന്റെയും അനുപാതം (4.81) വളരെ ഉയർന്നതായിരുന്നു. നേന്ത്രൻ (AAB), കർപൂരവല്ലി (ABB) ഇനങ്ങളുടെ മാംസം നല്ല ഉറച്ച പ്രകൃതവും പഴത്തിന്റെ മാംസത്തിന്റെ ദൃഢത യഥാക്രമം 0.08, 0.09 സെ.മീ ^{2} കി.ഗ്രാം $^{-1}$ ആയിരുന്നു. വാഴപ്പഴത്തിലെ അഭികാമ്യമായ ബയോകെമിക്കൽ സ്വഭാവസവിശേഷതകളായ ടൈട്രേറ്റബിൾ അസിഡിറ്റി (0.34 %) ആകെ ലയിക്കുന്ന ഖരവസ്തുക്കൾ (23.90 ° ബ്രിക്സ്), മൊത്തം കാർബോഹൈഡ്രേറ്റുകൾ (37.51 %), മൊത്തം ചാരം (14.89 %), കൂടാതെ അസംസ്കൃത നാരുകളുടെ തോത് (0.90 %) എന്നിവ നേന്ത്രപ്പഴത്തിനാണ്(AAB) ഏറ്റവും കൂടുതൽ ലഭിച്ചത്. അതേസമയം കാൽസ്യം (168.90 mg/100g), പൊട്ടാസ്യം (406.60 mg/100g) പോലുള്ള ധാതുക്കൾ യംഗമ്പി km5 (AAA) ഇനത്തിൽ കൂടുതൽ സമൃദ്ധമായിരുന്നു. ഈ സവിശേഷതകളെല്ലാം കൊണ്ട് ഇന്റർമീഡിയറ്റ് മോയിസ്ചർ പഴത്തിന് (ഐഎം പഴം) ഏറ്റവും ഉതകുന്ന ഇനമാണ് നേന്ത്രൻ എന്ന് കണ്ടെത്തി.

ഐഎം പഴം തയ്യാറാക്കുന്നതിനായി ആറ് ഇനങ്ങളിൽ നിന്നുള്ള പഴുത്ത വാഴപ്പഴത്തിന്റെ കഷ്ണങ്ങൾ (8 മില്ലിമീറ്റർ നീളം) ഓസ്മോട്ടിക് ലായനിയിൽ മുക്കി അസ്കോർബിക് ആസിഡ് (AA) (ആൻറി ഓക്സിഡൻറ്), പൊട്ടാസ്യം മെറ്റാബൈസൾഫൈറ്റ് (KMS) (ആന്റിമൈക്രോബിയൽ) എന്നിവ അടങ്ങിയ വ്യത്യസ്ത ലായനികളിൽ, അതായത് സുക്രോസ് + AA + KMS, ഗ്ലൂക്കോസ് + AA + KMS, സുക്രോസ് + സോർബിറ്റോൾ + AA+ KMS, ഗ്ലൂക്കോസ് + സോർബിറ്റോൾ + AA + KMS, പനം

ശർക്കര + AA + KMS, തേൻ + AA + KMS, സുക്രോസ് + NaCl + KMS എന്നിവ ശ്രമിച്ചു നോക്കി. ഇവ ഓരോന്നിൽ നിന്നും തയാറാക്കിയ ഐഎം പഴത്തിന്റെ ഗുണനിലവാരത്തിൽ വ്യത്യാസം കാണപ്പെട്ടു. സുക്രോസ്+സോർബിറ്റോൾ ലായനി ഉപയോഗിച്ച് തയാറാക്കിയ നേന്ത്രൻ ഇനമാണ് ഏറ്റവും മികച്ചതായി കണ്ടെത്തിയത്. ഈ ട്രീറ്റ്മെന്റിനാണ് ഏറ്റവും കൂടുതൽ കരോട്ടിനോയിഡുകൾ (233.87µg/100g), ഫിനോൾസ് (335.00 mg/100g), ഏറ്റവും കുറഞ്ഞ എൻസൈമാറ്റിക് ബ്രൗണിംങ് (0.13 OD), സ്വാദും, നിറവും, മൃദുത്വവും, സ്വീകാര്യതയ്ക്കുമുള്ള ഉയർന്ന സ്കോറുകൾ (7.67) രേഖപ്പെടുത്തിയത്. പിസാങ് ലിലിൻ ഇനത്തിലെ പഴക്ഷണങ്ങൾ ഗ്ലൂക്കോസ് ലായനിയിൽ മുക്കിയെടുത്തു തയാറാക്കിയ ഐഎം വാഴപ്പഴത്തിൽ 0.33×10^{-3} കുമിളകൾ രേഖപ്പെടുത്തിയിട്ടുണ്ട്. Yangambi km5 ഇനത്തിൽ 0.67×10^{-5} cfu/g ബാക്ടീരിയകൾ സുക്രോസ് ലായനിയിലും ഗ്ലൂക്കോസ് ലായനിയിലും രേഖപ്പെടുത്തിയിട്ടുണ്ട്. അത് പോലെ 0.33×10^{-4} cfu/g യീസ്റ്റ് കോളനികൾ ഗ്ലൂക്കോസ് ലായനിയിലും രേഖപ്പെടുത്തിയിട്ടുണ്ട്. എന്നിരുന്നാലും, ഐഎം വാഴപ്പഴം തയാറാക്കാൻ ഉപയോഗിച്ച എല്ലാ ഓസ്മോട്ടിക് ലായനികളും സൂക്ഷ്മാണുക്കളുടെ വളർച്ച പരിമിതപ്പെടുത്തുന്ന കാര്യത്തിൽ സുരക്ഷിതമാണ്. സുക്രോസ് + സോർബിറ്റോൾ ലായനി ഉപയോഗിച്ച് തയ്യാറാക്കിയ ഓസ്മോ-ഡീഹൈഡ്രേറ്റഡ് വാഴപ്പഴ കഷ്ണങ്ങൾ വാകുവം ഡ്രയിങ്ങിലൂടെ ഉണക്കിയെടുത്തപ്പോൾ മെച്ചപ്പെട്ട ഗുണനിലവാരം നിലനിർത്താൻ സാധിച്ചു. ജലത്തിന്റെ പ്രവർത്തനം (0.79) കുറയ്ക്കുന്നതിൽ മികച്ചതാണ് ഈ രീതി. അതുപോലെ തന്നെ ഉയർന്ന വിറ്റാമിൻ സി (34.67 mg/100g), കരോട്ടിനോയിഡുകൾ (502.48 µg/100g), ഫിനോൾസ് (290.00 mg/100g), കുറഞ്ഞ ബ്രൗണിംഗ് (0.25 OD മൂല്യം) എന്നിവയും കാണാൻ സാധിച്ചു.

ഓസ്മോട്ടിക് ലായനി താപനിലയും ഓസ്മോട്ടിക് ഗാഢതയും യഥാക്രമം 40°C, 60°ബ്രിക്സ് എന്നിവയിൽ സ്ഥിരമായി നിലനിർത്തി, പഴങ്ങളും ഓസ്മോട്ടിക് ലായനിയും തമ്മിൽ 1:3 അനുപാതത്തിൽ നാല് മണിക്കൂർ മുക്കിവെച്ചു വികസിപ്പിച്ചെടുത്ത ഐഎം പഴമാണ് ഏറ്റവും മികച്ചതായി കണ്ടെത്തിയത്. ഈ ഉൽപ്പന്നത്തിന് കുറഞ്ഞ ജല പ്രവർത്തനം (0.73), മൊത്തത്തിൽ ലയിക്കുന്ന ഖരപദാർഥങ്ങൾ (69.50°ബ്രിക്സ്), നോൺ-റെഡ്യൂസിങ് പഞ്ചസാര (25.03 %), മൊത്തം പഞ്ചസാര (38.87 %), വിറ്റാമിൻ സി (48.17 mg/100g) കൂടാതെ ആകെ കരോട്ടിനോയിഡുകൾ (1149.58 µg/100g) എന്നിവ രേഖപ്പെടുത്തി. രൂപഭാവം (8.13), നിറം (7.93), സ്വാദ് (7.93), മാർദ്ദവം (7.53), രുചി (8.13), മൊത്തത്തി ലുള്ള സ്വീകാര്യത (8.20) എന്നിങ്ങനെ ഉയർന്ന ഓർഗാനോലെപ്റ്റിക് സ്കോറുകളാണ് ഇവയ്ക്ക് ലഭിച്ചത്.

പോളിയെത്തിലീൻ ലാമിനേറ്റ് ചെയ്ത അലുമിനിയം പൗച്ചുകളിൽ പായ്ക്ക് ചെയ്ത് 5-7°C താപനിലയിൽ സൂക്ഷിച്ച ഐഎം വാഴപ്പഴം, മൂന്ന് മാസത്തിലുടനീളം താഴ്ന്ന ജല പ്രവർത്തനമാണ് (0.80) നിലനിർത്തിയത്. അത് പോലെ മികച്ച ബയോകെമിക്കൽ ഗുണങ്ങളും, അതായത് ടൈട്രേറ്റബിൾ

അസിഡിറ്റി (0.63%), മൊത്തം ചാരം (7.33 %), pH (3.54), റെഡ്യൂസിങ് പഞ്ചസാര (15.35%), നോൺ-റെഡ്യൂസിങ് പഞ്ചസാര (7.97 %), മൊത്തം പഞ്ചസാര (23.39 %), വിറ്റാമിൻ സി (42.63 mg/100g), മൊത്തം കരോട്ടിനോയിഡുകൾ (1338.67 µg/100g), മൊത്തം ഫിനോൾസ് (311.67 mg/100g), നോൺ-എൻസൈമാറ്റിക് ബ്രൗണിംഗ് (0.17 OD), മൊത്തത്തിലുള്ള സ്വീകാര്യതയ്ക്കുള്ള ഏറ്റവും ഉയർന്ന സ്കോറുകൾ (8.10) നിലനിർത്താൻ സാധിച്ചു.

താഴ്ന്ന മർദ്ദത്തിൽ ഉണ്ടാക്കിയെടുത്ത IMF വാഴപ്പഴം സാധാരണ ഡ്രൈയറിൽ ഉണ്ടാക്കിയെടുത്തതിനെക്കാൾ മെച്ചമാണെന്ന് തെളിഞ്ഞതിനോടൊപ്പം സൂക്ഷ്മാണുക്കളുടെ വളർച്ചയെ പ്രതിരോധിക്കുന്നതിലും മികച്ചതാണെന്ന് ബോധ്യപ്പെട്ടു പഴുത്ത വാഴപ്പഴത്തിൽ നിന്നും പ്രത്യേകിച്ച് നേന്ത്രപ്പഴത്തിൽ നിന്നും ഉല്പാദിപ്പിക്കുന്ന ഗുണമേന്മയേറിയ, ഉയർന്ന നിലവാരമുള്ള ഒരു മൂല്യവർദ്ധിത ഉല്പന്നമാണ് ഇടത്തരം ജലാംശമുള്ള ഐ. എം. എഫ് (IMF).