DEVELOPMENT OF OSMO DEHYDRATED RED BANANA (*Musa* spp.)

by

ARCHANA A.K

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"DEVELOPMENT OF OSMO DEHYDRATED RED BANANA (*Musa* spp.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"DEVELOPMENT OF OSMO DEHYDRATED RED BANANA (*Musa* spp.)"** is a record of research work done independently by Ms. Archana A K under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Archana A.K

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LIST OF ABBREVIATIONS AND SYMBOLS USED

°C	Degree Celsius
%	Per cent
min	Minute
kg	Kilo gram
s	Second
µg	Micro gram
mg	Milli gram
g	Gram
et al.	And co-workers
viz.,	Namely
TSS	Total Soluble Solids
OD	Osmotic Dehydration
SG	Solid gain
NS	Non significant
h	Hour
CRD	Completely Randomised Design
CD	Critical difference
Fig.	Figure
°Brix or °B	Degree brix

Introduction

1. INTRODUCTION

Fruits contain more than 75% water and get spoiled very quickly due to their high water content. Drying and dehydration are important processing methods and are widely used. Osmotic dehydration is one of the best and suitable methods to increase the shelf life of fruits and vegetables and the process is preferred over others due to its vitamins, minerals, color, flavor and taste retention property and prevention of microbial spoilage. Osmotic dehydration is a concentration process in which water is removed from the plant tissue to a hypertonic solution and solutes flow from the solution into the food (Ahmed *et al.*, 2016). Osmotic dehydration, preceding the air-drying preserves fruits and vegetables from undesirable colour changes and increases the retention of flavour during drying. The products obtained by osmotic dehydration are more stable during storage due to low water activity imparted by solute gain and water loss (Akbarian *et al.*, 2014)

Banana (*Musa* spp.) is one of the most important tropical fruit crop well known for its high nutritional value, being rich in starch, sugars, vitamins and minerals. However, its high moisture content leads to rapid deterioration and causes a postharvest loss of about 40% in main producer countries (Silva *et al.* 2014). Processing of banana into diverse products with longer shelf life has been proposed as a way of absorbing seasonal surpluses and reducing postharvest losses thus increasing farmer's income (Balasooriya *et al.*, 2006).

Osmo dehydration is one of the best and suitable methods to increase the shelf life of fruits and vegetables and osmo dehydrated fruit slices could be used as ingredients in food formulations such as pastry and confectionary products, ice cream, frozen desserts, fruit salads, cheese and yoghurt. Additionally, dried product can be used as snacks or components of cereals for direct usage (Torreggiani and Bertolo, 2001). Osmo dehydration reduces energy consumption, preserves flavour, nutritional characteristics and prevent microbial spoilage (Shete *et al.*, 2018).

Among the different species of banana, Red banana is most popular in South India, known for its characteristic flavour and colour. However its high perishability signifies a vast potential for processing into value added products. Most predominant preservation method such as solar drying techniques result in poor quality and product contamination. Thus osmotic dehydration has immense scope for the production of quality dehydrated product especially for highly perishable fruit like red banana. It also maximises the sugar acid ratio and enhances the stability of pigments during storage. Development of osmo dehydrated red banana can improve the shelf life while maintaining the natural product characteristics like flavour and nutritional qualities. Osmotic dehydration depend on process variables *viz.,* geometry of material (shape and size), osmotic agent, osmotic solution concentration and immersion time and has to be standardized for every raw material (Chavan *et al.,* 2012).

Hence the present study "Development of osmo dehydrated Red Banana (*Musa* spp.)" was carried out with the objective to standardize the different process variables *viz.,* fruit slice shape, osmotic solution concentration and time of immersion that have significant effect on mass transfer during osmotic dehydration of Red Banana and to assess the storage stability of osmo dehydrated red banana slices.

Review of Literature

2. REVIEW OF LITERATURE

Drying and dehydration are important processing methods and are widely used in fruit preservation. In recent years, osmotic dehydration has been used for fruit and vegetable preservation due to its vast potential to keep sensory and nutritional properties similar to fresh fruits and vegetables (Prothon *et al.*, 2001). Drying is one of the oldest methods of food preservation as removal of moisture reduced the water activity which increased the storage life (Mandala *et al.*, 2005). Osmotic dehydration is one of the best and suitable methods to increase the shelf life of fruits and vegetables and the problems of fruit marketing, handling and transport becomes much simpler and all types of fruits could be made available to the customer throughout the year. Osmotic dehydration is preferred over other preservation methods due to its high retention capacity for vitamins, minerals, colour, flavour and taste and ability to prevent microbial spoilage.

Osmotic dehydration followed by air drying yield dried fruits and vegetables with better sensory attributes. Osmotic dehydration is indeed a concentration process where water from the plant tissue is removed into a hypertonic solution and solutes from the hypertonic solution flow into the food (Ahmed *et al.*, 2016).

Research work on osmotic dehydration of red banana is meagre. Hence literature on osmo dehydration of different fruits had been reviewed in this section for mass transfer characters, biochemical, physical and sensory parameters.

2.1 OSMOTIC DEHYDRATION

The osmotic process has been recognized as one of the promising pre-treatment methods in drying as it reduces energy utilization and sucrose has been recommended as the popular hypertonic solution for osmotic dehydration of fruits because of its convenience, effectiveness and desired flavour (Lenart, 1996).

According to Madamba (2003) osmotic dehydration is a pretreatment process, which depends upon the phenomenon of diffusion of moisture from food materials by immersing in a hypertonic solution such as concentrated sugar solution. Two major simultaneous counter-current flows occur during osmotic dehydration include water flow out of the food into the hypertonic solution and simultaneous transfer of solute from the solution into the food product.

Tiwari (2005) stated that osmotic dehydration could be advantageous for numerous tropical fruits *viz.,* banana, jackfruit, sapota, mango, guava, and pineapple and this technology is preferred over other methods due to their colour, aroma, nutritional constituents and flavour compound retention value. Osmotic dehydration is considered one of the least energy consuming processes which results in the production of food products with extended shelf life (Astyk, 2009). It is usually followed by other drying methods such as air drying, deep fat frying, freeze drying, etc. to produce better quality final product (Khan, 2012).

2.2 MASS TRANSFER CHARACTERS

Mass transfer is a dynamic process that involves water out flow from the product to the osmotic solution and transfer of solute from the osmotic solution to product; thus possible to improve sensory quality of the product. These characters include water loss, solid gain, ratio of water loss to solid gain and percentage weight reduction.

Sankart and Castaigne (1992) reported that banana slices osmosed in sugar solution of 50°Brix for 36h resulted in 24.2% reduction in weight. Kar and Gupta (2001) reported osmotic process bring about 50% reduction in weight of fruits and vegetables.

Higher diffusion rate of water and solute was achieved by a higher osmotic potential difference between the fruit sample and the osmotic solution (Azoubel and Murr, 2004). According to Azoubel *et al.* (2009), increase in osmotic solution concentration increased pressure gradient which augmented water loss and prominent solid gain. Mass transfer characters are also affected by the physical properties related to the product, mainly the shape and thickness of the produce and sometimes also on the variety of the produce. The dewatering rate increased with increase in surface area of fruit and vegetable slices. Generally, 3 to 10 mm in rectangle, cube or ring shape fruit or vegetable slices which found to have better quality was suggested for use in the osmotic dehydration procedure (Tiwari and Jalali, 2004).

Gabriela *et al.* (2004) monitored the osmotic dehydration of mango slices where temperature and process time varied from 30°C to 50°C and 40 to 120 min respectively and reported that weight reduction (WR%), water loss (WL%) and solute gain (SG %) were greatly affected temperature and process time. Researches on effect of osmotic process duration on mass transfer characters revealed that exchange of masses occurred at a quicker rate during the initial 2h and a reduction in drying rate afterwards (Ramaswamy, 2005).

Falade and Igbeka (2007) studied effect of concentrations of sucrose solution (40°Brix, 50°Brix and 60°Brix) in osmo dehydration of water melon. The water loss and solid gain of the watermelon slices increased with increase in the concentration of osmotic solution and higher osmotic solution concentration showed higher water loss and solid gain.

The rate of mass transfer depends on several aspects like temperature, solution concentration, time of immersion, geometry and size of sample and quantity of sample to solution ratio (Panades *et al.*, 2008). Ispir and Togrul (2009) reported that during osmotic dehydration of apricot fruits using three different sucrose concentrations (40%, 50% and 60%), higher concentration of sucrose favoured greater osmotic pressure gradients, thereby contributed higher solid gain and water loss throughout the osmotic treatment period. They also evaluated the influence of different types of osmotic agents like glucose, sucrose, maltodextrin and sorbitol during osmotic dehydration of apricot and found that fructose and sucrose are the best osmotic agents for osmo dehydration since high water loss and solid gain was achieved using these osmotic agents. The increase in temperature and concentration of osmotic medium caused increased water loss and solid gain. Tortoe (2010) reported that high concentrated sucrose solution leads to increased loss of water and solid gain ratios.

Ali *et al.* (2010) studied osmo dehydration of tomato rings and banana and revealed that increase in immersion time caused a higher rate in weight reduction. The data also indicated that there existed a direct proportional relationship between the concentration of osmotic solution (NaCl) and weight reduction in tomato rings while banana slices showed substantial reduction in weight and maximum solid gains when 100% sucrose solution was used as an osmotic agent. Mundada *et al.* (2011) studied the mass transfer rate of pomegranate arils using sucrose solutions of varying concentrations (40°Brix, 50°Brixand 60°Brix). Osmotic dehydration of pomegranate arils in 60°Brix sucrose solution as osmotic agent showed higher water loss and solid gain as compared to the samples dehydrated in 40°Brix and 50°Brix sucrose solution. Similar findings were reported by Zapata *et al.* (2011) during the osmotic dehydration of pineapple where solid gain of 2.52% was obtained after 6h of the osmotic dehydration process. The increase in immersion time or process duration lead to higher water loss during osmotic dehydration. However, the case hardening effect of high sucrose concentration could reduce the mass flow within fruits and vegetables (Phisut, 2012).

Renu *et al.* (2012) osmotically dehydrated banana and suggested that solid gain increased with immersion time but the most effective weight reduction occurred between 60 to 90 min suggesting that it may not be necessary to carry out osmotic dehydration for longer hours. Kumari *et al.* (2013) studied osmo dehydration of ripe banana slices and reported that water loss in osmo dehydrated sample depends upon drying time and with increase in the treatment time weight loss increased but the rate at which this occur decreased.

According to Khanom *et al.* (2014), weight reduction, water loss and solid gain during osmotic dehydration of pineapple slices increased with increase in the concentration of sugar solution. Water loss values of the pineapple at 40% sugar solution were found to be significantly lower than those with 60% sugar solution as the osmotic agent. Najafi *et al.* (2014) reported that higher extent of mass transfer in terms of water loss, solid gain and weight loss was achieved by using more concentrated osmotic solution when osmotic dehydration of red pitaya was conducted using sucrose solutions of 40°Brix, 50°Brix and 60°Brix.

According to Pandharipande and Gaikar (2015), percentage weight reduction of osmo dehydrated orange carpel varied from 9 to 44% depending upon the operating parameters like sugar syrup concentration (20, 30 and 50°Brix), temperature (27, 35 and 45°C) and duration of treatment time (1h, 2h and 4h). The most parameters were recorded as sugar solution concentration of 50°Brix at a temperature of 45°C with a duration of osmosis for 4h.

The efficiency of mass transfer during osmotic dehydration is determined by several factors which include the physico chemical properties of raw material, type and concentration of osmotic agent used, mass ratio of raw material to osmotic solution, temperature and process time (Ciurzynska *et al.*, 2016).

Ravula *et al.* (2017) observed the effect of temperature (45–55°C), immersion time (2 and 3h), and sucrose concentration (45–55% w/v) on moisture loss and solid gain during the osmotic dehydration of carrot slices. Moisture loss increased with sucrose solution concentration and immersion time at constant temperature because of the decrease in moisture content, weight loss of the carrot slices after the osmotic dehydration occurred. Zahoor and Khan (2017) performed osmotic dehydration of pineapple using three different temperature (40°C, 50°C and 60°C), three different osmotic solution concentration (40%, 50% and 60%) with sample to solution ratio of 1:4, 1:5 and 1:6 respectively. Water loss and solid gain increased with increase in temperature and osmotic solution concentration. The highest mass transfer was observed at 60% osmotic solution concentration and temperature of 60°C.

Correa *et al.* (2018) found that water loss, weight reduction and solid gain increased with increase in temperature and concentration of hypertonic solution during osmotic dehydration of pumpkin slices and the most significant change in moisture loss occurred during the first 6h of the treatment. It was shown that higher temperature and higher sucrose concentration led to greater transfer of solutes upto 2.53% in 10h immersion time.

Shukla *et al.* (2018) studied osmotic dehydration of banana using three solution concentrations (40, 50 and 60%) of osmotic agents *viz.,* sucrose, fructose and maltodextrin at three different temperature of osmotic solution (40, 50 and 60°C) and reported that water loss and solid gain increased with increase in concentration and temperature of sucrose solution.

2.3 BIOCHEMICAL CHARACTERS

Sagar *et al.* (1998) estimated total sugar and reducing sugar content in osmo dehydrated mango pieces which varied from 56.21% to 67.30% and 25.35% to 29.79% respectively. Rashmi *et al.* (2005) studied osmo air dehydration of pineapple in 70°Brix sugar syrup and observed removal of significant amount of moisture and observed that reducing sugar increased with increase in concentration of sugar solution and it was 41.86, 38.34 and 37.34% at 50°Brix, 60°Brix and 70°Brix respectively. Fernandes *et al.* (2006) explained that higher osmotic solution concentrations increased the total soluble solids of the final dried product even upto 64.4°Brix when bananas were osmotically treated using sugar solutions of 50 and 70°Brix both at 50 and 70°C. Rai *et al.* (2007) conducted osmotic dehydration of pineapple slices with 70°Brix sugar solution and reported increase in TSS with a final value of 79°Brix at 50°C. Kumar *et al.* (2008) osmotically dehydrated guava slices and observed that total sugar and reducing sugar content increased with increase in the osmotic concentration. Chavan *et al.* (2010) observed that osmo dehydrated banana slices prepared by immersing in 60°Brix sugar solution containing 0.1% KMS + 0.1% citric acid + 0.2% ascorbic acid had better quality with increased TSS of 66°Brix, improved appearance, colour, flavour, texture, taste and overall acceptability with non stickiness of the product.

Anand and Genitha (2011) demonstrated that concentration of osmotic solution and duration of treatment is directly proportional to TSS and maximum increase of 20% was observed at 55°Brix at 50°C for 90 min whereas minimum increase of 11.11% at 45°Brix at 30°C for 30 min during osmotic dehydration of banana spears. Ghadge (2013) reported higher TSS for osmotically dehydrated ripe banana with increase in the sugar syrup concentration. Percentage of total sugar and reducing sugar also exhibited an increasing trend with increase in the concentration of sugar syrup used for osmotic dehydration. Pineapple slices treated with 40% sucrose w/v and 2% $CaCl_2$ was identified as the best osmodehydrated sample with lowest acidity (0.10%), average ascorbic acid (7.73 to 8.70 mg $100g^{-1}$), reducing sugar (22.50%), total sugar (43.06%) and rehydration ratio (4.50) and was most accepted by the sensory panel (Sneha *et al.*, 2013).

Thippanna and Tiwari (2015) experimented osmotic dehydration of Robusta and Ney Poovan varieties of banana and statistically significant differences were observed for moisture content, reducing and total sugar content and titrable acidity in dehydrated slices. Osmotic pretreatment using 70°Brix sugar syrup for 24h resulted in maximum reducing sugar (53.78%), non-reducing sugar (19.93%) and total sugar (73.73%) in banana slices. 'Robusta' slices had higher acidity (1.31 %) than the 'Ney Poovan' (1.00%). They concluded that sugar syrup of 60°Brix for 24h was best for banana varieties Robusta and Ney Poovan and osmodehydrated Robusta slices were significantly superior over Ney Poovan slices. According to Rahim *et al.* (2018), osmotic concentration of 50°Brix is ideal for osmo dehydration of pineapple slices which resulted in the highest TSS of 19.23°Brix and reducing sugar of 18.90%. Increase in osmotic concentration and immersion time resulted in decreased acidity of osmo dehydrated carrot slices (Selvakumar and Tiwari, 2018).

In many studies, ascorbic acid has been taken as an index of nutrient quality of foods (Gregory, 1996). Ascorbic acid is known to be a labile vitamin that loses activity because of pH, moisture content, oxygen, temperature and metal ion catalysis (Uddin *et al.,* 2001). Several researchers reported degradation of ascorbic acid during osmo dehydration in several fruits (Vieira *et al.,* 2000; Uddin *et al.,* 2002).

Roble-Manzanares *et al.* (2004) osmotically dried quince slices in fructose solution having concentrations of 45, 55 and 60°Brix at 30, 40 and 50°C and suggested that osmotic concentration of 45 and 55°Brix at a temperature of 30°C resulted in maximum retention of ascorbic acid. Ramallo and Mascheroni (2010) observed about 30% loss of ascorbic acid and citric acid during osmotic dehydration of pineapple. Torte (2010) reported that osmotic dehydration lead to reduction in acidity of the treated fruits. In prolonged OD treatment of cantaloupe followed by hot air drying, Phisut *et al.* (2013) reported high losses of ascorbic acid when using a long osmotic dehydration time. Studies of cashew apple (Azoubel *et al.,* 2009) and sea buckthorn fruits (Araya-Farias *et al.,* 2014) revealed lower ascorbic acid content after osmo dehydration. According to Kurozawa *et al.* (2014) ascorbic acid is heat sensitive thus higher drying temperature led to higher degradation as well as a rapid enzymatic inactivation of ascorbic acid oxidase activity. Lower ascorbic acid were attributed to the leaching of vitamin C from the product to the osmotic solution (Yadav and Singh, 2014). Singh *et al.* (2015) osmotically dried papaya slices in sugar concentrations of 50, 55 and 60°Brix and reported that vitamin C content exhibited a decreasing trend from 45 mg $100g^{-1}$ to 44.6 mg $100g^{-1}$ with increase in osmotic solution concentration.

de Castro *et al.* (2016) conducted osmotic dehydration of guava slices in sucrose syrup of 40, 50 and 60°Brix at temperatures of 30, 40 and 50°C and reported that osmotic dehydration followed by drying process lead to an increase in both total sugar and reducing sugar percentage of guava slices while a reduction in acidity and vitamin C was observed as a result of osmotic dehydration and drying process. During osmo dehydration of black mulberry fruit in sugar solution of 55°Brix for 5h at a temperature of 40°C, reduction of acidity, vitamin C and antioxidant activity was observed while increase in TSS was noticed after osmotic dehydration (Ojha *et al.*, 2017).

Madan and Dhawan (2005) conducted an osmotic dehydration experiment on carrot slices using 65°Brix sugar syrup as osmotic agent for 3h followed by drying at 60°C for 15h and reported higher retention of carotene compared to air dried slices without osmosis. Kaur and Sogi (2017) studied osmo dehydration of carrot slices and reported reduction in carotenoid content in both red and orange carrot. According to Lenka and Tiwari (2018), decrease in carotenoid content was observed when mango slices of alphonso and totapuri varieties were osmotically dehydrated for 24h. The reduction of the carotenoid content during osmo dehydration may be due to destabilization of polyene chains present in carotenoid and therefore making them prone to many alterations by oxidation or isomerization causing changes in their primary structure (Salazar *et al.*, 2019).

Wojdylo *et al.* (2007) reported that osmo dehydration process caused degradation of some phenolic compounds and thus reduces the antioxidant capacity and the reduction in antioxidant activity increases with increase in osmotic solution concentration and duration of treatment. Antioxidant components like polyphenols and anthocyanin content in bilberries significantly decreased as a result of long exposure time and high osmotic concentration (Michalczyk *et al.*, 2009). According to Martin-Cabrejas *et al.* (2009) and Qu *et al.* (2010), a decrease in antioxidant activity during drying can also be attributed to the binding of polyphenols with other compounds (proteins) or due to alterations in the chemical structure of polyphenols which cannot be extracted or determined by available methods. According to Devic *et al.* (2010), decrease in antioxidant compounds during osmo dehydration of apples might be due to leaching of water soluble phenolics into the osmotic solution. The decrease in antioxidant activity in osmotic dehydration might be due to drying temperature which cause destruction of some endogenous antioxidants (Udomkun *et al.*, 2015). Prolonged immersion time were found to be unfavourable for the retension of antioxidant compounds (Chiu *et al.*, 2017). Islam *et al.* (2019) studied osmo dehydration of papaya and observed significantly reduced antioxidant activity during osmo dehydration and drying process.

2.4 PHYSICAL CHARACTERS

Khedkar and Roy (1988) observed lower rehydration ratio in osmo dehydrated mango which might be due to degradation of pectic polysaccharides during drying procedure.

Colour is associated with the quality of product and may be taken as the indicator of level of natural deterioration of fresh foods (Krokida *et al.*, 2000). Fruits and vegetables undergo volumetric changes upon water loss which is expressed as textural quality. Any modifications during osmo dehydration affect the moisture transport properties as well as texture of the product (Raghavan and Silveria, 2001).

Osmotic dehydration increased the sugar to acid ratio and improves the texture and stability of pigments during dehydration (Rastogi *et al.*, 2002). According to Rodrigues *et al.* (2003), higher sugar concentration resulted in browning of osmo dehydrated papaya and the colour development increased with osmotic concentration. Increased yield in osmo dehydrated fruits is due to penetration of sugar into the fruits and yield increased with increase in osmotic concentration and immersion time (Togrul and Ispir, 2007).

Generally, the colour of the osmo dehydrated sample was found more attractive than the control due to sugar infusion which improved pigment stability and inhibited browning reaction (Sagar and Kumar, 2010). Slightly darker colour was obtained in osmo dehydrated mango probably due to Maillard reactions induced by the presence of sugar (Korbel *et al.*, 2013). Increased browning index may be due to Maillard reactions (Phisut *et al.*, 2013). Pedapati and Tiwari (2014) conducted osmotic dehydration of different varieties of guava and found that yield was highest in Allahabad Safeda (34.73%) than Pink Flesh (33.79%) and yield increase was due to the increase in solid gain and weight reduction of osmo dehydrated products. Browning index of any osmo dehydrated product show the colour change towards the brownness of the product. Browning index exhibited an increasing trend with increase in osmotic solution concentration in longitudinal, round and ring slices of nendran banana. It may be due to an increase of soluble solids content of the fruit (Keerthishree *et al.*, 2017).

Singh *et al.* (2007) reported decrease in rehydration ratio with increase in osmo dehydration time. Fante *et al.* (2011) conducted osmo dehydration of plums with sucrose solution of 40, 50 and 60°Brix and reported that increased sucrose concentration resulted in decreased rehydration ratio. Rehydration ratio of osmo dehydrated product depends on process parameters and when glycerol and sucrose were used as osmotic agents, significant difference was observed in rehydration ratio of osmo dehydrated carambola slices (Barman and Badwaik, 2017). According to Doymaz (2017), rehydration characteristics of dried products are widely used as the quality index. Rehydration ratio is an indication of the extent of damage during drying of osmo dehydrated samples. Popescu *et al.* (2018) observed lower rehydration ratio during osmo dehydration of plums which might be due to the absorbed sugar that lead to more compact tissue structure and fruit surface saturated in sugar made it difficult to absorb the water. The reconstitution characteristics of the dehydrated product depends on the internal structure of the product as well as the extent of damages occurred to the water holding components of the product during drying. Salazar *et al.* (2019) reported lower rehydration values during reconstitution of dehydrated pineapple slices which could be due to the formation of a protector at a structural level before dehydration.

2.5 SENSORY ANALYSIS OF OSMO DEHYDRATED FRUITS

According to Torreggiani (1993) immersion of papaya and mango slices in 0.4% ascorbic acid solution and 0.4% ascorbic acid + 0.1% KMS solution for 30 min prior to osmotic dehydration resulted in a highly acceptable product. The osmotic dehydration process can be applied to various fruits such as strawberries, mangoes, pineapple, banana, plantain and apples, as well as to vegetables such as pepper, potato and tomato. Sunjka and Raghavan (2004) suggested that immersion of fruits and vegetables in acid or alkaline solutions prior to drying helped in retaining the colour of the final product.

In the case of mango, sensory attributes such as flavour, colour and texture are retained to an acceptable level for about one year (Falade and Aworh, 2005). Since osmotic dehydration is efficient at room temperature, heat damage to several organoleptic properties is reduced and high sugar concentration of the osmotic solution which surrounds the fruits and vegetables prevent discolouration. According to Panda *et al.* (2005) osmo dehydration of grapes at 55°C temperature, 60°Brix sugar solution concentration and sample to solution ratio 1:4 were the best with respect to colour, texture and overall acceptability and scored maximum mean score for taste. Sensory evaluation of osmo dehydrated star fruit revealed that osmotic dehydration of star fruits in 50°Brix sugar syrup at 27°C secured higher mean scores and were more accepted by consumers with respect to appearance, texture, and flavour compared to air-dried star fruits (Shigematsu *et al.*, 2005). Ehabe *et al.* (2006) demonstrated that soaking in sugar solutions improved the texture of banana figs and consumers showed preference for osmo dehydrated bananas than air dried bananas. According to Sachadev *et al.* (2007) when apple slices were osmotically dehydrated using 50°Brix and 70°Brix osmotic solution and KMS and blanching as pretreatments, apple slices treated with KMS for 15 min and osmotic dehydration using 50°Brix sugar syrup showed better retention of colour, appearance and taste of apple slices.

Osmotic dehydration improves textural properties of final dried product making it more flexible and less dense (Blanda *et al.*, 2009). Banana slices were osmotically dried in acidified or sulfited sucrose solution (60°Brix) for 1.5, 3h, 6 and 12h and air-dehydrated at 60°C for 12h and mean scores for overall acceptability increased with increase in process time with highest mean score for 12h immersion time (Youssef, 2009). The osmo dehydrated banana slices prepared by soaking fruit slices in 60°Brix sugar syrup containing 0.1% KMS + 0.1% citrate + 0.2% ascorbic acid were found better with respect to colour and appearance, flavour, texture, taste and overall acceptability with non-stickiness of the product (Chavan *et al.*, 2010).

Acceptability of dehydrated products by the consumer is highly dependent on its sensory attributes. Sensory evaluation of food products is a method of accurate measurement of human responses to food with minimal biasing effects (Ong and Law, 2010).

Osmotic dehydration of carrot cubes in 50°Brix sugar solution for 2h immersion time was found to be the best with respect to improvement in colour and highest mean score (Singh *et al.*, 2010). Osmo dehydrated products have sweeter taste compared to conventionally dried products. The final product after osmo dehydration were very much appreciated for direct utilization due to their better physicochemical properties and nutritional profile (Tortoe, 2010). Enzymatic browning of fruits and vegetable products can be prevented by dipping them in 1.0% citric acid solution before osmotic dehydration process and the use of highly concentrated sugar solution for osmosis retains the colour of the final product (Yetenayet and Hosahalli, 2010).

Osmo dehydration of pineapple slices in 40°Brix sucrose solution at 60°C for an immersion time of 24h were most preferred in terms of sensory attributes *viz*., colour, flavour, texture and taste of the dehydrated slices (Sawant *et al*., 2011). Najafi *et al.* (2014) conducted osmo dehydration studies in red pitaya using sugar solutions of 40, 50 and 60°Brix at 30°C and analysed different organoleptic characters mainly the texture of the final product and observed that the osmotically dehydrated samples were considerably softer in texture than the untreated samples and suggested that increasing trend in sucrose concentration and immersion time caused softer tissue of dehydrated product compared with the fresh red pitaya.

Singh *et al.* (2015) conducted osmotic dehydration of papaya slices and reported that 60°Brix sugar solution concentration at 50°C and cabinet drying at 70°C resulted in most accepted product with better texture (8.20), colour (9.00), taste (8.00) and the highest mean score of 9.00 for overall acceptability. Thippanna and Tiwari (2015) reported that osmo dehydration of banana slices in 60°Brix sugar syrup for 24h resulted in best quality final product with highest sensory score.

Mahesh *et al.* (2017) reported highest overall acceptability for osmo dehydrated pineapple slices when osmotic dehydration was carried out using 50°Brix sugar syrup at a temperature of 25°C for 24h treatment time. Ravula *et al.* (2017) investigated the effect of temperature (45-55°C), immersion time (2h and 3h) and osmotic concentration (45°Brix and 55°Brix) on sensory attributes *viz.*, appearance, colour, flavour, taste and overall acceptability of the dehydrated carrot slices. Sensorial quality of osmo dehydrated carrot slices was determined using 9 point hedonic scale with a 10 member consumer panel. Based on the quality studies, the optimum operating conditions were found to be 55°Brix osmotic solution at 55°C for an immersion time of 2h with highest sensory evaluation score for overall acceptability, colour, appearance and odour.

Priyanka *et al*. (2018) reported that osmotically dried banana slices in sucrose solution of 70°Brix with sample to solution ratio 1:3 with final moisture content of 14% was best in organoleptic properties with the highest mean score of 8.00 for colour, appearance, texture, flavour and overall acceptability and 7 for texture. The osmo dehydrated carrot slices prepared in sugar syrup of 60°Brix concentration containing 0.1% citric acid+ 0.1% KMS were found better with respect to colour, appearance, flavour, texture, taste and overall acceptability with non-stickiness of the product (Selvakumar and Tiwari, 2018).

According to Kumar *et al.* (2019), osmotic dehydration of papaya slices in 55°Brix at 60°C resulted in highly accepted final product with highest mean score for colour (6.00), taste (7.00), flavour (8.00) and overall acceptability (9.00).

2.6 STORAGE STUDIES OF OSMO DEHYDRATED FRUITS

Good quality, food grade and air tight containers are suggested as packaging materials for the storage of osmo dehydrated foods. According to Sagar and Khurdiya (1999), aluminum foil, laminated polypropylene pouches are suggested as ideal packaging materials for osmo dehydrated products. Storage studies of osmo dehydrated products were conducted mainly by packing the dehydrated products in 200 gauge polypropylene covers and monitoring the changes in biochemical, microbial and organoleptic characters at monthly intervals. Chavan and Amarowicz

(2012) conducted storage studies of osmo dehydrated banana slices in polypropylene covers and reported a shelf life of six months under room temperature.

2.6.1 Biochemical Parameters of stored osmo dehydrated fruits

Osmo dehydrated papaya slices packed in high density polyethylene pouches and stored at room temperature remained stable up to 6 months to 1 year (Ahmed and Choudhary, 1995). Since water activity level of osmo dehydrated fruits and vegetables was much lesser, various chemical reactions as well as growth of microorganisms are ceased. Sagar and Khurdiya (1999) reported that laminated polypropylene pouches and aluminum foil are better for packaging of osmo dehydrated products. Optimum relative humidity of 55-70% and moisture content from 2-20% is suggested as the optimum storage condition for osmo dehydrated products (Perera, 2005).

Kumar *et al.* (2008) reported decline in carotenoid content in osmo dehydrated mango slices when stored for a period of six months. Storage study of osmo dehydrated banana slices for a period of 6 months revealed that there was a marginal decrease in ascorbic acid (11.1mg $100g^{-1}$ to 10.4mg $100g^{-1}$) and mean score of organoleptic qualities *viz.*, colour and appearance (8.8 to 8.3), flavour (8.2 to 7.8), texture (8.4 to 7.6), taste (8.3 to 7.5) and overall acceptability (8.4 to 7.8) and increase in TSS (66.5°Brix to 67.7°Brix), total sugar (63% to 64%) and reducing sugar content (10.7% to 11.1%) of osmo dehydrated banana slices (Chavan *et al.*, 2010). Decrease in antioxidant activity was observed when osmo dehydrated apples, sour cherries and blackcurrants were stored for a period of 12 months (Piasecka *et al.*, 2011). Khan *et al.* (2014) studied storage stability of osmo dehydrated strawberry osmosed in 30°Brix sugar syrup containing different chemical preservatives and storage study for 3 months resulted in decreased pH (3.49 to 3.32), ascorbic acid, non-reducing sugar, colour score, texture score, flavour score and overall acceptability score (9 to 5.40) while recorded increase in TSS from 17.17°Brix to 21.01°Brix and reducing sugar from 8.35 to 11.16% throughout storage period.

Gamit (2015) during storage analysis of osmo dehydrated pomegranate arils for a period of 6 months observed that there was an increasing trend in TSS (44.08 to 49.11°Brix), reducing sugar (34.92% to 37.16%) and decreasing trend for acidity (1.53% to 1.41%) and ascorbic acid (20.51mg $100g^{-1}$ to 19.33 mg $100g^{-1}$). Storage quality of osmo dehydrated pineapple slices were analysed for a duration of 90 days by Mahesh *et al.* (2017) and results showed increase in moisture content, total sugar and reducing sugar while a decreasing trend was observed for ascorbic acid and acidity.

Priyanka *et al.* (2018) observed that osmo dehydrated banana fig packed in aluminium and polypropylene pouches were acceptable in terms of nutritional and biochemical aspects throughout the storage period of 6 months. Osmotic dehydration of pineapple in 50°Brix sugar solution and further storage analysis revealed that TSS showed a slight increase from 19.23°Brix to 19.42°Brix and marginal decline in titrable acidity from the initial to 8 months of storage (Rahim *et al.*, 2018). Selvakumar and Tiwari (2018) conducted storage studies of osmo dehydrated carrot slices prepared using 40°Brix, 50°Brix, 60°Brix and 70°Brix sugar solution and there was a reduction in titrable acidity (0.40% to 0.33%), organoleptic quality and carotenoid content during storage whereas increase in total sugar and reducing sugar was observed during a storage period of 6 months.

2.6.2 Sensory analysis of stored osmo dehydrated fruits

Sabrina *et al.* (2009) observed decline in overall acceptability of osmo dehydrated mango slices during storage. The sensory analysis during storage of osmo dehydrated banana showed a marginal decrease in colour, flavour, texture, taste and overall acceptability during the storage period of 6 months (Chavan *et al.*, 2010).

Khan *et al*. (2014) observed a marginal decrease in mean score for sensory attributes *viz.,* colour, texture, flavour and overall acceptability of stored osmo dehydrated strawberry fruit throughout the storage period of 3 months. Gamit (2015) studied the effect of process temperature in osmotic dehydration of pomegranate arils and subsequent changes during storage period and observed that sensory score of pomegranate arils showed a decreasing trend in mean score for colour, flavour, texture, taste and overall acceptability.

According to Mahesh *et al.* (2017), mean scores of osmo dehydrated pineapple slices during storage for 90 days declined with the progress of storage period. Aparna *et al.* (2018) observed slight reduction in mean scores for sensory parameters *viz.,* taste, colour, flavor, texture and overall acceptability when storage study was conducted on osmo dehydrated bilimbi for a period of four months. Gurumeenakshi and Varadharaju (2018) studied osmotic dehydration of Bangalora and Pairi varieties of mango and observed a considerable decrease in mean scores for various sensory attributes and suggested that osmo dehydrated fruit slices pretreated with ascorbic acid, KMS and citric acid retained high acceptable qualities throughout the storage period. Sensory attributes of osmo dehydrated banana fig for a period of 6 months showed a decreasing trend in colour, appearance, taste, flavour and overall acceptability (8 to 7) throughout the storage period (Priyanka *et al*., 2018). According to Selvakumar and Tiwari (2018), after subsequent storage period there was slightly lower score for colour, texture and flavour for osmo dehydrated carrot slices obtained with 50°Brix sugar solution in 40h and 60°Brix sugar solution in 20h and was found to maintain superior organoleptic qualities even at the end of six months of storage at room temperature.

2.6.3 Microbial analysis of stored osmo dehydrated fruits

Osmo dehydration process decreases the moisture content and water activity to a desirable level which is low enough to prevent the growth of microorganism

(Ahmed and Choudhary, 1995). Osmotic treatment of banana figs in NaCl and sugar composite solution improved the quality of final product during storage period and no visible fungal load was present on the surface of figs (Ehabe *et al.*, 2006). The combination of low pH and water available for microbial growth significantly reduced the incidence of microbial spoilage (Tiganitas *et al.*, 2009). Chavan *et al.* (2010) reported that osmo dehydrated banana slices was found microbiologically safe with acceptable nutritional and sensory quality after storage period of 6 months.

According to Gamit (2015), no apparent microbial spoilage was observed in osmo dehydrated pomegranate arils. Osmo dehydrated pomegranate arils packed in polyethylene packs of 200 gauge HDPE possessed good microbial quality throughout the storage period of 6 months and was safe for consumption. According to Gurumeenakshi and Varadharaju (2018), storage of osmo dehydrated Bangalora and Pairi mango slices in metallised polypropylene packs revealed there was no bacterial incidence initially in all the treatments and a negligible growth in bacterial population was noticed after 180 days of storage, while no fungal and yeast colonies was found in both the varieties.

Banana figs packed in aluminium and polypropylene pouches were subjected to storage studies for 6 months at room temperature and the samples showed no microbial incidence *viz.*, bacterial, fungal and yeast population and was also free from E. coli bacteria (Priyanka *et al.*, 2018).

Materials and Methods

3. MATERIALS AND METHODS

The materials used and methodologies adopted during the present investigation "Development of osmo dehydrated Red Banana (*Musa* spp.)" conducted with the objective to standardize different process variables *viz.* fruit slice shape, osmotic concentration and immersion time for osmo dehydration of red banana and to assess the storage stability of the prepared osmo dehydrated red banana are described in this chapter.

3.1 DEVELOPMENT OF OSMO DEHYDRATED RED BANANA

The experiment was conducted at Department of Post Harvest Technology, College of Agriculture, Vellayani, Kerala Agricultural University, during the year 2017-2019. Good quality uniform sized, fully ripe red banana free from pests, diseases and mechanical damages were procured from the Instructional Farm, Vellayani and from VFPCK progressive farmers. After removing the outer peel of optimally ripened red banana, the edible fruit portion was made into slices of 5 mm thickness, in three shapes *viz*., ring, round and chunks. Sucrose syrup of three different concentrations *viz*. 40°Brix, 60°Brix, 80°Brix were prepared and 0.1% potassium metabisulphite, 0.1% citric acid and 0.2% ascorbic acid were added to the osmotic solution.

Prepared red banana slices of three different shapes; ring (S_1), round (S_2) and chunks (S_3) were osmosed in 40°Brix (C_1), 60°Brix (C_2) and 80°Brix (C_3) for different immersion time of 60 minutes (T_1), 120 minutes (T_2) and 180 minutes (T_3) with three replications (Plate 1). The ratio of fruits to osmotic solution was maintained at 1:1 w/w. After the osmotic treatment, solution was drained quickly and the samples were analysed for different mass transfer characters.

3.1.1. Mass Transfer Characters of Osmosed Red Banana Slices

Mass transfer characters *viz*., solid gain, water loss, percentage weight reduction and ratio of water loss to solid gain (WL/SG) were determined using standard procedure.

3.1.1.1 Water Loss (%)

Weight of fresh red banana slices and weight after osmosis was recorded in electronic balance (Cyber Lab-0.01mg to 1000mg). Dry mass of fresh fruit and dry mass after osmosis were recorded and water loss in terms of percentage was calculated by the method described by Sridevi and Genitha (2012) using following formula:

a. Slicing of optimally ripened red banana

b. Osmotic treatment

c. Drying

Plate 1. Osmo dehydration process of red banana

$$WL(\%) = \frac{(Wo - Wt) + (St - So)}{Wo} x100$$

W_o = Initial weight of fruit slices

W_t = Weight of fruit slices after osmotic dehydration

S_0 = Initial dry mass of fruit slices

S_t = Dry mass of fruit slices after osmotic dehydration

3.1.1.2 Solid Gain (%)

Solid gain (%) of osmo dehydrated red banana was determined as per the procedure described by Kowalski and Mierzwa, (2011).

$$SG(\%) = \frac{St - Si}{mi} X\,100$$

Where, S_t = dry mass at time t, S_i = Initial dry mass (of fresh) and m_i= initial mass of wet sample.

3.1.1.3 Weight Reduction (WR)

Weight reduction of red banana slices after osmosis in terms of percentage was calculated using the method described by Yadav *et al.* (2012).

$$WR(\%) = \frac{Mo - M}{Mo} \times 100$$

Mo = Initial mass of fruit slices prior to osmosis (g)

M = Mass of fruit slices after osmosis (g)

3.1.1.4 Water Loss to Solid Gain (WL/SG)

Water loss to solid gain is expressed as ratio of calculated value of water loss and solid gain.

$$\frac{WL}{SG} = \frac{\%waterloss}{\%solidgain}$$

3.1.2 Dehydration of Osmosed Red banana slices

The osmosed banana slices were finally dehydrated using a cabinet dryer (Plate 2.) at 50°C till the product attained moisture of 17±1%. Biochemical parameters, physical parameters and sensory attributes of osmo dehydrated red banana were analysed.

3.1.2.1 Biochemical Parameters

Biochemical parameters *viz.* TSS, total sugar, reducing sugar, vitamin C, titrable acidity, carotenoids and antioxidant activity were analysed.

3.1.2.1.a. Total Soluble Solids (°Brix)

Total Soluble Solids (TSS) of osmo dehydrated red bananan slices was recorded by Atago - 0 to 53% digital refractometer and was expressed in °Brix.

3.1.2.1.b. Total Sugar (%)

The total sugar content was expressed as per cent (Ranganna, 1986) according to the following formula

$$\text{Total sugar (\%)} = \frac{\text{Glucose Eq. (0.05) x Total vol. made up (ml) x Vol. made up after inversion (ml) x 100}}{\text{Titre value x Weight of pulp taken (g) x Aliquot taken for inversion (ml)}}$$

3.1.2.1.c. Reducing Sugar (%)

The titrimetric method of Lane and Eynon described by Ranganna (1986) was adopted for the estimation of reducing sugar. Reducing sugar expressed as percentage was calculated according to the following formula

$$\text{Reducing sugar (\%)} = \frac{\text{Glucose Eq. (0.05) x Total vol. made up (ml) x 100}}{\text{Titre value x Weight of pulp taken (g)}}$$

3.1.2.1.d. Acidity (% citric acid)

Titrable acidity was measured as per the procedure described by Ranganna (1986). The titrable acidity was expressed in terms of per cent citric acid equivalent using following formula.

$$\text{Acidity} = \frac{\text{Titre value X 0.1 X Volume made up (ml) X 0.064}}{\text{Volume of sample taken (ml) X Wt of the sample (g) X 10}}$$

3.1.2.1.e. Vitamin C (mg $100g^{-1}$)

The titrimetric method using 2,6 dichlorophenol Indophenol described by Ranganna (1986) was adopted for the determination of vitamin c.

$$\text{Vitamin C} = \frac{\text{Titre value X Dye factor X Volume made up (ml)} \quad \text{X 100}}{\text{Aliquot of extract taken (ml) X Wt. of sample (g)}}$$

3.1.2.1. f. Carotenoids ($\mu g\ 100g^{-1}$)

Carotenoids were estimated as per the procedures of Saini *et al.* (2001) and expressed as $\mu g\ 100g^{-1}$ of treated fruit.

3.1.2.1. g. Antioxidant Activity (%)

Total antioxidant activity of osmodehydrated red banana was determined using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay. The scavenging effect on DPPH free radical was measured according to the procedure described by Sharma and Bhat (2009). Scavenging effect was expressed as per cent DPPH as shown in the following equation:

$$\text{\% inhibition of DPPH} = \frac{\{A_{blank} - A_{sample}\} \times 100}{A_{blank}}$$

Where,

A_{blank} – Absorbance of DPPH solution without sample

A_{sample} – Absorbance of the test sample after 30 min

3.1.2.2. Physical Parameters

Physical parameters of osmo dehydrated red banana slices *viz.* yield, rehydration ratio, colour (browning index) and textural quality were analysed according to the standard procedures.

3.1.2.2.a. Yield (%)

Weight of osmodehydrated product obtained from a known quantity of fresh red banana fruit slices were recorded and the yield was calculated using the formula.

$$\text{Yield} = \frac{\text{Weight of dehydrated fruit}}{\text{Weight of fresh fruit}} \times 100$$

3.1.2.2.b. Rehydration ratio

Five gram of dehydrated red banana sample was added to 100 ml of water, boiled for 3 minutes, filtered and the sample was weighed. The rehydration ratio was calculated as described by Yadav *et al*. (2012).

$$\text{Rehydration ratio} = \frac{\text{Weight of rehydrated sample}}{\text{Weight of dried sample}}$$

3.1.2.2.c Browning Index (BI)

Colour of the dehydrated product was recorded using Konica Minolta colourimeter by measuring 'L', 'a' and 'b' values where 'L' indicates lightness or darkness, 'a' greenness or redness and 'b' blueness or yellowness. From these primary colour values, the browning index was calculated as below given by the commission Internationale d' Eclairage.

$$BI = \frac{100(X - 0.31)}{0.17}$$

$$\text{Where } X = \frac{(a + 1.75\,L)}{(5.645L + a - 3.012b)}$$

3.1.2.2.d. Textural properties

Textural properties of the dried slices were measured using a texture analyzer TA–HD® (Stable Micro systems, Surrey, England) (Plate 3.). Following conditions/settings were adopted for the experiments, mode-force/cutting: option-return to start, pre test speed = 5mm/s; test speed = 2 mm/s; post test speed = 10 mm/s; distance = 10 mm; trigger force = 5 g; strain= 90%. Samples were placed on the platform of the texture analyzer in their natural resting position to get a uniform contact area between the platform and cutting device. The slices were placed with their major axis perpendicular to the knife edge. Cutting force (kg) was measured by cutting the samples by fixing a HDP/BSK blade set with knife provided along with the instrument and cutting energy (kgs) of the samples was measured as area from the graph plotted with force and time as Y and X axis (Sajeev *et al*., 2011).

Plate 2. Cabinet drier

Plate 3. Food Texture Analyser

3.1.2.3. Sensory analysis

3.1.2.3.a Sensory analysis of osmo dehydrated red banana slices

Osmo dehydrated red banana slices prepared by different treatments were evaluated for sensory characteristics *viz.*, appearance, taste, colour, flavour, odour, texture and overall acceptability by 30 semi trained members. Each character was given a score from 1 to 9 according to Hedonic rating (Ranganna, 1986). Sensory analysis was separately carried out for each shape to obtain the best 3 treatments (from each shape) (Plate 4.) from total 27 treatments.

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

The score was statistically analysed using Kruskall-Wallis test (chi-square value) and ranked (Shamrez *et al.*, 2013). The three best treatments from each shape were selected for further storage studies.

3.1.2.3.b Sensory analysis of osmo dehydrated red banana slices after binding agent treatment

The best osmo dehydrated red banana obtained from Part I was subjected to binding agent treatment, corn starch, at 2 and 4 % level and was analysed for its sensory qualities as per the procedure described in *3.1.2.3.a.*

3.1.3 Storage Studies of Osmo dehydrated Red banana slices

Storage potential of three best osmo dehydrated red banana treatments from each shape was studied. Osmo dehydrated red banana slices (50g) packed and sealed in polypropylene cover (200 gauge) were stored at room temperature in five replications were analysed at

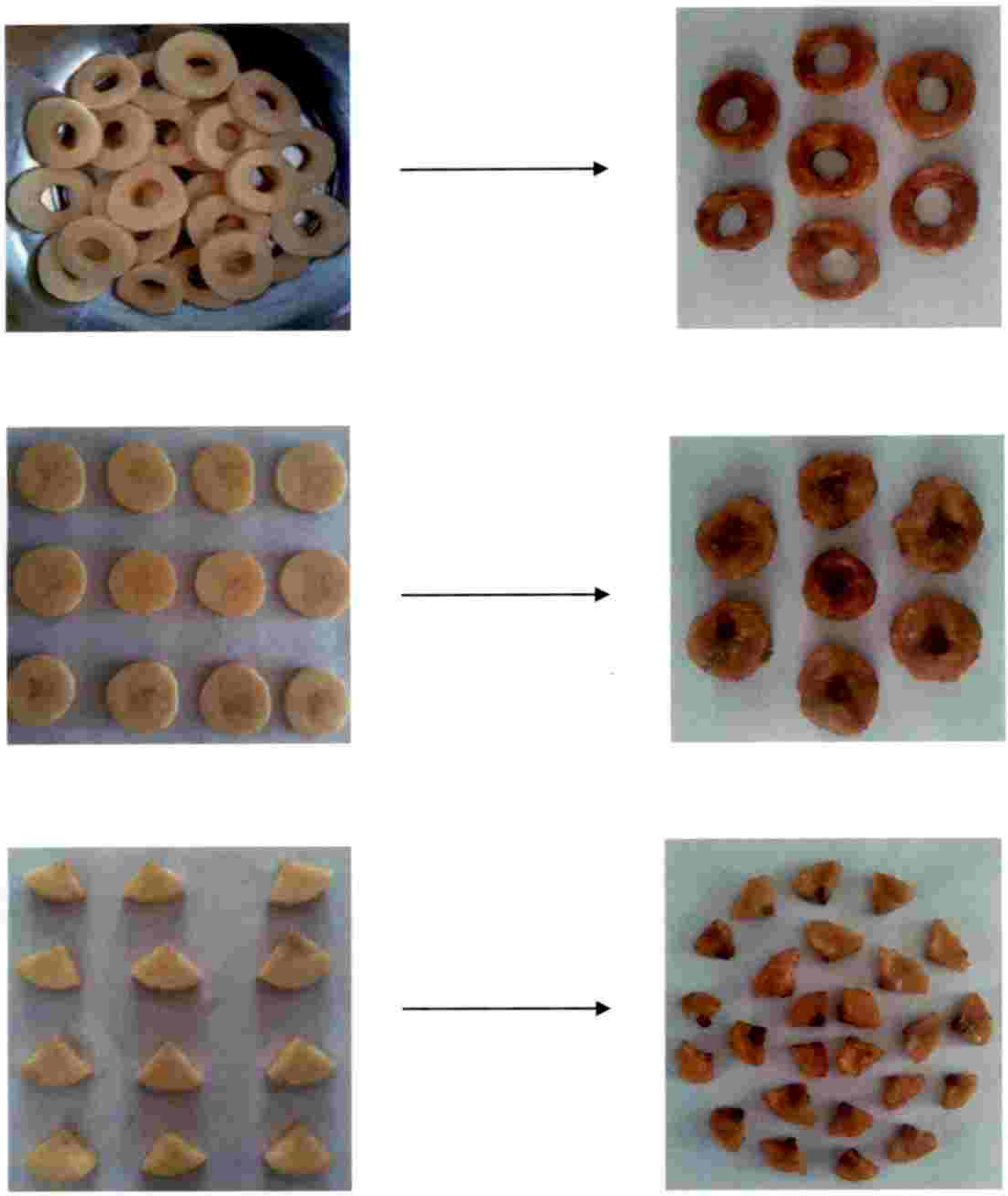

Plate 4. Osmo dehydrated red banana of different shapes

monthly interval for a period of four months for biochemical, sensory and microbial parameters.

3.1.3.1 Biochemical Parameters

3.1.3.1. a TSS (°Brix)

TSS during storage was calculated as described in 3.1.2.1.a

3.1.3.1. b Total Sugar(%)

Total sugar during storage was calculated as described in 3.1.2.1.b

3.1.3.1. c Reducing Sugar(%)

Reducing sugar during storage was calculated as described in 3.1.2.1.c

3.1.3.1.d Acidity (% citric acid)

Titrable acidity during storage was calculated as described in 3.1.2.1.d

3.1.3.1.e Vitamin C(mg 100g^{-1})

Vitamin C during storage was calculated as described in 3.1.2.1.e

3.1.3.1.f Carotenoids (µg 100g^{-1})

Carotenoids during storage was calculated as described in 3.1.2.1.f

3.1.3.1.g Antioxidant Activity (%)

Antioxidant activity as radical scavenging activity (DPPH) during storage was calculated as described in 3.1.2.1.g

3.1.3.2 Sensory analysis

Sensory analysis was conducted using hedonic scale as described in 3.1.2.3

3.1.3.3 Evaluation of Microbial Counts during Storage

The quantitative assay of the micro flora in stored osmo dehydrated red banana samples were carried out by serial dilution spread plate techniques. Nutrient agar, Rose Bengal agar medium and YEPD medium were used for the enumeration of bacterial, fungal and yeast population of dehydrated fruit slices respectively.

$$\text{No. of colony forming units Per gram of samples} = \frac{\text{Total no. of colony formed X dilution factor}}{\text{Aliquot taken}}$$

3.13.4 Statistical analysis

The data generated from experiments were statistically analyzed using Completely Randomized Design (CRD). Sensory parameters were statistically analysed using Kruskall Wallis test.

Results

4. RESULTS

Results of the present study "Development of osmo dehydrated Red Banana (*Musa* spp.)" are described in this chapter.

4.1 DEVELOPMENT OF OSMO DEHYDRATED RED BANANA

The effect of different shapes (Ring, Round and Chunks), osmotic solution concentration (40°Brix, 60°Brixand 80°Brix) and immersion time (60 min, 120 min and 180 min) on various mass transfer characters, biochemical, physical and sensory parameters of osmo dehydrated red banana slices were statistically analyzed and results are presented below.

4.1.1 Mass Transfer Characters

Mass transfer involves water out flow from the product to solution and solute transfer from the solution to product; thus possible to improve sensory quality of the product. These characters include water loss, solid gain, ratio of water loss to solid gain and percentage weight reduction.

4.1.1.1 *Water loss (%)*

Osmosed red banana slices showed varied water loss values with respect to different shape, osmotic solution concentration and immersion time, and are depicted in Table 1.

Osmotically dehydrated red banana chunks (S_3) showed the highest water loss of 4.51%, followed by ring shaped red banana (S_1) with a water loss of 3.52% and the lowest water loss of 3.19% was observed for round shaped red banana slices (S_2). With respect to osmotic concentration, 80°Brix (C_3) showed the highest water loss (5.35%) followed by 60°Brix (C_2) having a water loss of 3.59% and the lowest water

Table 1: Effect of shape, osmotic concentration and immersion time on water loss (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	1.09	3.41	4.16	2.89	1.15	1.48	2.68	1.77	2.58	2.40	4.52	3.17
T_2	1.93	3.52	4.39	3.20	1.42	2.84	4.28	2.85	2.60	4.40	7.14	4.71
T_3	2.90	4.48	5.81	4.40	3.97	5.30	5.56	4.94	2.84	4.52	9.59	5.65
Mean	1.98	3.80	4.79		2.18	3.21	4.17		2.67	3.77	7.08	
Mean	S_1 - 3.52 S_2 - 3.19 S_3 - 4.51		C_1 - 2.28 C_2 - 3.59 C_3 - 5.35			T_1 - 2.61 T_2 - 3.61 T_3 - 4.50						
SE(±m)	S - 0.106 S×C - 0.184		C - 0.106 S×T - 0.184		T - 0.106 C×T - 0.184			S×C×T - 0..318				
CD (0.05)	S - 0.300 S×C - 0.520		C - 0.300 S×T - 0.520			T - 0.300 C×T - 0.520			S ×C×T - 0.901			

loss of 2.28% was observed for 40°Brix (C_1). Among the different immersion time, T_3 (180 min) showed the highest water loss of 4.50% followed by T_2 (120 min) with 3.61% water loss and the lowest water loss of 2.61% was recorded for T_1 (60 min).

Osmo dehydrated red banana chunks at 80°Brix osmotic concentration recorded the highest water loss of 7.08% (S_3C_3) and it was 4.79% (S_1C_3) and 4.17% (S_2C_3) for round and ring slices respectively. Similarly, osmo dehydrated red banana chunks, round shaped and red banana rings at the immersion time of 180 min recorded the highest water loss of 5.65% (S_3T_3), 4.94% (S_2T_3) and 4.40% (S_1T_3) respectively.

Among the interactions, the highest water loss of 9.59% was observed for $S_3C_3T_3$ (chunks, 80°Brix, 180 min) followed by $S_3C_3T_2$ (chunks, 80°Brix, 120 min) with a water loss of 7.14% and the lowest water loss of 1.09% was observed for $S_1C_1T_1$ (ring, 40°Brix, 60 min).

4.1.1.2 *Solid gain (%)*

Solid gain during osmotic process of red banana slices influenced by shape, osmotic concentration and immersion time are given in Table 2.

Osmo dehydrated ring shaped red banana slices (S_1) recorded the highest solid gain of 7.01% followed by chunks shape (S_3) with a solid gain of 6.35% which was found to have no significant difference with round shaped osmo dehydrated red banana (S_2). When different osmotic concentration is considered, the highest solid gain of 7.02% was recorded for 80°Brix (C_3) followed by 60°Brix (C_2) with 6.41% solid gain which showed no significant difference with 40°Brix (C_1). Among different immersion time, the highest solid gain of 8.25% was observed for 180 min immersion time (T_3) whereas 7.31% was recorded for T_2 (120 min) and the lowest solid gain of 4.02% was recorded for T_1 (60 min).

Table 2: Effect of shape, osmotic concentration and immersion time on solid gain (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	3.29	6.64	7.63	5.85	3.10	3.35	3.30	3.25	2.75	3.07	3.02	2.95
T_2	6.90	7.00	7.68	7.19	7.32	6.75	7.75	7.27	7.53	7.41	7.49	7.48
T_3	7.84	7.30	8.80	7.98	8.19	7.64	8.62	8.15	8.41	8.56	8.90	8.62
Mean	6.01	6.98	8.04		6.20	5.91	6.56		6.23	6.35	6.47	
Mean	S_1 - 7.01 S_2 - 6.23 S_3 - 6.35		C_1 - 6.15 C_2 - 6.41 C_3 - 7.02		T_1 -4.02 T_2 -7.31 T_3 -8.25							
SE($\underline{+}$m)	S - 0.106 S×C - 0.184		C - 0.106 S×T - 0.184		T - 0.106 C×T - 0.184			S×C×T – 0.319				
CD (0.05)	S - 0.301 S×C - 0.522		C - 0.301 S×T - 0.522		T - 0.301 C×T - 0.522			S×C×T – 0.904				

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The highest solid gain of 8.04% was noticed in ring shaped osmo dehydrated red banana slices at 80°Brix (S_1C_3) and 6.56% (S_2C_3) was recorded for round which statistically showed no significant difference with osmo dehydrated red banana chunks (S_3C_3). Osmo dehydrated red banana chunks at an immersion time of 180 min recorded the highest solid gain of 8.62% (S_3T_3) and it was found to have no significant difference with S_2T_3 (round, 180 min). A solid gain of 7.98% was observed for ring shaped red banana slices for 180 min immersion time (S_1T_3).

When interaction effects were studied, $S_3C_3T_3$ (chunks, 80°Brix, 180 min) which recorded the highest solid gain of 8.90% which did not show significant difference with $S_1C_3T_3$ (ring, 80°Brix, 180 min) and the lowest solid gain of 2.75% was observed for $S_3C_1T_1$ (chunks, 40°Brix, 60 min).

4.1.1.3 *Percentage Weight Reduction (%)*

Percentage weight reduction of osmo dehydrated red banana slices at different osmotic concentration and immersion time are given in Table 3.

Osmo dehydrated round shaped red banana (S_2) recorded the highest percentage weight reduction of 7.97%, followed by ring shaped osmo dehydrated red banana (S_1) with 6.69% which statistically showed no significant difference with red banana chunks (S_3). When different osmotic concentration was considered, the highest percentage weight reduction of 8.99% was recorded for 80°Brix (C_3) which has no significant difference with 60°Brix (C_2) and 40°Brix (C_1) showed the lowest reduction in weight (3.52%). Among different immersion time, highest percentage weight reduction of 8.47% was observed for 180 min immersion time (T_3) whereas 7.18% was recorded for T_2 (120 min) and the lowest of 5.61% was recorded for T_1 (60 min).

The highest percentage weight reduction of 9.93% was noticed for round shaped red banana slices at osmotic concentration of 80°Brix (S_2C_3). Similarly

Table 3: Effect of shape, osmotic concentration and immersion time on percentage weight reduction (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	2.25	8.00	7.00	5.75	2.40	6.71	7.75	5.62	1.63	7.50	7.25	5.46
T_2	2.38	8.63	8.50	6.50	4.85	10.00	10.28	8.38	3.38	8.25	8.38	6.67
T_3	4.38	9.13	10.00	7.83	6.41	11.57	11.75	9.91	4.00	9.00	10.00	7.67
Mean	3.00	8.58	8.5		4.55	9.43	9.93		3.00	8.25	8.54	
Mean	S_1 - 6.69 S_2 - 7.97 S_3 - 6.60		C_1 - 3.52 C_2 - 8.75 C_3 - 8.99		T_1 -5.61 T_2 -7.18 T_3 -8.47							
SE($\pm$m)	S - 0.181		C - 0.181		T - 0. 181			S×T - 0.314				
CD (0.05)	S - 0.514		C - 0.514		T - 0.514			S×T - 0.890				

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percentage weight reduction of 8.54% was recorded for osmo dehydrated red banana chunks at 80°Brix (S_3C_3) which showed no significant difference with ring shaped red banana slices at 80°Brix (S_1C_3). Osmo dehydrated round red banana slices at an immersion time of 180 min recorded the highest reduction in weight of 9.91% (S_2T_3) and the lowest weight reduction of 7.83% was observed for ring slices (S_1T_3) which showed no significant difference with osmo dehydrated red banana chunks immersed for 180 min (S_3T_3).

The highest weight reduction of 11.75% was observed in $S_2C_3T_3$ (round, 80°Brix, 180 min) followed by $S_2C_2T_3$ (round, 60°Brix, 180 min) with 11.57% reduction in weight and the lowest reduction in weight (1.63%) was observed for $S_3C_1T_1$(chunks, 40°Brix, 60 min).

4.1.1.4 *Water loss to solid gain*

Water loss to solid gain values of osmo dehydrated red banana slices in different osmotic concentration and immersion time is depicted in Table 4.

Highest water loss to solid gain ratio of 0.80 was noticed in osmo dehydrated red banana chunks (S_3) followed by osmo dehydrated round shaped red banana (S_2) with 0.52 water loss to solid gain which showed no significant difference with ring shaped red banana slices (S_1). When different osmotic concentration was considered, the highest water loss to solid gain (0.82) was recorded for 80°Brix (C_3) followed by 60°Brix (C_2) with a water loss/solid gain of 0.58 whereas 40°Brix (C_1) recorded the lowest water loss/solid gain of 0.42. With respect to immersion time, the highest water loss to solid gain of 0.72 was observed for 60 min immersion time (T_1) whereas 0.60 was recorded for T_3 (180 min) and the lowest ratio of water loss to solid gain (0.49) was recorded for T_2 (120 min).

Osmo dehydrated red banana chunks at the osmotic concentration of 80°Brix (S_3C_3) recorded the highest water loss to solid gain ratio of 1.18 and it was 0.67 and

Table 4: Effect of shape, osmotic concentration and immersion time on water loss to solid gain of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	0.35	0.51	0.55	0.49	0.39	0.46	0.82	0.55	0.99	0.86	1.52	1.12
T_2	0.29	0.50	0.57	0.45	0.20	0.44	0.55	0.40	0.35	0.60	0.95	0.63
T_3	0.37	0.61	0.66	0.55	0.49	0.70	0.65	0.61	0.34	0.53	1.07	0.65
Mean	0.33	0.54	0.59		0.36	0.53	0.67		0.56	0.66	1.18	
Mean	S_1 - 0.49 S_2 - 0.52 S_3 - 0.80		C_1 - 0.42 C_2 - 0.58 C_3 - 0.82		T_1 - 0.72 T_2 - 0.49 T_3 - 0.60							
SE(±m)	S - 0.032 S×C - 0.055		C - 0.032 S×T - 0.055		T - 0.032							
CD (0.05)	S - 0.091 S×C - 0.157		C - 0.091 S×T - 0.157		T - 0.091							

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0.59 for round (S_2C_3) and ring shaped red banana slices (S_1C_3) respectively. Osmo dehydrated red banana chunks at 60 min immersion time recorded the highest water loss to solid gain of 1.12 (S_3T_1) whereas it was 0.61 (S_2T_3) for round shaped red banana slices at an immersion time of 180 min which was found to have no significant difference with ring shaped red banana slices.

4.1.2 Biochemical Characters

4.1.2.1: *TSS (°Brix)*

Total soluble solids of osmo dehydrated red banana with respect to different shape, osmotic solution concentration and immersion time and are given in Table 5.

Osmo dehydrated ring shaped red banana slices (S_1) showed the highest TSS of 51.85°Brix followed by round shaped red banana slices (S_2) with a TSS of 50.72°Brix whereas the lowest TSS of 37.52°Brix was noticed in osmo dehydrated red banana chunks (S_3). With respect to different osmotic concentration, the highest TSS of 52.79°Brix was shown by fruits slices immersed in 80°Brix (C_3) solution followed by 60°Brix (C_2) with a TSS of 46.37°Brix and the lowest TSS (40.93°Brix) was recorded in osmotic concentration of 40°Brix (C_1). The immersion time of 180 min (T_3) showed the highest TSS of 48.62°Brix followed by 120 min (T_2) with a TSS of 47.22°Brix and the lowest TSS (44.25°Brix) was recorded in fruit slices immersed in osmotic solution for a period of 60 min (T_1).

Osmo dehydrated red banana rings at 80°Brix concentration (S_1C_3) recorded the highest TSS of 58.38°Brix and it was 54.79°Brix and 45.19°Brix for round shaped (S_2C_3) and red banana chunks (S_3C_3) respectively. The highest TSS of 54.41°Brix was noticed for ring shaped osmo dehydrated red banana slices for an immersion time of 180 min (S_1T_3) and it was 52.78°Brix and 38.68°Brix for round (S_2T_3) and red banana chunks (S_3T_3).

Table 5: Effect of shape, osmotic concentration and immersion time on TSS (°Brix) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	39.33	48.90	56.64	48.29	43.57	49.19	53.43	48.73	29.17	35.50	42.48	35.72
T_2	47.69	51.88	58.99	52.85	47.50	49.66	54.80	50.65	31.47	36.63	46.35	38.14
T_3	48.57	55.15	59.49	54.41	49.13	53.09	56.13	52.78	31.93	37.36	46.76	38.68
Mean	45.20	51.98	58.38		46.73	50.65	54.79		30.86	36.50	45.19	
Mean	S_1 - 51.85 S_2 - 50.72 S_3 - 37.52			C_1 - 40.93 C_2 - 46.37 C_3 - 52.79		T_1-44.25 T_2-47.22 T_3-48.62						
SE(±m)	S - 0.309 S×C- 0.536		C - 0. 309 S×T - 0.536		T - 0. 309 C×T - 0.536							
CD (0.05)	S - 0.877 S×C - 1.519			C - 0.877 S×T - 1.519			T - 0.877 C×T - 1.519					

4.1.2.2: *Total Sugars (%)*

Osmo dehydrated ring shaped red banana slices (S_1) showed the highest total sugar (45.00%) followed by round shaped osmo dehydrated red banana slices (S_2) with 44.33% and the lowest total sugar of 39.92% was observed for osmo dehydrated red banana chunks (S_3) (Table 6). With respect to osmotic solution concentration, 80°Brix (C_3) showed the highest total sugar (49.81%) followed by 60°Brix (C_2) having a total sugar of 41.67% and the lowest (37.78%) was observed for 40°Brix (C_1). Among the different immersion time, T_3 (180 min) showed the highest total sugar of 47.48% followed by T_2 (120 min) with 42.08% and the lowest total sugar of 39.70% was recorded for T_1 (60 min).

Among the interactions, the highest total sugar of 54.15% was observed for $S_2C_3T_3$ (round, 80°Brix, 180 min) which showed no significant difference with $S_3C_3T_3$ (chunks, 80°Brix, 180 min) and the lowest total sugar of 30.61% was observed for $S_3C_1T_1$ (chunks, 40°Brix, 60 min).

4.1.2.3: *Reducing Sugars (%)*

Osmo dehydrated round shaped red banana slices (S_2) showed the highest reducing sugar of 27.30% which showed no significant difference with ring shaped red banana slices (S_1) whereas the lowest reducing sugar of 21.64% was noticed in osmo dehydrated red banana chunks (S_3) (Table 7). With respect to different osmotic concentration, the highest reducing sugar of 32.87% was shown by fruits slices immersed in 80°Brix (C_3) solution followed by 60°Brix (C_2) having a reducing sugar of 24.67% and the lowest reducing sugar of 16.48% was recorded in osmotic concentration of 40°Brix (C_1). Among the immersion time, 180 min (T_3) showed the highest reducing sugar of 29.03% followed by 120 min (T_2) with a reducing sugar of 25.15% and the lowest reducing sugar of 19.84% was recorded in fruit slices for a period of 60 min immersion time (T_1).

Table 6: Effect of shape, osmotic concentration and immersion time on total sugar (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	37.83	41.21	48.39	42.48	35.89	38.36	47.77	40.67	30.61	32.83	44.38	35.94
T_2	41.55	42.49	49.34	44.46	39.27	40.03	50.85	43.38	32.61	35.30	47.25	38.39
T_3	42.86	49.06	52.27	48.06	45.18	47.47	54.15	48.94	34.17	48.28	53.87	45.44
Mean	40.75	44.25	50.00		40.11	41.96	50.92		32.46	38.81	48.50	
Mean	S_1 - 45.00 S_2 - 44.33 S_3 - 39.92		C_1 –37.78 C_2 –41.67 C_3 –49.81		T_1-39.70 T_2-42.08 T_3-47.48							
SE(±m)	S - 0.196 S×C- 0.340		C - 0. 196 S×T - 0.340		T -0.196 C×T - 0.340		S×C×T – 0.589					
CD (0.05)	S- 0.556 S×C- 0.964		C - 0.556 S×T - 0.964		T - 0.556 C×T - 0.964				S×C×T -1.669			

Table 7: Effect of shape, osmotic concentration and immersion time on reducing sugar (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	10.95	25.00	28.87	21.61	13.77	18.76	27.40	19.97	10.14	18.94	24.72	17.93
T_2	14.43	28.87	30.64	24.64	22.39	26.37	37.47	28.75	11.72	18.77	35.66	22.05
T_3	17.68	32.64	36.63	28.98	30.72	30.97	37.82	33.17	16.49	21.72	36.63	24.95
Mean	14.35	28.84	32.05		22.30	25.36	34.23		12.78	19.81	32.34	
Mean	S_1 - 25.08 S_2 - 27.30 S_3 - 21.64		C_1 – 16.48 C_2 – 24.67 C_3 – 32.87			T_1 -19.84 T_2 -25.15 T_3 -29.03						
SE(±m)	S - 0.815 S×C- 1.412		C - 0.815		T -- 0.815							
CD (0.05)	S - 2.312 S×C - 4.005		C - 2.312			T - 2.312						

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4.1.2.4: *Acidity (%)*

Osmo dehydrated ring shaped red banana (S_1) showed the highest acidity of 1.05% followed by red banana chunks (S_3) with an acidity of 0.89% whereas the lowest acidity of 0.81% was noticed for round shaped osmo dehydrated red banana (S_2) (Table 8). With respect to different osmotic concentration, the highest acidity of 1.09% was recorded by fruits slices immersed in 40°Brix (C_1) followed by 60°Brix (C_2) with an acidity of 0.93% and the lowest acidity (0.73%) was recorded for 80°Brix (C_3). Among the different immersion time, 60 min (T_1) recorded the highest acidity of 1.01% followed by 120 min (T_2) with an acidity of 0.92% and fruit slices immersed in osmotic solution for a period of 180 min (T_3) recorded the lowest acidity of 0.82%.

Osmo dehydrated ring shaped red banana slices at 40°Brix osmotic concentration (S_1C_1) recorded the highest acidity of 1.21% and it was 1.09% and 0.99% in round (S_2C_1) and chunks (S_3C_1) respectively. The highest acidity of 1.15% was observed for osmo dehydrated red banana rings for an immersion time of 60 min (S_1T_1) and it was 1.00% and 0.89% in chunks (S_3T_1) and round shaped (S_2T_1) osmo dehydrated red banana slices respectively.

Among the interactions, $S_1C_2T_1$ (ring, 60°Brix, 60 min) recorded the highest acidity of 1.33% followed by $S_1C_1T_1$ (ring, 40°Brix, 60 min) with an acidity of 1.28% and the lowest acidity (0.61%) was observed for $S_2C_3T_3$ (round, 80°Brix, 180 min).

4.1.2.5: *Ascorbic acid (mg $100g^{-1}$)*

Ascorbic acid values of osmo dehydrated red banana slices with respect to different shape, osmotic solution concentration and immersion time are depicted in Table 9.

Ascorbic acid content showed no significant difference with respect to change in shape of red banana slices. When different osmotic concentration is considered, the highest ascorbic acid of 17.19 mg $100g^{-1}$ was recorded for 40°Brix (C_1) followed by 60°Brix (C_2) with 15.47 mg $100g^{-1}$ and 80°Brix (C_3) recorded the lowest ascorbic acid content of 13.23 mg 100 g^{-1}. Among different immersion time, the highest ascorbic acid of 18.12 mg $100g^{-1}$ was observed for 60 min immersion time (T_1) whereas 16.14 mg $100g^{-1}$ was recorded for T_2 (120 min) and the lowest ascorbic acid content of 11.64 mg $100g^{-1}$ was noticed for T_3 (180 min).

4.1.2.6: *Carotenoids (μg $100g^{-1}$)*

Round shaped osmo dehydrated red banana (S_2) recorded the highest carotenoid content of 17.27 μg $100g^{-1}$ whereas the lowest carotenoid content (10.97 μg $100g^{-1}$) was noticed in osmo dehydrated red banana rings (S_1) (Table 10). With respect to different osmotic concentration, fruit slices immersed in 40°Brix (C_1) recorded the highest carotenoid content of 18.00 μg $100g^{-1}$ followed by 60°Brix (C_2) with a carotenoid content of 12.70 μg $100g^{-1}$ and the lowest carotenoid content (9.14 μg $100g^{-1}$) was recorded in osmotic concentration of 80°Brix (C_3). Among the different immersion time, 60 min (T_1) recorded the highest carotenoid content of 18.84 μg $100g^{-1}$ followed by 120 min (T_2) with 11.79 μg $100g^{-1}$ carotenoid content and fruit slices immersed in osmotic solution for a period of 180 min (T_3) recorded the lowest carotenoid content of 9.22 μg $100g^{-1}$.

Among the interactions, $S_2C_1T_1$ (round, 40°Brix, 60 min) recorded the highest carotenoid content of 33.58 μg $100g^{-1}$ followed by $S_2C_2T_1$ (round, 60°Brix, 60 min) with a carotenoid content of 26.00 μg $100g^{-1}$ and the lowest carotenoid content (6.00 μg $100g^{-1}$) was observed for $S_1C_3T_3$ (ring, 80°Brix, 180 min).

Table 8: Effect of shape, osmotic concentration and immersion time on acidity (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	1.28	1.33	0.85	1.15	1.14	0.85	0.68	0.89	1.04	1.01	0.94	1.00
T_2	1.19	1.31	0.73	1.08	1.09	0.65	0.63	0.79	1.02	0.85	0.77	0.88
T_3	1.16	0.91	0.68	0.92	1.02	0.63	0.61	0.76	0.91	0.84	0.63	0.79
Mean	1.21	1.18	0.76		1.09	0.711	0.643		0.99	0.90	0.78	
Mean	S_1 - 1.05 S_2 - 0.81 S_3 - 0.89		C_1 - 1.09 C_2 - 0.93 C_3 - 0.73		T_1 -1.01 T_2-0.92 T_3-0.82							
SE(±m)	S - 0.009 S×C- 0.016		C – 0.009 S×T – 0.016		T - 0.009 S× C×T – 0.028							
CD (0.05)	S - 0.026 S×C - 0.046				C - 0.026 S×T - 0.046				T - 0.026 S ×C×T – 0.079			

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Table 9: Effect of shape, osmotic concentration and immersion time on ascorbic acid (mg 100^{-1}) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	20.24	20.24	14.28	18.25	20.24	16.67	17.85	18.25	19.05	17.86	16.67	17.85
T_2	19.05	17.86	11.90	16.27	15.47	15.47	15.47	15.47	19.05	15.47	15.47	16.66
T_3	15.47	11.90	8.33	11.90	11.90	11.90	10.71	11.51	14.28	11.90	8.33	11.51
Mean	18.25	16.67	11.51		15.87	14.68	14.68		17.46	15.08	13.49	
Mean	S_1 - 15.47 S_2 - 15.08 S_3 - 15.34		C_1 – 17.19 C_2 – 15.47 C_3 – 13.23			T_1-18.12 T_2-16.14 T_3-11.64						
SE(±m)	C – 0.512	T – 0.512		S×C – 0.887								
CD (0.05)	C – 1.453		T – 1.453			S×C – 2.516						

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Table 10: Effect of shape, osmotic concentration and immersion time on carotenoids (µg $100g^{-1}$) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	24.00	12.12	9.12	15.08	33.58	26.00	16.68	25.42	25.83	14.84	7.38	16.01
T_2	12.73	9.99	7.38	10.03	15.83	15.22	13.19	14.75	15.69	9.20	6.92	10.60
T_3	9.98	7.47	6.00	7.81	12.81	12.65	9.50	11.65	11.59	6.85	6.09	8.18
Mean	15.57	9.86	7.50		20.741	17.96	13.12		17.70	10.30	6.80	
Mean	S_1 - 10.97 S_2 - 17.27 S_3 - 11.60		C_1 -18.00 C_2 -12.70 C_3 – 9.14			T_1 -18.84 T_2-11.79 T_3- 9.22						
SE(±m)	S - 0.209 S×C- 0.361		C - 0.209 S×T - 0.361		T - 0.209 C×T – 0.361			S×C×T – 0.626				
CD (0.05)	S - 0.592 S×C - 1.025			C - 0.592 S×T - 1.025			T - 0.592 C×T – 1.025			S ×C×T -1.775		

4.1.2.7: *Antioxidant activity (%)*

Antioxidant activity expressed as radical scavenging activity (DPPH) of osmo dehydrated red banana slices as influenced by different shape, osmotic concentration and immersion time is depicted in Table 11.

The highest antioxidant activity of 94.37% was noticed in round shaped osmo dehydrated red banana slices (S_2) followed by osmo dehydrated red banana chunks (S_3) with an antioxidant activity of 93.12% and the lowest antioxidant activity of 92.07% was noticed in osmo dehydrated red banana rings (S_1).

Osmo dehydrated round shaped red banana slices at osmotic concentration of 40°Brix (S_2C_1) recorded the highest antioxidant activity of 94.89% which showed no significant difference with S_3C_1 (chunks, 40°Brix) and 93.12% was noticed in osmo dehydrated red banana rings at an osmotic concentration of 80°Brix (S_1C_3). Round shaped osmo dehydrated red banana for an immersion time of 120 min (S_2T_2) recorded the highest antioxidant activity of 94.84% followed by ring shaped osmo dehydrated red banana slices at 180 min immersion time (S_1T_3) with an antioxidant activity of 93.51% which showed no significant difference to S_3T_2 (chunks, 120 min).

Among the interactions, the highest antioxidant activity of 95.30% was noticed in $S_2C_1T_3$ (round, 40°Brix 180 min) which is found to have statistically no significant difference with $S_2C_1T_2$ (round, 40°Brix, 120 min) and the lowest antioxidant activity (89.00%) was observed for $S_3C_3T_3$ (chunks, 80°Brix, 180 min).

4.1.3 Physical characters

4.1.3.1 Yield (%)

Yield of osmo dehydrated red banana influenced by different process parameters are shown in Table 12. The highest yield of 28.82% was noticed in osmo

Table 11: Effect of shape, osmotic concentration and immersion time on antioxidant activity (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	90.67	91.46	93.20	91.78	94.22	93.47	93.29	93.66	93.96	92.82	95.04	93.94
T_2	91.22	89.88	91.62	90.91	95.14	94.50	94.89	94.84	94.09	93.33	92.50	93.31
T_3	93.51	92.49	94.54	93.51	95.30	94.60	93.88	94.59	94.35	92.95	89.00	92.10
Mean	91.80	91.28	93.12		94.89	94.19	94.02		94.13	93.03	92.18	
Mean	S_1 - 92.07 S_2 - 94.37 S_3 - 93.12		C_1 - 93.61 C_2 - 92.83 C_3 - 93.11			T_1 – 93.13 T_2 – 93.02 T_3 – 93.40						
SE(±m)	S - 0.221 S×C – 0.383		S×T – 0.383			C×T – 0.383			S×C×T – 0.663			
CD (0.05)	S - 0.627 S×C - 1.086		S×T - 1.086				C×T - 1.086			S ×C×T - 1.881		

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Table 12: Effect of shape, osmotic concentration and immersion time on yield (%) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	20.06	28.13	25.88	24.69	25.38	29.51	29.47	28.12	27.90	27.25	28.38	27.84
T_2	23.48	30.00	27.25	26.91	25.60	28.70	29.47	27.92	29.25	28.38	30.13	29.25
T_3	23.58	28.90	30.37	27.62	26.98	29.47	29.58	28.68	28.38	28.00	31.75	29.38
Mean	22.37	27.34	29.50		25.99	29.23	29.51		28.51	27.87	30.08	
Mean	S_1 - 26.40 S_2 - 28.24 S_3 - 28.82		C_1 - 25.62 C_2 - 28.70 C_3 - 29.14		T_1 - 26.88 T_2 - 28.03 T_3 - 28.56							
SE(±m)	S - 0.233 S×C – 0.403		C - 0.233 C×T – 0.403		T - 0.233							
CD (0.05)	S - 0.660 S×C - 1.143		C - 0.660 C×T - 1.143		T - 0.660							

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dehydrated red banana chunks (S_3) which was found to have no significant difference with round shaped osmo dehydrated red banana (S_2) and the lowest yield of 26.40% was noticed in ring shaped red banana slices (S_1). When different osmotic concentration is considered, the highest yield of 29.14% was recorded for 80°Brix (C_3) which showed no significant difference with 60°Brix (C_2) and 40°Brix (C_1) has the lowest yield of 25.62%. Among different immersion time, the highest yield of 28.56% was observed for 180 min immersion time (T_3) which showed no significant difference with T_2 (120 min) and the lowest yield 26.88% was recorded for T_1 (60 min).

Osmo dehydrated red banana chunks at osmotic concentration of 80°Brix recorded the highest yield of 30.08% (S_3C_3), which statistically showed no significant difference with round and ring shaped red banana slices. Osmo dehydrated red banana chunks at immersion time of 180 min (S_3T_3) recorded the highest yield of 29.38% and it was 28.68% and 27.62% for round (S_2T_3) and ring shaped (S_1T_3) red banana slices respectively.

Among the interactions, $S_3C_3T_3$ (chunks, 80°Brix, 180 min) recorded the highest yield of 31.75% followed by $S_1C_3T_3$ (ring, 80°Brix, 180 min) with a yield of 30.37% and the lowest yield (20.06%) was observed for $S_1C_1T_1$ (ring, 40°Brix, 60 min).

4.1.3.2 Rehydration ratio

Rehydration ratio of osmo dehydrated red banana slices influenced by different shapes, osmotic concentration and immersion time are given in Table 13.

The highest rehydration ratio (1.45) was obtained for ring shaped osmo dehydrated red banana (S_1) followed by round shaped osmo dehydrated red banana (S_2) with a rehydration ratio of 1.43 and the lowest rehydration ratio (1.36) was noticed in chunks shaped red banana slices (S_3). With respect to different osmotic

Table 13: Effect of shape, osmotic concentration and immersion time on rehydration ratio of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	1.56	1.43	1.51	1.50	1.75	1.36	1.38	1.50	1.42	1.38	1.39	1.39
T_2	1.49	1.41	1.46	1.45	1.64	1.34	1.24	1.41	1.28	1.44	1.29	1.34
T_3	1.42	1.42	1.31	1.39	1.45	1.41	1.28	1.38	1.32	1.44	1.33	1.36
Mean	1.49	1.42	1.43		1.62	1.37	1.30		1.34	1.42	1.33	
Mean	S_1 - 1.45 S_2 - 1.43 S_3 - 1.36		C_1 - 1.48 C_2 - 1.40 C_3 - 1.36			T_1 - 1.46 T_2 - 1.40 T_3 - 1.38						
SE($\pm$m)	S - 0.007 S×C - 0.012		C - 0.007 S×T - 0.012		T - 0.007 C×T - 0.012		S×C×T- 0.020					
CD (0.05)	S - 0.019 S×C - 0.033		C - 0. 019 S×T - 0.033			T - 0. 019 C×T - 0.033		S×C×T – 0.058				

concentration, 40°Brix (C_1) recorded the highest rehydration ratio (1.48) followed by 60°Brix (C_2) with a rehydration ratio of 1.40 and the lowest rehydration ratio (1.36) was noticed for 80°Brix (C_3). Among different immersion time, the highest rehydration ratio (1.46) was observed for 60 min immersion time (T_1) whereas 1.40 was recorded for T_2 (120 min) and the lowest rehydration ratio (1.38) was recorded for T_3 (180 min).

Round shaped osmo dehydrated red banana at osmotic concentration of 40°Brix showed the highest rehydration ratio of 1.62 (S_2C_1) whereas rehydration of 1.49 was noticed for osmo dehydrated red banana rings at 40°Brix (S_1C_1) and 1.42 was noticed at osmotic concentration of 60°Brix for osmo dehydrated red banana chunks (S_3C_2).

When interaction effects are studied, $S_2C_1T_1$ (round, 40°Brix, 60 min) recorded the highest rehydration ratio of 1.75 followed by $S_2C_1T_2$ (round, 40°Brix, 120 min) with a rehydration ratio of 1.64 and $S_2C_3T_2$ (round, 80°Brix, 120 min) recorded the lowest rehydration ratio of 1.24.

4.1.3.3 Browning Index (BI)

Effect of process variables on browning index of osmo dehydrated red banana is depicted in Table 14.

Round shaped red banana slices (S_2) showed the lowest browning index of 65.98 followed by ring shaped red banana slices (S_1) with a browning index of 84.09 whereas the highest browning index of 96.05 was noticed in osmo dehydrated red banana chunks (S_3). With respect to different osmotic concentration, the lowest browning index (72.24) was shown by fruits slices immersed in 40°Brix (C_1) solution followed by 60°Brix (C_2) with a browning index of 78.79 and the highest browning index (95.09) was recorded for osmotic concentration of 80°Brix (C_3). The immersion time of 60 min (T_1) showed the lowest browning index (77.01) followed by 120 min

(T_2) with a browning index of 82.63 and the highest browning index (86.48) was recorded in fruit slices immersed in osmotic solution for a period of 180 min (T_3).

Among the interactions, $S_2C_1T_3$ (round, 40°Brix, 180 min) recorded the lowest browning index (39.57) followed by $S_2C_2T_1$ (round, 60°Brix, 60 min) with a browning index 43.11 and the highest (118.73) was observed for $S_3C_3T_3$ (chunks, 80°Brix, 180 min).

4.1.3.4 Textural quality

4.1.3.4.a Hardness (kg)

Hardness of osmo dehydrated red banana slices influenced by shape, osmotic concentration and immersion time are depicted in Table 15.

Osmo dehydrated red banana chunks (S_3) showed the lowest hardness of 1.78 kg followed by round shaped red banana (S_2) with a hardness of 3.32 kg whereas the highest hardness of 4.40 kg was noticed in osmo dehydrated red banana rings (S_1) (Table 15). With respect to different osmotic concentration, the lowest hardness of 2.75 kg was recorded by fruits slices immersed in 60°Brix (C_2) which recorded no significant difference with 80°Brix (C_3) and the highest hardness (3.86) was recorded for fruits slices immersed in 40°Brix (C_1).

Among the interactions, $S_3C_3T_3$ (chunks, 80°Brix, 180 min) recorded the lowest hardness of 1.24 kg followed by $S_2C_2T_1$ (round, 60°Brix, 60 min) with a hardness of 1.47 kg and the highest hardness (8.42 kg) was observed for $S_1C_1T_1$ (ring, 40°Brix, 60 min).

Table 14: Effect of shape, osmotic concentration and immersion time on colour (browning index) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	54.47	70.47	106.89	77.28	54.32	43.11	88.23	61.89	92.04	79.10	104.44	91.86
T_2	79.10	92.42	94.22	88.58	59.56	72.09	75.17	68.94	94.34	75.34	101.41	90.37
T_3	75.99	97.23	75.99	86.40	39.57	81.05	80.75	67.12	100.75	98.28	118.73	105.92
Mean	69.85	86.71	95.70		51.15	65.42	81.38		95.71	84.24	108.19	
Mean	S_1 - 84.09 S_2 - 65.98 S_3 - 96.05		C_1 - 72.24 C_2 - 78.79 C_3 - 95.09			T_1 - 77.01 T_2 - 82.63 T_3 - 86.48						
SE(±m)	S – 0.813 S×C – 1.409		C – 0.813 S×T - 1.409		T– 0.813 C×T - 1.409			S×C×T- 2.440				
CD (0.05)	S - 2.307 S×C - 3.995		C - 2.307 S×T - 3.995			T - 2.307 C×T - 3.995			S×C×T- 6.920			

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Table 15: Effect of shape, osmotic concentration and immersion time on hardness (kg) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	8.42	3.25	2.60	4.76	3.09	1.47	2.87	2.48	1.88	2.11	1.77	1.92
T_2	3.93	4.09	3.96	3.99	4.88	2.92	2.48	3.42	1.65	2.02	1.86	1.84
T_3	3.14	4.26	5.99	4.46	6.24	2.65	3.23	4.04	1.48	2.03	1.24	1.58
Mean	5.16	3.86	4.18		4.74	2.34	2.86		1.67	2.05	1.62	
Mean	S_1 - 4.40 S_2 - 3.32 S_3 - 1.78			C_1 - 3.86 C_2 - 2.75 C_3 - 2.89			T_1-3.05 T_2-3.09 T_3-3.36					
SE($\pm$m)	S - 0.157 S×C - 0.272		C - 0.157 S×T - 0.272		C×T - 0.272		S×C×T - 0.471					
CD (0.05)	S - 0.445 S×C - 0. 770			C - 0.445 S×T - 0. 770			C×T - 0. 770			S×C×T - 1.334		

4.1.3.4.b Cutting energy (kg s)

Osmo dehydrated red banana chunks (S_3) showed the lowest cutting energy (0.97 kg s) followed by round shaped red banana (S_2) with a cutting energy of 1.77 kg s whereas the highest cutting energy of 2.31 kg s was noticed in osmo dehydrated red banana rings (S_1) (Table 16). With respect to different osmotic concentration, fruits slices immersed in 60°Brix (C_2) recorded the lowest cutting energy of 1.37 kg s which showed no significant difference with 80°Brix (C_3) and fruit slices immersed in 40°Brix (C_1) recorded the highest cutting energy of 2.21 kg s.

Among the interactions, $S_2C_2T_1$ (round, 60°Brix, 60 min) recorded the lowest cutting energy (0.55 kg s) followed by $S_3C_1T_3$ (chunks, 40°Brix, 180 min) with a cutting energy of 0.61 kg s and the highest cutting energy (5.44 kg s) was observed for $S_1C_1T_1$ (ring, 40°Brix, 60 min).

4.1.4 Sensory analysis

Osmo dehydrated red banana of different shapes subjected to osmotic solution concentration of 40°Brix, 60°Brix and 80°Brix for an immersion time of 60, 120 and 180 min were analysed for various sensory attributes *viz.*, appearance, taste, colour, flavour, odour, texture and overall acceptability using 9 point hedonic scale for their acceptance. The mean scores of osmo dehydrated red banana with respect to different sensory attributes are given in Table 17. The statistical analysis using Kruskal Wallis test revealed that significant difference exist between the treatments in terms of sensory quality.

With respect to each shape, ring shaped osmo dehydrated red banana immersed in 80°Brix for an immersion time of 180 min ($S_1C_3T_3$) recorded the highest mean score of 8.09 for appearance followed by $S_1C_3T_1$ (ring, 80°Brix, 60 min) with a mean score of 7.27 and the lowest mean score (5.27) was noticed in ring shaped red banana slices immersed in osmotic concentration of 40°Brix for 60 min ($S_1C_1T_1$).

Table 16: Effect of shape, osmotic concentration and immersion time on cutting energy (kg s) of osmo dehydrated red banana

Immersion time (min)	Osmo dehydrated red banana											
	S_1(Ring)				S_2 (Round)				S_3 (Chunks)			
	Osmotic concentration				Osmotic concentration				Osmotic concentration			
	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean	C_1 (40°B)	C_2 (60°B)	C_3 (80°B)	Mean
T_1	5.44	1.41	1.21	2.69	2.15	0.55	1.28	1.33	1.24	1.29	0.94	1.16
T_2	1.51	1.98	1.70	1.73	2.81	1.24	1.12	1.72	0.76	1.09	0.87	0.91
T_3	1.33	2.52	3.70	2.52	3.99	1.02	1.75	2.26	0.61	1.19	0.72	0.84
Mean	2.76	1.97	2.20		2.98	0.94	1.39		0.87	1.19	0.84	
Mean	S_1 - 2.31 S_2 - 1.77 S_3 - 0.97		C_1 - 2.21 C_2 - 1.37 C_3 - 1.48			T_1-1.72 T_2-1.45 T_3-1.87						
SE(±m)	S - 0.130 S×C - 0.225		C - 0.130 S×T - 0. 225		T - 0.130 C×T - 0. 225		S×C×T- 0.391					
CD (0.05)	S – 0.369 S×C – 0.639			C -0. 369 S×T – 0.639			C×T – 0. 639			S×C×T- 1.107		

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When taste is considered, the highest mean score of 8.36 was observed in $S_1C_3T_3$ (80°Brix, 180 min) followed by $S_1C_3T_2$ (80°Brix, 120 min) with a mean score of 8.09 and the lowest mean score of 5.64 was noticed in red banana slices in 60°Brix for an immersion time of 120 min ($S_1C_2T_2$). The mean scores for colour recorded that the highest score of 7.91 was observed in $S_1C_3T_3$ (ring, 80°Brix, 180 min) followed by the treatment $S_1C_3T_1$ (ring, 80°Brix, 60 min) (7.64) and the lowest score of 5.00 was noticed in $S_1C_1T_1$ (ring, 40°Brix, 60 min). Statistical analysis revealed that there is no significant difference among the treatments for the sensory attribute flavour. Osmo dehydrated ring shaped red banana slices in osmotic concentration of 80°Brix for an immersion time of 180 min ($S_1C_3T_3$) recorded the highest mean score for texture (6.91) followed by $S_1C_3T_1$ (ring, 80°Brix, 60 min) with a mean score of 6.64 and $S_1C_1T_1$ (ring, 40°Brix, 60 min) recorded the lowest mean score of 4.73. The highest mean score for overall acceptability (8.00) was noticed in $S_1C_3T_3$ (ring, 80°Brix, 180 min) followed by 7.45 in $S_1C_3T_1$ (ring, 80°Brix, 60 min) and the lowest score of 5.45 was recorded in $S_1C_2T_1$ (ring, 60°Brix, 60 min).

When round shaped osmo dehydrated red banana were considered, the highest mean score for appearance (8.30) was recorded by red banana slices immersed in 80°Brix for an immersion time of 180 min ($S_2C_3T_3$) followed by 8.00 in $S_2C_3T_2$ (round, 80°Brix, 120 min) and the lowest score for appearance was 6.00 which was recorded in $S_2C_2T_3$ (round, 60°Brix, 180 min). Osmo dehydrated red banana slices in osmotic concentration of 80°Brix for an immersion time of 180 min ($S_2C_3T_3$) recorded the highest mean score of 8.10 for colour followed by 80°Brix for an immersion time of 120 min ($S_2C_3T_2$) with a score of 7.90 and the lowest mean score of 6.60 was noticed by $S_2C_2T_2$ (round, 60°Brix, 120 min) and $S_2C_2T_3$ (round, 60°Brix, 180 min) respectively. The mean score for the sensory attributes taste and flavour did not show any significant difference among the treatments statistically. When texture is considered, $S_2C_3T_3$ (round, 80°Brix, 180 min) recorded the highest mean score of 7.10 followed by 6.90 which was noticed in $S_2C_3T_2$ (round, 80°Brix, 120 min) and the lowest mean score (5.00) was for $S_2C_1T_2$ (round, 40°Brix, 120 min). Red banana slices immersed in 80°Brix for an immersion time of 180 min ($S_2C_3T_3$) recorded the highest mean score for overall acceptability (7.90) followed by $S_2C_3T_2$ (round, 80°Brix, 120 min) with sensory score of 7.30 and the lowest score of 6.10 was recorded in $S_2C_2T_1$ (round, 60°Brix, 60 min) and $S_2C_2T_2$ (round, 60°Brix, 120 min) respectively.

For osmo dehydrated red banana chunks, $S_3C_3T_3$ (chunks, 80°Brix, 180 min) recorded the highest mean score of 8.60 for appearance followed by 8.30 for $S_3C_3T_2$ (chunks, 80°Brix, 120 min) and the lowest mean score (5.90) was noticed in $S_3C_1T_1$ (chunks, 40°Brix, 60 min). The highest score for taste (8.00) was noticed in red banana immersed in 80°Brix for an immersion time of 180 min ($S_3C_3T_3$) followed by 7.60 in $S_3C_3T_2$ (chunks, 80°Brix, 120 min) and the lowest score of 5.80 for taste was recorded in $S_3C_1T_1$ (chunks, 40°Brix, 60 min). Osmo dehydrated red banana chunks in osmotic concentration of 80°Brix for an immersion time of 180 min ($S_3C_3T_3$) and osmotic concentration of 80°Brix for an immersion time of 120 min ($S_3C_3T_2$) recorded the highest mean score for colour (8.10) followed by $S_3C_3T_1$ (chunks, 80°Brix, 60 min) with a mean score of 8.00 and the lowest mean score (5.50) was noticed in $S_3C_1T_1$ (chunks, 40°Brix, 60 min). The highest mean score for flavour (7.50) was noticed in $S_3C_3T_3$ (chunks, 80°Brix, 180 min) followed by 7.30 in $S_3C_3T_2$ (chunks, 80°Brix, 120 min) and the lowest score of 6.10 was recorded in $S_3C_1T_1$ (chunks, 40°Brix, 60 min) and $S_3C_1T_2$ (chunks, 40°Brix, 120 min) respectively. Osmo dehydrated red banana chunks in osmotic concentration of 80°Brix for an immersion time of 180 min ($S_3C_3T_3$) recorded the highest mean score for texture (7.90) followed by $S_3C_3T_1$ (chunks, 80°Brix, 60 min) and $S_3C_1T_3$ (chunks, 40°Brix, 180 min) recorded the lowest mean score of 6.10. The highest mean score for overall acceptability (8.10) was noticed in $S_3C_3T_3$ (chunks, 80°Brix, 180 min) followed by $S_3C_3T_2$ (chunks, 80°Brix, 120 min) and the lowest score of 5.90 was recorded in $S_3C_1T_1$ (chunks, 40°Brix, 60 min) and $S_3C_1T_2$ (chunks, 40°Brix, 120 min).

Table 17: Effect of shape, osmotic concentration and immersion time on organoleptic attributes of osmo dehydrated red banana

Treatments	Mean scores					
	Appearance	Taste	Colour	Flavour	Texture	Overall acceptability
$S_1C_1 T_1$	5.27	5.91	5.00	5.91	4.73	5.64
$S_1C_1 T_2$	5.36	5.82	5.36	5.82	5.00	5.82
$S_1C_1 T_3$	5.90	6.36	6.18	6.00	6.27	6.27
$S_1C_2 T_1$	5.91	6.45	5.36	5.73	5.27	5.45
$S_1C_2 T_2$	6.45	5.64	6.64	5.72	5.45	6.36
$S_1C_2 T_3$	6.81	5.91	7.18	5.36	6.18	6.82
$S_1C_3 T_1$	7.27	7.91	7.64	6.36	6.64	7.45
$S_1C_3 T_2$	7.00	8.09	7.00	6.27	6.54	7.00
$S_1C_3 T_3$	8.09	8.36	7.91	6.55	6.91	8.00
K value	31.65	38.76	37.15	2.91	19.76	30.81
χ^2	15.51					

Treatments	Mean scores					
	Appearance	Taste	Colour	Flavour	Texture	Overall acceptability
$S_2C_1 T_1$	6.90	7.10	7.20	7.00	5.60	6.90
$S_2C_1 T_2$	6.50	6.80	7.00	6.70	5.00	6.60
$S_2C_1 T_3$	6.60	6.80	7.10	6.70	5.10	6.30
$S_2C_2 T_1$	6.90	6.70	6.90	6.80	5.80	6.10
$S_2C_2 T_2$	6.30	7.10	6.60	6.80	6.10	6.10
$S_2C_2 T_3$	6.00	7.00	6.60	6.60	5.90	6.20
$S_2C_3 T_1$	7.80	7.20	7.80	7.40	6.80	7.20
$S_2C_3 T_2$	8.00	7.40	7.90	7.50	6.90	7.30
$S_2C_3 T_3$	8.30	7.60	8.10	7.60	7.10	7.90
K value	34.45	5.93	21.14	11.98	24.55	20.46
χ^2	15.51					

Treatments	Mean scores					
	Appearance	Taste	Colour	Flavour	Texture	Overall acceptability
$S_3C_1 T_1$	5.90	5.80	5.50	6.10	6.30	5.90
$S_3C_1 T_2$	6.50	5.90	6.10	6.10	6.20	5.90
$S_3C_1 T_3$	6.20	6.60	6.00	6.40	6.10	6.00
$S_3C_2 T_1$	7.00	7.00	6.60	6.70	6.80	6.70
$S_3C_2 T_2$	7.10	7.10	6.60	6.90	6.60	6.50
$S_3C_2 T_3$	7.00	7.00	6.60	7.00	6.60	6.90
$S_3C_3 T_1$	8.20	7.50	8.00	7.20	7.40	7.40
$S_3C_3 T_2$	8.30	7.60	8.10	7.30	7.40	7.90
$S_3C_3 T_3$	8.60	8.00	8.10	7.50	7.90	8.10
K value	50.28	32.81	48.51	20.70	28.76	43.37
χ^2	15.51					

From the sensory analysis of all the three shapes of osmo dehydrated red banana, fruit slices immersed in osmotic concentration of 80°Brix for an immersion time of 180 min was selected as the best accepted one in terms of sensory quality.

On analysis of mass transfer characters, biochemical, physical and sensory parameters, best treatment combination from each fruit shape were selected for binding agent treatment studies. Accordingly, three treatments (ring, 80°Brix, 180 min; round, 80°Brix, 180 min and chunks, 80°Brix, 180 min) were selected from Part I of the study and were subjected to corn starch treatment at 2 and 4% concentrations and were analysed for sensory attributes.

4.1.5 Sensory analysis of osmo dehydrated red banana treated with corn starch

Corn starch treated (2% and 4%) osmo dehydrated red banana slices of different shapes (ring, round and chunks) selected from Part I experiment were subjected to sensory analysis along with the untreated as control. The mean scores of various sensory attributes were subjected to statistical analysis (Kruskal Wallis test) and the results are depicted in Table 18.

The selected ring shaped osmo dehydrated red banana without corn starch treatment (control) recorded the highest mean score of 8.70 followed by S_1B_2 (ring, 4% corn starch) with mean score of 7.90 and the lowest score for appearance (7.80) was noticed in 2% corn starch treated ring shaped red banana (S_1B_1). When taste is considered, the highest mean score of 8.30 was noticed in control sample followed by S_1B_2 (ring, 4% corn starch) and the lowest score of 6.80 was observed in 2% corn starch treatment (S_1B_1). The highest sensory score for colour (8.50) was recorded in red banana without corn starch treatment (control) followed by 4% corn starch treated slices (S_1B_2) with mean score of 7.50 and 2% corn starch treated slices (S_1B_1) recorded the lowest mean score of 6.90. For the sensory attribute flavour, red banana slices without corn starch treatment (control) recorded the highest mean score of 8.60

followed by S_1B_2 (ring, 4% corn starch) with mean score of 7.20 and the lowest score (6.90) was noticed in 2% corn starch treated ring shaped red banana slices (S_1B_1). The highest sensory score of 8.40 for texture was noticed in red banana slices without corn starch treatment (control) as compared to corn starch treatments. In the case of overall acceptability, control sample without corn starch treatment (control) recorded the highest mean score of 8.70 followed by 7.20 and 7.10 in 4% (S_1B_2) and 2% (S_1B_1) corn starch treated ring shaped red banana slices respectively.

In osmo dehydrated red banana of round shape, the highest sensory score of 8.20 for appearance was noticed in red banana slices without corn starch treatment (control)followed by S_2 B_1 (round, 2% corn starch) with a mean score of 7.20 whereas the lowest mean score (7.00) was noticed in 4% corn starch treated red banana slices (S_2 B_2). Osmo dehydrated red banana without corn starch treatment (control) recorded the highest sensory score for taste (8.10) followed by 6.60 in 2% corn starch treated slices (S_2B_1) and the lowest score of 6.30 was noticed by S_2B_2 (round, 4% corn starch). The highest mean score for colour (8.20) was observed in control sample without corn starch treatment (control) whereas the lowest mean score (6.50) was noticed in 4% corn starch treated red banana slices (S_2B_2). For the sensory attribute flavour, the highest score of 7.60 was recorded by control (without corn starch treatment) and 4% (S_2B_2) corn starch concentration recorded a mean score of 6.00 respectively. The highest sensory score of 7.10 for texture was noticed in red banana slices without corn starch treatment (control) and the lowest mean score of 6.60 was observed in 4% corn starch treated slices (S_2B_2). In the case of overall acceptability, control sample without corn starch treatment recorded the highest mean score of 8.00 and 4% (S_2B_2) corn starch treated round shaped red banana slices showed the lowest score.

Osmo dehydrated red banana chunks without corn starch treatment (control) recorded the highest mean score for appearance (8.60) and 4% (S_3B_2) corn starch

Table 18: Effect of binding agent (corn starch) on sensory qualities of osmo dehydrated red banana

Treatments	Appearance		Taste		Colour		Flavour		Texture		Overall acceptability	
	Mean score	Mean Rank	Mean score	Mean Rank	Mean score	Mean Rank	Mean score	Mean Rank	Mean score	Mean Rank	Mean score	Mean Rank
S_1B_1 (Ring-2%)	7.80	48.75	6.80	40.15	6.90	35.30	6.90	42.85	7.00	43.55	7.10	45.60
S_1B_2 (Ring-4%)	7.90	50.00	7.10	46.25	7.50	50.50	7.20	48.90	7.00	43.05	7.20	46.40
$S_1C_3T_3$ - control	8.70	72.10	8.30	68.50	8.50	73.10	8.60	77.50	8.40	78.20	8.70	76.00
S_2B_1 (Round-2%)	7.20	37.75	6.60	34.45	6.60	32.50	6.40	34.00	6.80	41.35	6.30	31.35
S_2B_2 (Round-4%)	7.00	32.30	6.30	29.10	6.50	29.10	6.00	27.10	6.60	36.40	6.20	29.45
$S_2C_3T_3$- control	8.20	58.25	8.10	64.80	8.20	67.40	7.60	57.60	7.10	45.35	8.00	62.00
S_3B_1 (Chunks-2%)	5.80	21.50	6.40	33.75	6.10	24.90	6.10	33.05	6.40	30.05	6.00	28.60
S_3B_2 (Chunks-4%)	5.80	19.40	5.90	25.50	6.40	31.10	5.60	26.35	6.20	24.00	5.80	24.10
$S_3C_3T_3$- control	8.60	69.45	8.20	67.00	8.10	65.60	7.80	62.15	7.90	67.55	8.20	66.00
K value	47.36		35.56		44.76		37.72		38.03		43.26	
χ^2	15.51											

treatment recorded the lowest sensory score of 5.80. When taste is considered, the highest score of 8.20 was noticed in control sample and the lowest score of 5.90 was recorded by S_3B_2 (chunks, 4% corn starch). The highest sensory score for colour (8.10) was observed in red banana chunks without corn starch treatment ($S_3C_3T_3$) and the lowest score was for 2% (S_3B_1) corn starch treated red banana chunks. For the sensory attribute flavour, the highest score of 7.80 was observed in control sample and the lowest mean score of 5.60 was recorded by red banana slices treated with 4% corn starch (S_3B_2). The highest sensory score for texture (7.90) was recorded by red banana chunks without corn starch treatment (control) whereas the lowest mean score of 6.20 was noticed in red banana chunks treated with 4% corn starch (S_3B_2). Osmo dehydrated red banana chunks without corn starch treatment (control) recorded the highest mean score for overall acceptability (8.20) and the lowest mean score for overall acceptability (5.80) was recorded by S_3B_2 (chunks, 4% corn starch).

Corn starch treated (2% and 4%) osmo dehydrated red banana chunks recorded the lowest acceptance in case of sensory attributes *viz.* appearance, taste, colour, flavour, texture and overall acceptability as compared to the untreated osmo dehydrated red banana (control).

Osmo dehydrated red banana without corn starch treatment secured higher mean scores for all the sensory attributes and higher acceptance than corn starch treated samples (2% and 4%) in all the three shapes (ring, round and chunks) of osmo dehydrated red banana. Hence the best treatments selected from Part I (ring, 80°Brix, 180 min; round, 80°Brix, 180 min and chunks, 80°Brix, 180 min) were subjected to storage stability studies.

4.1.6 STORAGE STUDIES

The selected best treatments from Part I of the study (ring, 80°Brix, 180 min; round, 80°Brix, 180 min and chunks, 80°Brix, 180 min) packed in polypropylene

(200 gauge) were stored at room temperature and analysed for changes in biochemical parameters, sensory attributes and microbial population at monthly interval for a period of four months.

4.1.6.1 Biochemical characters

Effect of storage on biochemical parameters of osmo dehydrated red banana were analysed and described below.

4.1.6.1.a TSS (°Brix)

Changes in TSS of osmo dehydrated red banana slices of different shapes during a storage period of four months are depicted in Table 19.

With respect to storage period, TSS increased with the storage time but there was no significant difference among the interaction effects. At the time of storage, TSS was 53.73°Brix which increased to 54.17°Brix after first month of storage, 54.47°Brix after second month of storage, 54.83°Brix after third month of storage and 55.48°Brix after fourth month of storage.

TSS of osmo dehydrated red banana rings (A_1) was 58.50°Brix at the time of storage which increased during storage and recorded 60.50°Brix after four months of storage. Similarly, round shaped osmo dehydrated red banana (A_2) recorded 56.19°Brix at the time of storage which increased to 57.45°Brix after four months of storage. A TSS of 46.50°Brix was observed at the time of storage for osmo dehydrated red banana chunks (A_3) which increased to 48.50°Brix after four months of storage.

Table 19: Effect of storage on TSS (°Brix) of osmo dehydrated red banana

Osmo dehydrated red banana (A)	TSS (^{0}B) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1 (Ring,80^{0}B, 180 min)	58.50	58.70	58.90	59.50	60.50	59.22
A_2 (Round,80^{0}B, 180 min)	56.19	56.55	56.75	57.00	57.45	56.79
A_3 (Chunks,80^{0}B, 180 min)	46.50	47.25	47.75	48.00	48.50	47.60
Mean (M)	53.73	54.17	54.47	54.83	55.48	
SE($\pm$m)	A- 0.299		M- 0.385			
CD	A- 0.847		M- 1.093		A×M- NS	

4.1.6.1.b Total sugar (%)

With respect to storage period, the total sugar content of 53.72% at the time of storage increased to 54.65 after first month of storage and it was 55.02%, 55.61% and 56.20% after 2nd, 3rd and fourth month of storage (Table 20).

Total sugar of osmo dehydrated red banana rings (A_1) was 54.87% at the time of storage which increased to 56.88% after four months of storage. Whereas for round shaped osmo dehydrated red banana (A_2), total sugar content at the time of storage (53.65%) increased with storage and recorded 56.32% after four months of storage. Similar trend was observed for osmo dehydrated red banana chunks (A_3) with a total sugar of 52.65% at the time of storage which increased to 55.41% after fourth month of storage. Total sugar exhibited an increasing pattern throughout the storage period but there was no significant difference among the interaction effects.

4.1.6.1.c Reducing sugar (%)

Changes in reducing sugar of osmo dehydrated red banana during storage is depicted in Table 21.

Reducing sugar of osmo dehydrated red banana was 37.30% at the time of storage which increased during storage and recorded a reducing sugar of 37.91% after first month, 38.47% after second month, 39.13% after third month and 39.80% after 4th month of storage but the interaction effects were statistically non significant.

Reducing sugar of osmo dehydrated red banana rings (A_1) was 37.13% at the time of storage which increased to 39.92% after fourth month of storage. Similarly, for round shaped osmo dehydrated red banana (A_2), reducing sugar was 38.22% at the time of storage which increased to 40.44% after 4th month of storage. Osmo dehydrated red banana chunks (A_3) recorded 36.55% at the time of storage which increased with storage period and recorded 39.05% after fourth month of storage.

Table 20: Effect of storage on total sugar (%) of osmo dehydrated red banana

Osmo dehydrated red banana (A)	Total sugar (%) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1 (Ring,80^{0}B, 180 min)	54.87	55.35	55.60	56.10	56.88	55.76
A_2 (Round,80^{0}B, 180 min)	53.65	54.93	55.38	55.85	56.32	55.23
A_3 (Chunks,80^{0}B, 180 min)	52.65	53.66	54.07	54.88	55.41	54.13
Mean (M)	53.72	54.65	55.02	55.61	56.20	
SE($\pm$m)	A- 0.177	M- 0.228				
CD	A- 0.502	M- 0.648	A×M- NS			

Table 21: Effect of storage on reducing sugar (%) of osmo dehydrated red banana

Osmo dehydrated red banana (A)	Reducing sugar (%) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1 (Ring,80^{0}B, 180 min)	37.13	37.85	38.62	39.42	39.92	38.59
A_2 (Round,80^{0}B, 180 min)	38.22	38.72	39.25	39.83	40.44	39.29
A_3 (Chunks,80^{0}B, 180 min)	36.55	37.15	37.55	38.15	39.05	37.69
Mean (M)	37.30	37.91	38.47	39.13	39.80	
SE($\pm$m)	A- 0.230	M- 0.297				
CD	A- 0.653	M- 0.843	A×M- NS			

4.1.6.1.d Acidity (% citric acid)

Changes in acidity of osmo dehydrated red banana during storage period is given in Table 22.

Acidity of osmo dehydrated red banana decreased with storage, and it decreased from 0.62% at the time of storage to 0.30% after four months of storage. Even though acidity decreased in all the treatments, the interaction effects were statistically non significant.

Acidity of osmo dehydrated red banana rings (A_1) was 0.65% at the time of storage which decreased during storage and recorded an acidity of 0.32% after four months of storage. Whereas an acidity of 0.59% was noticed in round shaped osmo dehydrated red banana (A_2) at the time of storage which decreased to 0.28% after four months of storage. Osmo dehydrated red banana chunks (A_3) recorded an acidity of 0.61% at the time of storage which decreased with storage and recorded 0.30% after 4th month of storage.

4.1.6.1.e Ascorbic acid (mg 100g $^{-1}$)

Effect of storage on ascorbic acid content of osmo dehydrated red banana is depicted in Table 23.

Ascorbic acid content of osmo dehydrated red banana decreased with storage from 9.59 mg 100g^{-1} at the time of storage to 8.62 mg 100g^{-1} after four months of storage, but no significant difference was observed between the interaction effects.

Ascorbic acid exhibited a decreasing trend with advancement of storage period and osmo dehydrated red banana rings (A_1) recorded ascorbic acid of 9.03 mg 100g^{-1} at the time of storage which decreased to 8.33 mg 100g^{-1} after four months of storage. Ascorbic acid of round shaped osmo dehydrated red banana (A_2) recorded

Table 22: Effect of storage on acidity (%) of osmo dehydrated red banana

Osmo dehydrated red banana (A)	Acidity (%) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1 (Ring,80^0B, 180 min)	0.65	0.55	0.50	0.42	0.32	0.49
A_2 (Round,80^0B, 180 min)	0.59	0.48	0.42	0.38	0.28	0.43
A_3 (Chunks,80^0B, 180 min)	0.61	0.50	0.44	0.40	0.30	0.45
Mean (M)	0.62	0.51	0.45	0.40	0.30	
SE($\pm$m)	M- 0.023					
CD	A- NS		M- 0.064		A×M- NS	

Table 23: Effect of storage on ascorbic acid (mg 100g $^{-1}$) of osmo dehydrated red banana

Osmo dehydrated red banana (A)	Ascorbic acid (mg $100g^{-1}$) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1 (Ring,80^0B, 180 min)	9.03	8.83	8.73	8.58	8.33	8.70
A_2 (Round,80^0B, 180 min)	10.80	10.60	10.10	9.90	9.70	10.22
A_3 (Chunks,80^0B, 180 min)	8.93	8.53	8.41	8.41	7.82	8.42
Mean (M)	9.59	9.32	9.08	8.96	8.62	
SE($\pm$m)	A- 0.094		M- 0.121			
CD	A- 0.265		M- 0.343		A×M- NS	

10.80 mg 100g^{-1} at the time of storage which decreased to 9.70 mg 100g^{-1} after four months of storage. Similarly, ascorbic acid of 8.93 mg 100g^{-1} at the time of storage noticed in osmo dehydrated red banana chunks (A_3) decreased with storage period and recorded 7.82 mg 100g^{-1} at the end of storage of four months.

4.1.6.1.f Carotenoids (μg 100g $^{-1}$)

Changes in carotenoid content of osmo dehydrated red banana during storage period of four months are depicted in Table 24.

Carotenoid content of osmo dehydrated red banana was 7.52 μg 100g^{-1} at the time of storage which exhibited a decreasing trend with storage period and recorded 6.78 μg 100g^{-1} after first month, 6.25 μg 100g^{-1}, 5.70 μg 100g^{-1} and 5.37 μg 100g^{-1} after 2nd, 3rd and fourth month of storage.

Carotenoid content of osmo dehydrated red banana rings (A_1) was 6.01 μg 100g^{-1} at the time of storage which decreased to 4.42 μg 100g^{-1} after fourth month of storage. For round shaped osmo dehydrated red banana (A_2), at the time of storage, it was 9.61 μg 100g^{-1} which decreased to 7.54 μg 100g^{-1} after 4th month of storage. Similarly osmo dehydrated red banana chunks (A_3) recorded a decreasing trend from 6.94 μg 100g^{-1} to 4.15 μg 100g^{-1} after the storage of four months.

4.1.6.1.g Antioxidant activity (%)

Antioxidant activity of osmo dehydrated red banana during storage period of four months is depicted in Table 25. Antioxidant activity of osmo dehydrated red banana decreased with storage, and it decreased from 93.85% to 91.17% after four months of storage whereas the interaction effects were found statistically non significant.

Table 24: Effect of storage on carotenoids (µg $100g^{-1}$) of osmo dehydrated red banana

Osmo dehydrated red banana (A)	Carotenoids (µg $100g^{-1}$) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1 (Ring,80^0B, 180 min)	6.01	5.02	4.95	4.62	4.42	5.01
A_2(Round,80^0B, 180 min)	9.61	9.05	8.35	7.62	7.54	8.44
A_3(Chunks,80^0B, 180 min)	6.94	6.25	5.45	4.85	4.15	5.53
Mean (M)	7.52	6.78	6.25	5.70	5.37	
SE(±m)	A- 0.086		M- 0.111		A×M- 0.192	
CD	A- 0.243		M- 0.314		A×M- 0.544	

Table 25: Effect of storage on antioxidant activity (%) of osmo dehydrated red banana

Osmo dehydrated red banana (A)	Antioxidant activity (%) Months after storage (M)					Mean (A)
	0	1	2	3	4	
A_1 (Ring,80^0B, 180 min)	94.98	94.33	94.00	93.14	92.94	93.88
A_2 (Round,80^0B, 180 min)	93.68	92.78	92.18	91.68	90.88	92.24
A_3 (Chunks,80^0B, 180 min)	92.88	92.28	91.48	90.48	89.68	91.36
Mean (M)	93.85	93.13	92.55	91.77	91.17	
SE(±m)	A- 0.187		M- 0.241			
CD	A- 0.530		M- 0.684		A×M- NS	

Osmo dehydrated red banana rings (A_1) recorded an antioxidant activity of 94.98% at the time of storage which decreased to 92.94% after fourth month of storage. Whereas for round shaped osmo dehydrated red banana (A_2), antioxidant activity of 93.68% at the time of storage decreased to 90.88% after four months of storage. Osmo dehydrated red banana chunks (A_3) also exhibited decreasing trend with increase in storage period and recorded 92.88% at the time of storage which decreased to 89.68% at the end of storage.

4.1.6.2 Sensory analysis of osmo dehydrated red banana during storage

Sensory attributes *viz.,* appearance, taste, colour, flavour, texture and overall acceptability of osmo dehydrated red banana were analysed using 9 point hedonic scale at monthly interval.

Effect of storage on appearance, taste and colour of osmo dehydrated red banana is depicted in Table 26a. At the time of storage, osmo dehydrated red banana rings (A_1) recorded the highest mean score for appearance (7.91) followed by A_3 (chunks) and A_2 (round) with mean scores of 7.36 and 7.09 respectively. The sensory score decreased with storage and A_1 (ring) recorded a mean score of 7.82 after 1st month, 7.73 after 2nd month, 7.55 after 3rd month and 7.45 after 4th month of storage. Similarly, a mean score of 7.00 after 1st month, 6.91 after 2nd month, 6.82 after 3rd month and 6.73 after 4th month was observed for round shaped osmo dehydrated red banana (A_2). Osmo dehydrated red banana chunks (A_3) recorded a mean score of 7.27, 7.18, 7.09 and 7.00 respectively after 1st, 2nd, 3rd and 4th month of storage.

At the time of storage, osmo dehydrated red banana rings (A_1) recorded the highest score for taste (8.27) and A_3 (chunks) recorded a mean score of 7.82 and it was 7.18 for A_2 (round). Sensory scores showed a decreasing pattern with storage and A_1 (ring) recorded mean score of 8.18 after one month of storage, 8.09 after two months of storage, 7.82 after three months of storage and 7.73 after four months of storage. Sensory mean score of 7.09, 7.00, 6.73 and 6.63 were observed for round shaped osmo dehydrated red banana (A_2) after 1st, 2nd, 3rd and 4th months of storage respectively. Osmo dehydrated red banana chunks (A_3) recorded a sensory score of 7.73, 7.64, 7.36 and 7.27 after 1st, 2nd, 3rd and 4th month of storage.

At the time of storage, mean score for sensory attribute colour was 8.36, 8.00 and 7.36 for A_1 (ring), A_3 (chunks) and A_2 (round) respectively. Sensory scores decreased with storage and it was 8.27 after 1st month, 8.18 after 2nd month, 8.00 after 3rd month and 7.91 after 4th month of storage for osmo dehydrated red banana rings (A_1). The sensory mean score of round shaped osmo dehydrated red banana (A_2) was 7.27 after 1st month of storage which decreased to 6.91 after 4th month of storage. It was 7.91, 7.81, 7.64 and 7.55 after 1st, 2nd, 3rd and 4th month of storage for A_3 (chunks).

Changes in sensory mean score of osmo dehydrated red banana with respect to flavour, texture and overall acceptability is depicted in Table 26b. When sensory attribute flavour is considered, at the time of storage, mean score for osmo dehydrated red banana rings (A_1), round shaped osmo dehydrated red banana (A_2) and osmo dehydrated red banana chunks (A_3) was 8.45, 7.64 and 8.27 respectively. Mean scores decreased with the advancement of storage period and ring shaped osmo dehydrated red banana (A_1) recorded 8.36, 8.27, 7.91 and 7.82 respectively after 1st, 2nd, 3rd and 4th month of storage. Round shaped osmo dehydrated red banana (A_2) recorded a sensory score of 7.55, 7.45, 7.09 and 7.00 respectively after 1st, 2nd, 3rd and 4th month of storage. Similarly, mean score of 8.18 after 1st month, 8.09 after 2nd month, 7.72 after 3rd month and 7.64 after 4th month of storage was observed for osmo dehydrated red banana chunks (A_3).

At the time of storage, A_1 (ring) recorded the highest mean score (8.18) for texture and A_2 (round) recorded a sensory mean score of 7.18 and it was 7.73 for osmo dehydrated red banana chunks (A_3). Mean scores decreased with storage and were observed as 8.09, 7.91, 7.82 and 7.73 respectively after 1st, 2nd, 3rd and 4th month of storage for A_1 (ring). A sensory score of 7.00 after 1st month, 6.91 after 2nd month, 6.73 after 3rd month and 6.64 after 4th month of storage was observed for round shaped osmo dehydrated red banana (A_2). Osmo dehydrated red banana chunks (A_3) recorded a mean score of 7.64, 7.55, 7.45 and 7.36 respectively after 1st, 2nd, 3rd and 4th month of storage.

At the time of storage, osmo dehydrated red banana rings (A_1) recorded the highest mean score for overall acceptability (8.36) followed by chunks (A_3) and round (A_2) with a mean score of 8.00 and 7.36 respectively. With the advancement of storage period, sensory scores decreased and A_1 (ring) recorded a sensory score of 8.18 after 1st month, 7.91 after 2nd month , 7.72 after 3rd month and 7.55 after 4th month of storage. The sensory mean score of round shaped osmo dehydrated red banana (A_2) was 7.27 after 1st month of storage which decreased to 6.73 after 4th month of storage. It was 7.82, 7.64, 7.45 and 7.27 after 1st, 2nd, 3rd and 4th month of storage for A_3 (chunks).

On analyzing the mean scores for various sensory parameters *viz.,* appearance, taste, colour, flavour, texture and overall acceptability of osmo dehydrated red banana for a period of four months, osmo dehydrated ring shaped red banana immersed in osmotic concentration of 80°B for an immersion time of 180 min (A_1) was the most accepted treatment followed by osmo dehydrated red banana chunks immersed in osmotic concentration of 80°B for an immersion time of 180 min (A_3) and round shaped red banana in 80°B for 180 min (A_3) secured the lowest sensory scores for all the sensory attributes. Even though during storage sensory mean score for all sensory attribute decreased, but it was within the range of consumer acceptance.

Table 26a. Effect of storage on appearance, taste and colour of osmo dehydrated red banana

Osmo dehydrated red banana	Appearance					Taste					Colour				
	Mean scores					Mean scores					Mean scores				
	At storage	1	2	3	4	At storage	1	2	3	4	At storage	1	2	3	4
A_1 (Ring)	7.91	7.82	7.73	7.55	7.45	8.27	8.18	8.09	7.82	7.73	8.36	8.27	8.18	8.00	7.91
A_2 (Round)	7.09	7.00	6.91	6.82	6.73	7.18	7.09	7.00	6.73	6.63	7.36	7.27	7.18	7.00	6.91
A_3 (Chunks)	7.36	7.27	7.18	7.09	7.00	7.82	7.73	7.64	7.36	7.27	8.00	7.91	7.81	7.64	7.55
K value	20.44	15.94	15.57	9.21	8.98	22.62	17.84	14.99	11.76	9.93	16.59	13.13	11.18	8.81	7.79
χ^2	5.99					5.99					5.99				

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Table 26b. Effect of storage on flavour, texture and overall acceptability of osmo dehydrated red banana

Osmo dehydrated red banana	Flavour					Texture					Overall acceptability				
	Mean scores					Mean scores					Mean scores				
	At storage	1	2	3	4	At storage	1	2	3	4	At storage	1	2	3	4
A_1 (Ring)	8.45	8.36	8.27	7.91	7.82	8.18	8.09	7.91	7.82	7.73	8.36	8.18	7.91	7.72	7.55
A_2 (Round)	7.64	7.55	7.45	7.09	7.00	7.18	7.00	6.91	6.73	6.64	7.36	7.27	7.09	6.91	6.73
A_3 (Chunks)	8.27	8.18	8.09	7.72	7.64	7.73	7.64	7.55	7.45	7.36	8.00	7.82	7.64	7.45	7.27
K value	11.84	10.50	8.58	7.76	7.01	24.94	19.92	13.32	11.89	9.61	20.49	15.81	13.48	10.28	8.08
χ^2	5.99					5.99					5.99				

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4.1.6.3 Microbial analysis of stored osmo dehydrated red banana

The osmo dehydrated red banana were analysed for yeast, bacteria and fungi at monthly interval for a period of four months. No microbial load was detected during the entire storage period of four months and was safe for consumption.

Discussion

5. DISCUSSION

The results obtained from the investigation on 'Development of osmo dehydrated Red Banana (*Musa* spp.)' conducted with the objective, to standardize different process variables *viz.*, fruit slice shape, osmotic concentration and immersion time for osmo dehydration of red banana and to assess the storage stability of the final dehydrated product are discussed in this chapter as described below.

5.1 DEVELOPMENT OF OSMO DEHYDRATED RED BANANA

5.2 STORAGE STUDIES OF OSMO DEHYDRATED RED BANANA SLICES

5.1 DEVELOPMENT OF OSMO DEHYDRATED RED BANANA

5.1.1 Mass transfer characters of osmosed red banana slices

Mass transfer characters *viz.* water loss, solid gain, water loss to solid gain and percentage weight reduction was analysed for different shapes (ring, round and chunks), osmotic concentrations (40°Brix, 60°Brix and 80°Brix) and immersion time (60 min, 120 min and 180 min).

Water loss of red banana slices varied with shapes and increased with increase in osmotic solution concentration and immersion time. Among the different fruit slice shapes, osmo dehydrated red banana chunks recorded the highest water loss (4.51%) followed by osmo dehydrated red banana rings (3.52%) and the lowest water loss (3.19%) was observed for round shaped red banana slices (Fig.1). For osmo dehydrated red banana rings, water loss ranged from 1.09 to 5.81% and it varied from 1.15% to 5.56% for round shaped red banana slices and 2.58% to 9.59% in case of red banana chunks. Rastogi *et al.* (2002) reported that mass transfer characters showed varied response with respect to fruit slice shapes which may be due to change in specific surface area of fruit slices. According to Ispir and Togrul (2009), during osmo dehydration of apricot, higher sucrose concentration favoured greater osmotic pressure gradients thereby leading to higher water loss throughout the osmotic treatment period. In the present study, water loss increased with increase in osmotic concentration with 2.28% for 40°Brix osmotic concentration, 3.59% for 60°Brix and it was 5.35% for osmotic concentration of 80°Brix. Zahoor and Khan (2017) observed that water loss increased with increase in concentration of the osmotic agent and the highest water loss was noticed with the concentration of 60°Brix when mass transfer character of pineapple was analysed using three different concentrations of 40°Brix, 50°Brix and 60°Brix. When different immersion time was considered, 180 min showed the highest water loss (4.5%) followed by 120 min (3.61%) and red banana slices osmosed for a period of 60 min recorded the lowest water loss of only 2.61%. Gabriela *et al.* (2004) and Ali *et al.* (2010) reported increased water loss values with increase in immersion time. Among all the red banana treatments, osmo dehydrated red banana chunks immersed at a concentration of 80°Brix for 180 min recorded the highest water loss (9.59%) and the lowest water loss (1.09%) was recorded for ring shaped slices at 40°Brix for 60 min immersion time. Similar results of increase in water loss with increase in osmotic concentration and immersion time were reported by various researchers in watermelon (Falade and Igbeka, 2007), apricot (Ispir and Togrul, 2009), pomegranate arils (Mundada *et al.*, 2011) and pumpkin (Correa *et al.*, 2018).

Solid gain of osmo dehydrated red banana rings ranged from 3.29% to 8.80% and was between 3.10% and 8.62% for round shaped osmo dehydrated red banana and it was 2.75% to 8.90% for osmo dehydrated red banana chunks. Among the different fruit slice shapes, osmo dehydrated red banana rings recorded the highest solid gain (7.01%) followed by osmo dehydrated red banana chunks (6.35) (Fig.2). This may be due to the fact that surface area of the sample greatly influenced the mass transfer rate and was supported by various researchers. Higher specific surface area sample shape (rings) gave higher solid gain compared to lower surface area samples (Lerici *et al.*, 1985). A sample size of 3 mm to 10 mm in ring or cube shape was suggested for osmo dehydration process (Chavan and Amarowicz, 2012). Azoubel and Murr (2004) indicated that

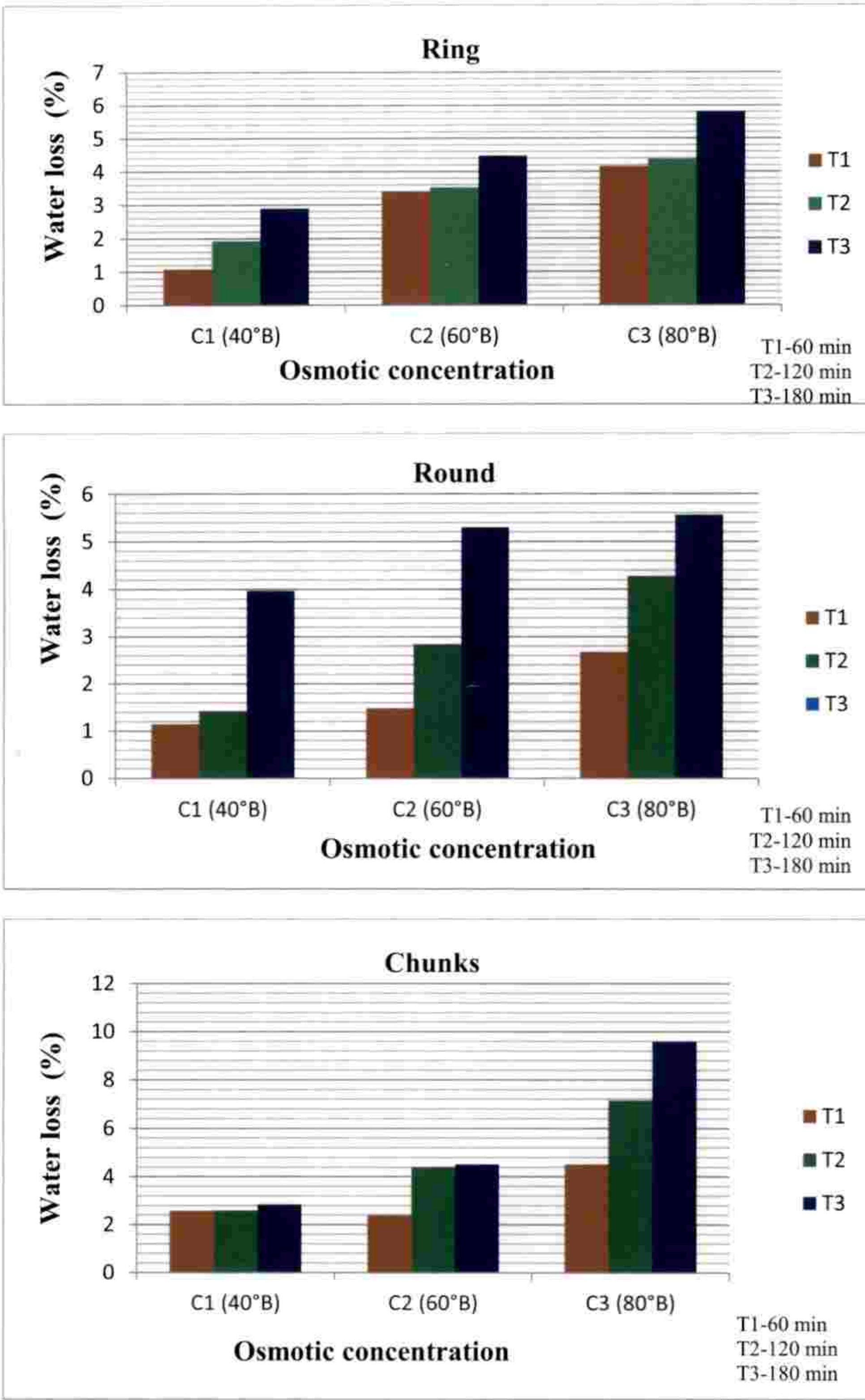
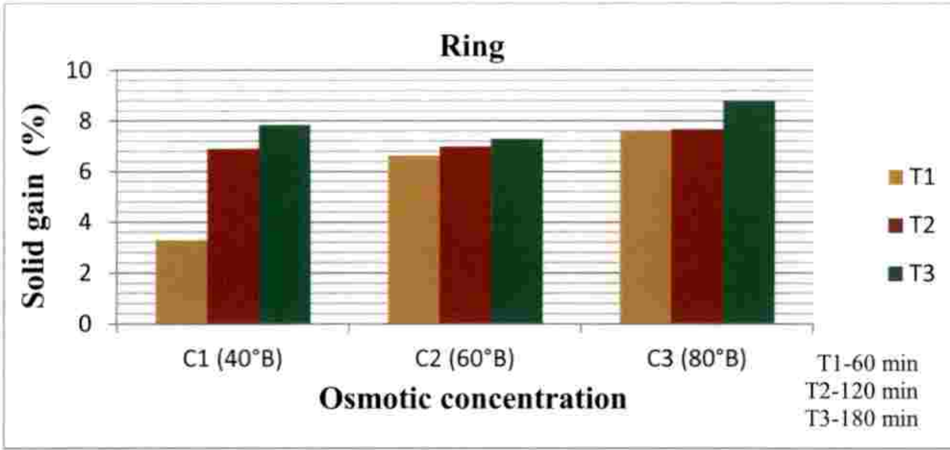
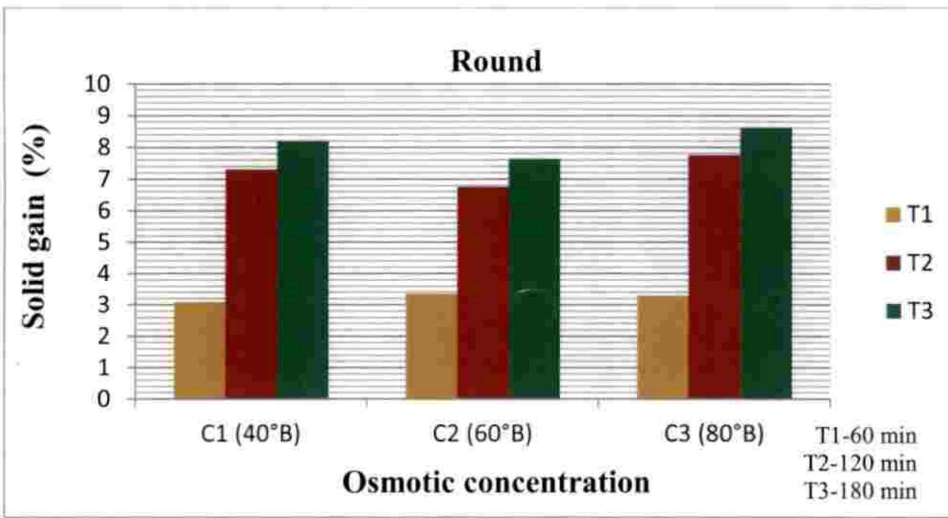


Fig.1. Water loss of osmo dehydrated red banana with respect to osmotic concentration and immersion time





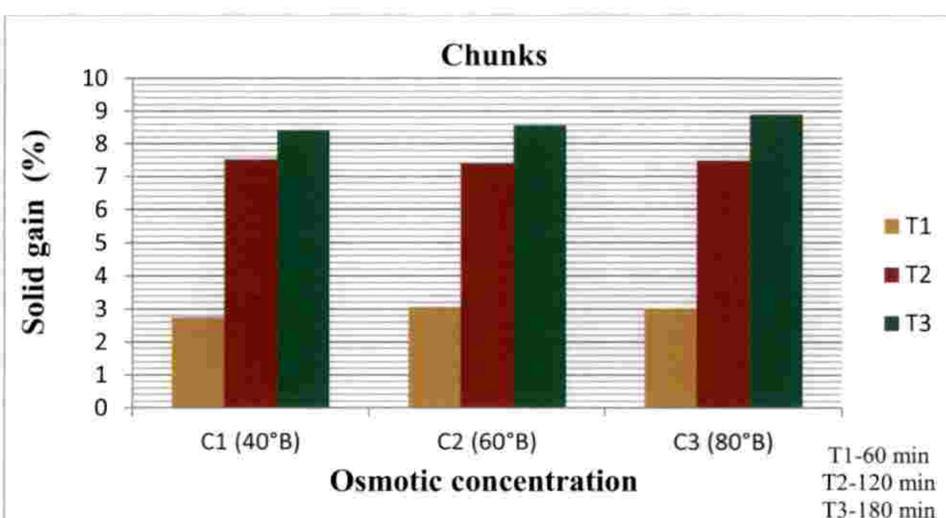


Fig.2. Solid gain of osmo dehydrated red banana with respect to osmotic concentration and immersion time

increase in osmotic solution concentration resulted in an increase in pressure gradient and thereby increased water loss which lead to a much greater solid gain. Falade and Igbeka (2007) studied the osmotic mass transfer phenomenon of water melon slabs using three different sucrose concentrations (40°Brix, 50°Brix and 60°Brix) and observed increased solid gain with increase in concentration of osmotic solution. In the present study, solid gain increased with increase in concentration and the highest solid gain was observed at 80°Brix (7.02%) followed by 60°Brix osmotic concentration with 6.41% solid gain. When the immersion time was considered, solid gain increased with immersion time with 4.02% for 60 min, 7.31% for 120 min and 8.25% for 180 min immersion time. Gabriela *et al.* (2004) monitored the osmotic dehydration of mango slices where process time varied from 40 to 120 min, the results shown that solute gain (SG %) was greatly affected by process time. Among all the red banana treatments osmo dehydrated chunks at 80°Brix with 180 min immersion time recorded the highest solid gain (8.90%) and the lowest (2.75%) was noticed in osmo dehydrated red banana chunks at 40°Brix for 60 min immersion time. Similar trend of increase in solid gain with increase in osmotic concentration and immersion time was observed during osmo dehydration of pomegranate arils (Mundada *et al.*, 2011), pineapple (Zapata *et al.*, 2011) and banana (Renu *et al.*, 2012; Shukla *et al.*, 2018).

Among the different fruit slice shapes, the highest percentage weight reduction (7.97%) was observed in round shaped osmo dehydrated red banana followed by osmo dehydrated red banana rings (6.69%). Tiwari and Jalali (2004) reported that mass transfer characters were affected by the shape of the produce and varied with the surface area of fruit slices. In the present study, osmotic concentration of 80°Brix recorded the highest percentage weight reduction (8.99%) which showed no significant difference with 60°Brix and 40°Brix recorded the lowest weight reduction (3.52%). The results were similar to the findings observed during osmo dehydration of pineapple (Khanom *et al.*, 2014) and red pitaya (Najafi *et al.*, 2014). When the immersion time was considered, 180 min recorded the highest weight reduction (8.47%) followed by 120 min (7.18%) whereas process time of 60 min recorded the lowest weight reduction of 5.61%. Among all the treatments, round shaped slices in 80°Brix for an immersion time of 180 min recorded the highest percentage weight reduction (11.75%) whereas the lowest (1.63%) was noticed in osmo dehydrated chunks at 40°Brix osmotic concentration for 60 min immersion time. Tiwari and Jalali (2004) reported that during osmotic dehydration of mango and pineapple, increase in osmotic duration resulted in increase in weight loss, but the rate of change decreased. Increased weight reduction with increase in immersion time was earlier reported by several researchers in tomato and banana (Ali *et al.*, 2010; Kumari *et al.*, 2013).

Water loss to solid gain (WL/SG) is considered as a good indicator for maximisation of water loss and minimisation of solid gain (Ravindra and Chattopadhyay, 2000). In the present study, osmo dehydrated red banana chunks recorded the highest WL/SG (0.80) followed by round shaped red banana (0.52). High concentrated sucrose solution lead to increased loss of water and solid gain ratios (Tortoe, 2010). In the present study, among the different concentrations, the highest WL/SG was noticed at 80°Brix (0.82) followed by 60°Brix (0.58) and 40°Brix (0.42). With respect to different immersion time, 60 min immersion time recorded the highest WL/SG (0.72) followed by 180 min immersion time (0.60). Increase in WL/SG with increase in osmotic concentration were reported in mango and pineapple by Tiwari and Jalali, (2004) and in banana by Renu *et al.* (2012).

5.1.2 Biochemical parameters of osmo dehydrated red banana slices

Tiwari (2005) stated that osmotic dehydration could be very much beneficial for banana, jackfruit, sapota, mango, guava, and pineapple and this technology is preferred over other methods due to their nutritional constituent retention value and attractiveness of the product due to their sensory qualities.

Osmo dehydrated red banana rings recorded the highest TSS (51.85°Brix) followed by round shaped osmo dehydrated red banana (50.72°Brix) whereas the lowest TSS (37.52°Brix) was observed in osmo dehydrated red banana chunks. Ghadge (2013) reported that the TSS of the osmotically dehydrated ripe banana showed an increasing trend with increase in the sugar syrup level. In the present study, TSS of osmo dehydrated fruits increased with increase in osmotic concentration where 80°Brix recorded the highest TSS (52.79°Brix) followed by 60°Brix (46.37) and 40°Brix recorded the lowest TSS (40.93°Brix). Chavan *et al.* (2010) reported that during osmo dehydration of banana slices, TSS increased with increase in concentration of osmotic solution and immersion time. When immersion time was considered, osmo dehydration of red banana at 180 min immersion time recorded the highest TSS (48.62°Brix) followed by 120 min (47.22°Brix) and 60 min recorded the lowest (44.25°Brix). Similar trend was observed by various researchers in banana (Fernandes *et al.*, 2006; Anand and Genitha, 2011), pineapple (Rai *et al.*, 2007; Sneha *et al.*, 2013; Rahim *et al.*, 2018) and black mulberry fruit (Ojha *et al.*, 2017). TSS of osmo dehydrated red banana rings varied between 39.33°Brix to 59.49°Brix whereas it ranged from 43.57°Brix to 56.13°Brix in round shaped slices and 29.17°Brix to 46.76°Brix in osmo dehydrated red banana chunks. TSS increase in all the samples might be due to the increase in solution concentration which resulted in increased osmotic pressure gradients and hence, higher sugar gain as reported by Shukla *et al.* (2018).

Among the different fruit slice shapes, osmo dehydrated red banana ring recorded the highest total sugar (45.00%) followed by round (44.33%) and chunk shaped slices (39.92%). In the present study, total sugar increased with increase in osmotic concentration with a total sugar of 37.78% at 40°Brix, 41.67% at 60°Brix and it was 49.81% at osmotic concentration of 80°Brix. de Castro *et al.* (2016) reported similar pattern of increase in both total sugar and reducing sugar percentage of guava slices. When different immersion time was considered, osmotic treatment for 180 min recorded the highest total sugar (47.48%) followed by 120 min (42.08%) and the lowest total sugar (39.70%) was recorded for osmotic treatment at 60 min immersion time. With increase in immersion time and osmotic concentration, both total and reducing sugar increased. Among all the osmo dehydrated red banana treatments, round shaped slices at 80°Brix for an immersion time of 180 min recorded the highest total sugar (54.15%) and the lowest (30.61%) was observed in osmo dehydrated red banana chunks at 40°Brix for 60 min immersion time.

The highest reducing sugar was observed for round shaped osmo dehydrated red banana (27.3%) and the lowest (21.64%) was observed for osmo dehydrated red banana chunks. Reducing sugar ranged between 10.95% to 36.63% in osmo dehydrated red banana rings, 13.77% to 37.82% in round shaped slices and 10.14% to 36.63% in case of osmo dehydrated red banana chunks. The present findings were supported by several researchers who had reported that during osmo dehydration, moisture removal and solute uptake resulted in increase of both total and reducing sugar which is a typical property during osmo dehydration process (Rashmi *et al.*, 2005; Kumar *et al.*, 2008; Ghadge, 2013; Thippanna and Tiwari, 2015; de Castro *et al.*, 2016). In the present study, reducing sugar increased with increase in osmotic concentration with 16.48% for 40°Brix, 24.67% for 60°Brix and it was 32.87% for osmotic concentration of 80°Brix. When different immersion time was considered, reducing sugar increased with increase in the process duration with the highest total sugar (29.03%) for 180 min immersion time followed by 120 min and the lowest (19.84%) for red banana slices osmo dehydrated for a period of 60 min. Similar results were observed in osmo dehydration of mango (Sagar *et al.*, 1998) and pineapple (Sneha *et al.*, 2013) where total and reducing sugar increased with solution concentration and immersion time.

With respect to different fruit slice shapes, osmo dehydrated red banana rings recorded the highest acidity (1.05%) followed by red banana chunks (0.89%) whereas the lowest acidity (0.81%) was noticed for round shaped osmo dehydrated red banana. Torte (2010) reported that osmotic dehydration leads to reduction in acidity of the treated fruits. Acidity of osmo dehydrated red banana decreased with increase in osmotic concentration and recorded an acidity of 1.09% for 40°Brix, 0.93% for 60°Brix and the lowest acidity (0.73%) for 80°Brix and it was observed that increased immersion time led to decrease in acidity of osmo dehydrated fruit slices. Reduction in acidity might be due to leaching of acid from fruits to hypertonic solution through a semi permeable membrane (Sagar and Kumar, 2008). Similar findings of reduction in acidity were reported by other researchers in pineapple by Ramallo and Mascheroni, (2010) and Phisut (2012) in guava, by de Castro *et al.* (2016) and Selvakumar and Tiwari (2018) in carrot.

Ascorbic acid content of osmo dehydrated red banana showed no significant difference with respect to change in shape of fruit slices. Ascorbic acid exhibited a decreasing trend with increase in osmotic concentration and immersion time for all the three shapes in the present study. Among the different osmotic concentration, 40°Brix recorded the highest ascorbic acid (17.19 mg $100g^{-1}$) followed by 60°Brix (15.47 mg $100g^{-1}$) and osmotic treatment in 80°Brix recorded the lowest ascorbic acid (13.23 mg $100g^{-1}$). This may be due to the transfer of ascorbic acid from fruit to the osmotic solution during osmosis. Yadav and Singh (2014) reported that the ascorbic acid losses during osmotic dehydration might be attributed to the leaching of the vitamin from the product to the osmotic solution during the osmotic process. With respect to different immersion time, the highest ascorbic acid (18.12 mg $100g^{-1}$) was noticed in 60 min immersion time and it was 16.14 mg $100g^{-1}$ for 120 min and the lowest (11.64 mg $100g^{-1}$) for immersion time of 180 min. These results were in conformity with the observations of Singh *et al.* (2015) who observed a decreasing trend of vitamin C with increase in osmotic concentration during osmotic dehydration of papaya slices. Ascorbic acid degradation during osmo dehydration was reported by other research workers in osmotically dried kiwifruits (Uddin *et al.*, 2002); quince slices (Roble-Manzanares *et al.*, 2004); cashewapple (Azoubel *et al.*, 2009); pineapple (Ramallo and Mascheroni, 2010);

sea buckthorn fruits (Araya-Farias *et al.*, 2014) ; papaya (Singh *et al.*, 2015) and black mulberry fruit (Ojha *et al.*, 2017).

In the present study, with respect to fruit slice shape, highest carotenoid content was noticed in round shaped osmo dehydrated red banana (17.27 µg $100g^{-1}$) whereas the lowest (10.97 µg $100g^{-1}$) was observed in osmo dehydrated red banana rings. Carotenoid content of osmo dehydrated red banana exhibited a decreasing trend with increase in osmotic concentration and it was 18.00 µg $100g^{-1}$ for 40°Brix, 12.70 µg $100g^{-1}$ for 60°Brix and 9.14 µg $100g^{-1}$ for 80°Brix. The loss of carotenoid content in osmo dehydrated fruits was mainly due to leaching of carotenoid to the osmotic solution and is supported by Selvakumar and Tiwari (2018). When different immersion time was considered, 60 min showed the highest carotenoid content (18.84 µg $100g^{-1}$) followed by 120 min (11.79 µg $100g^{-1}$) and red banana slices osmosed for a period of 180 min recorded the lowest carotenoid content of 9.22 µg $100g^{-1}$. This was supported by the results of Madan and Dhawan (2005) where carotenoid content in carrot slices decreased after osmo dehydration which may be due to destabilization of polyene chains present in carotenoid and therefore making them prone to many alterations by oxidation or isomerization causing changes in their primary structure (Salazar *et al.*, 2019).

When different fruit slice shape were considered, round shaped osmo dehydrated red banana recorded the highest antioxidant activity (94.37%) followed by osmo dehydrated red banana chunks (93.12%) and the lowest antioxidant activity (92.07%) was noticed in osmo dehydrated red banana rings. The antioxidant activity decreased with increase in osmotic concentration and immersion time. Among all the red banana treatments, round shaped slices at 40°Brix osmotic concentration for an immersion time of 180 min recorded the highest antioxidant activity (95.30%) whereas osmo dehydrated red banana chunks at 80°Brix for 180 min recorded the lowest antioxidant activity (89.00%). Wojdylo *et al.* (2007) reported that osmo dehydration process caused degradation of some phenolic compounds and thus reduces the antioxidant capacity and the reduction in antioxidant activity increased with increase in osmotic concentration and immersion time. Reduction in antioxidant activity with increase in osmotic solution concentration and immersion time was reported by Michalczyk *et al.* (2009) in bilberries, Devic *et al.* (2010) in apples, Chiu *et al.* (2017) in terung asam and Islam *et al.* (2019) in papaya. According to Martin-Cabrejas *et al.* (2009) and Qu *et al.* (2010), decrease in antioxidant activity can also be attributed to the binding of polyphenols with other compounds (proteins) or due to alterations in the chemical structure of polyphenols. Udomkun *et al.* (2015) reported that reduction might be due to drying temperature which resulted in destruction of some endogenous antioxidants.

5.1.3 Physical parameters of osmo dehydrated red banana slices

Physical characters *viz.* yield, rehydration ratio, colour (browning index) and textural quality were analysed for osmo dehydrated red banana.

The highest yield was observed for osmo dehydrated red banana chunks (28.82%) whereas osmo dehydrated red banana rings recorded the lowest yield (26.40%). The yield increased with increase in osmotic solution concentration and immersion time. Azoubel and Murr (2004) indicated that increase in concentration of osmotic solution resulted in an increase in pressure gradients and thereby increased solid gain and dry yield and it was also supported by the findings of Thippanna (2005). The increase in yield with increase in immersion time may be due to the increased penetration of sugar into the fruits (Ispir and Togrul, 2009). In the present study also, yield of osmo dehydrated red banana exhibited an increasing trend with immersion time and recorded a yield of 26.88% for 60 min and 28.56% for 180 min immersion time. Among all the treatments, the highest yield (31.75%) was noticed in osmo dehydrated red banana chunks at 80°Brix for 180 min immersion time whereas ring slices immersed in osmotic concentration of 40°Brix for 60 min recorded the lowest yield (20.06%). Increase in recovery of dried products by osmotic treatments was reported in guava by Pedapati and Tiwari (2014).

The rehydration ratio determines ability of the sample to regain the water without disintegration, which is considered as an important quality parameter (Thippanna and Tiwari, 2015). According to Doymaz (2017), reconstitution of the dehydrated product depends on the internal structure and the extent to which the water-holding component has been damaged during drying. Among the different fruit slice shapes, osmo dehydrated red banana rings recorded the highest rehydration ratio (1.45) followed by round shaped slices (1.43) and it was 1.36 for osmo dehydrated red banana chunks. Khedkar and Roy (1988) observed lower rehydration ratio in osmo dehydrated mango which might be due to degradation of pectic polysaccharides during drying procedure. In the present study, rehydration ratio exhibited a decreasing pattern with increase in osmotic concentration and immersion time. Among the different osmotic concentration, 40°Brix recorded the highest rehydration (1.48) followed by 60°Brix (1.40) and the lowest (1.36) was noticed in 80°Brix osmotic concentration. When different immersion time was considered, 60 min immersion time recorded the highest rehydration (1.46) and it was 1.40 for 120 min and the lowest (1.38) for 180 min immersion time which may be due to varying level of sugars present in slices affecting water absorption by fruit tissues. The lower rehydration ratio with increase in osmotic concentration and immersion time could be due to higher amount of sugar in the osmosed piece which would not permit absorption of water on account of the preoccupation of the pore spaces (Bakhara *et al.*, 2018). Salazar *et al.* (2019) reported lower rehydration values during reconstitution of dehydrated pineapple slices which could be due to the formation of a protector at a structural level before dehydration.

Colour is associated with the quality of product and may be taken as the indicator of level of natural deterioration of fresh foods (Krokida *et al.*, 2000). Round shaped osmo dehydrated red banana recorded the lowest browning index (65.98) followed by ring shaped red banana slices (84.09) whereas the highest browning index (96.05) was noticed in osmo dehydrated red banana chunks. The browning index increased with increase in concentration and recorded 72.24 for

40°Brix, 78.79 for 60°Brix and the highest (95.09) at osmotic concentration of 80°Brix. The fruit samples with higher concentrations of sugar suffered superficial darkening, this fact may be attributed to the more amount of sugar attached to the product surface, which upon contact with heat causes the darkening as a result of caramelization (de Castro *et al.*, 2016). Increased browning index may be due to Maillard reactions (Phisut *et al.*, 2013). With respect to different immersion time also, browning index exhibited an increasing pattern and recorded a browning index of 77.01 for 60 min, 82.63 for 120 min and fruit slices immersed in osmotic solution for a period of 180 min recorded the highest browning index (86.48). Slightly darker colour was obtained in osmo dehydrated mango slices which might be due to Maillard reactions induced by the presence of sugar (Korbel *et al.*, 2013). Similar results were obtained by various researchers in osmo dehydration of watermelon (Falade and Igbeka, 2007), banana (Chaguri *et al.*, 2017; Keerthishree *et al.*, 2017) and red pitaya (Najafi *et al.*, 2014).

Osmotic dehydration improves textural properties of final dried product making it more flexible and less dense (Blanda *et al.*, 2009). With respect to textural quality, osmo dehydrated red banana chunks recorded the lowest hardness (1.78 kg) and cutting energy (0.97 kg s) followed by round shaped red banana with a hardness of 3.32 kg and cutting energy of 1.77 kg s and the highest hardness (4.40 kg) and cutting energy (2.31 kg s) was recorded in osmo dehydrated red banana rings. The hardness and cutting energy of osmo dehydrated red banana decreased with increase in osmotic solution concentration and immersion time. Improvement in texture of osmotically dehydrated banana slices might be due to positive role of sugars available in the fruit slices (Thippanna and Tiwari, 2015). Water content reduction and sugar gain during osmotic dehydration have been observed to have some cryoprotectant effects on texture in several fruits (Chiralt *et al*, 2001). Among all the red banana treatments, the lowest hardness (1.24 kg) was noticed in osmo dehydrated red banana chunks at osmotic concentration of 80°Brix for an immersion time of 180 min and lowest cutting energy (0.55 kg s) for round shaped osmo dehydrated red banana at 60°Brix at 60 min immersion time whereas the highest hardness (8.42 kg) and cutting energy (5.44 kg s) was noticed in ring shaped slices at 40°Brix for 60 min immersion time. Tissue softness after osmotic dehydration were also reported by Lewicki and Lukaszuk (2000), Chiralt and Talens (2005), Katsiferis *et al.* (2008) and Castello *et al.* (2010) when osmotic studies were carried out in apples, orange, Granny Smith apple slices and strawberries.

5.1.4 Sensory attributes of osmo dehydrated red banana slices

Sensory evaluation for organoleptic qualities of ring, round and chunk shaped osmo dehydrated red banana slices were conducted separately.

Osmo dehydrated products have sweeter taste compared to conventionally dried products. The final product were very much appreciated for direct utilization due to their better physicochemical properties and nutritional profile (Tortoe, 2010).

Among all the treatments in ring shaped osmo dehydrated red banana, the highest mean score for appearance (8.09), taste (8.36), colour (7.91), texture (6.91) and overall acceptability (8.00) was recorded for osmotic treatment at concentration of 80°Brix for an immersion time of 180 min. According to Najafi *et al.* (2014), increase in sucrose concentration and immersion time resulted in better organoleptic properties of the dehydrated product. Similarly in round shaped osmo dehydrated red banana, the highest mean score for appearance (8.30), taste (7.60), colour (8.10), texture (7.10) and overall acceptability (7.90) was recorded at osmotic concentration of 80°Brix for an immersion time of 180 min. When osmo dehydrated red banana chunks were considered, osmotic treatment at a concentration of 80°Brix for an immersion time of 180 min recorded the highest sensory mean score for for appearance (8.60), taste (8.00), colour (8.10), flavour (7.50), texture (7.90) and overall acceptability (8.10). Since osmotic dehydration is efficient at room temperature, heat damage to the several organoleptic properties is minimized and high sugar concentration of the osmotic solution which surrounds the fruits prevent discoloration (Falade and Aworh, 2005).

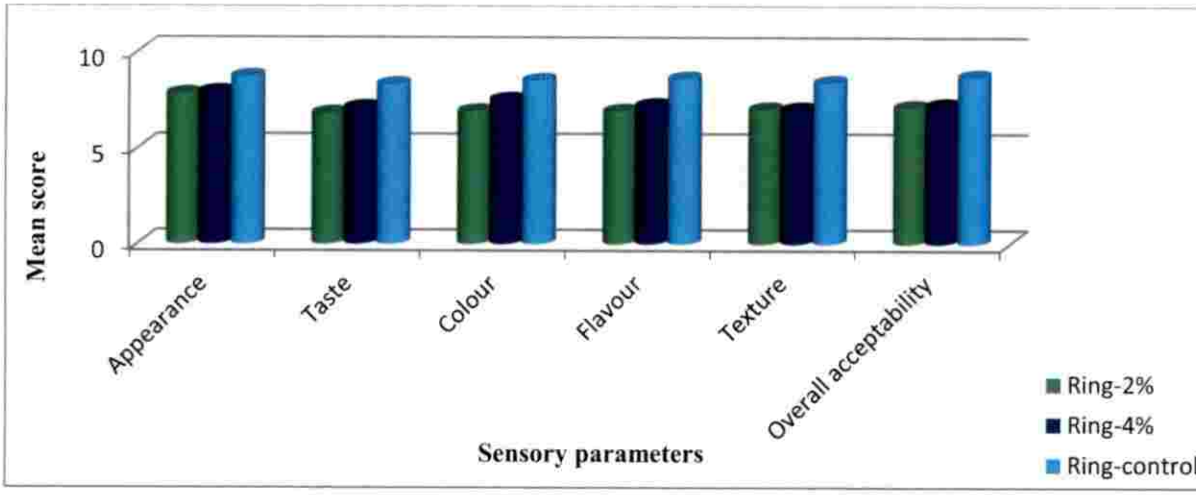
Studies conducted by Torreggiani (1993) in papaya and mango slices, Shigematsu *et al.* (2005) in star fruit, Panda *et al.* (2005) in grapes, Youssef (2009); Chavan *et al.* (2010); Thippanna and Tiwari (2015) and Priyanka *et al.* (2018) in banana, Najafi *et al.* (2014) in red pitaya, Singh *et al.* (2010) and Ravula *et al.* (2017) in carrot, Sawant *et al.* (2011) and Mahesh *et al.* (2017) in pineapple, Singh *et al.* (2015) and Kumar *et al.* (2019) in papaya reported that osmo dehydration at higher osmotic concentration and immersion time resulted in highly accepted final product with improved sensory qualities.

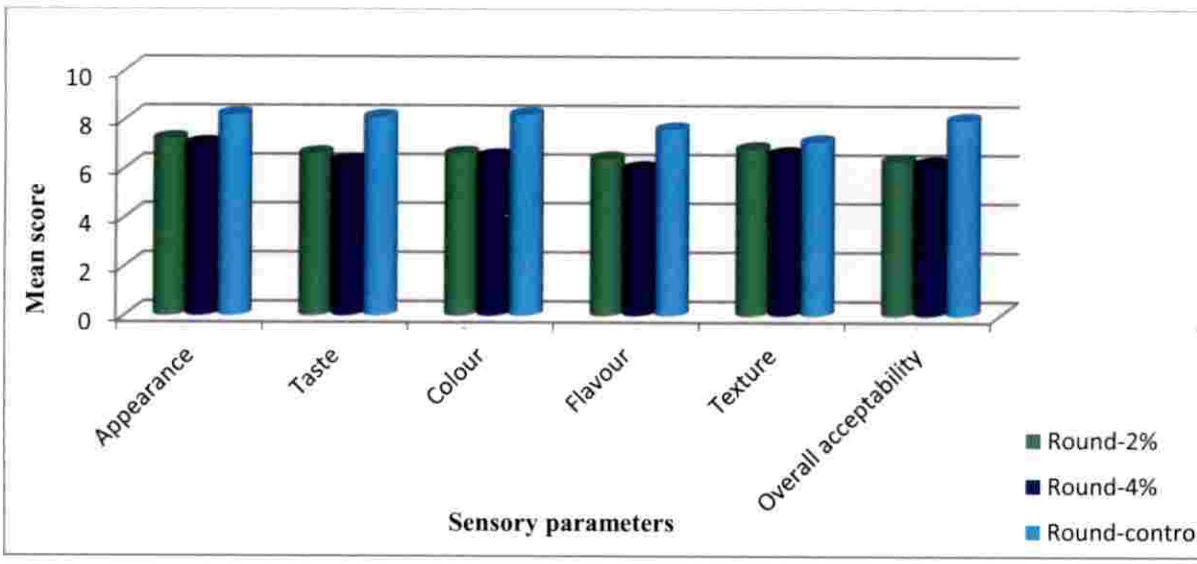
5.1.5 Sensory analysis of osmo dehydrated red banana treated with corn starch

Three best osmo dehydrated red banana from each shape were treated with corn starch at 2 and 4 % level and compared with untreated samples for sensory qualities.

Osmo dehydrated red banana rings without corn starch treatment recorded the highest mean score for appearance (8.70), taste (8.30), colour (8.50), flavour (8.60), texture (8.40) and overall acceptability (8.70). Whereas the lowest mean score for appearance (7.80), taste (6.80), colour (6.90), flavour (6.90), texture (7.00) and overall acceptability (7.10) was noticed in red banana slices treated with 2% corn starch. Similar trend was observed for round shaped osmo dehydrated red banana and osmo dehydrated red banana chunks. In all sensory parameters of appearance, taste, colour, flavour, texture and overall acceptability, the sensory mean score was higher for without corn starch treatment of osmo dehydrated red banana (Fig.3).

The lower acceptance for osmo dehydrated red banana slices with corn starch treatment in all the three shapes may be due to the reduction in sweetness





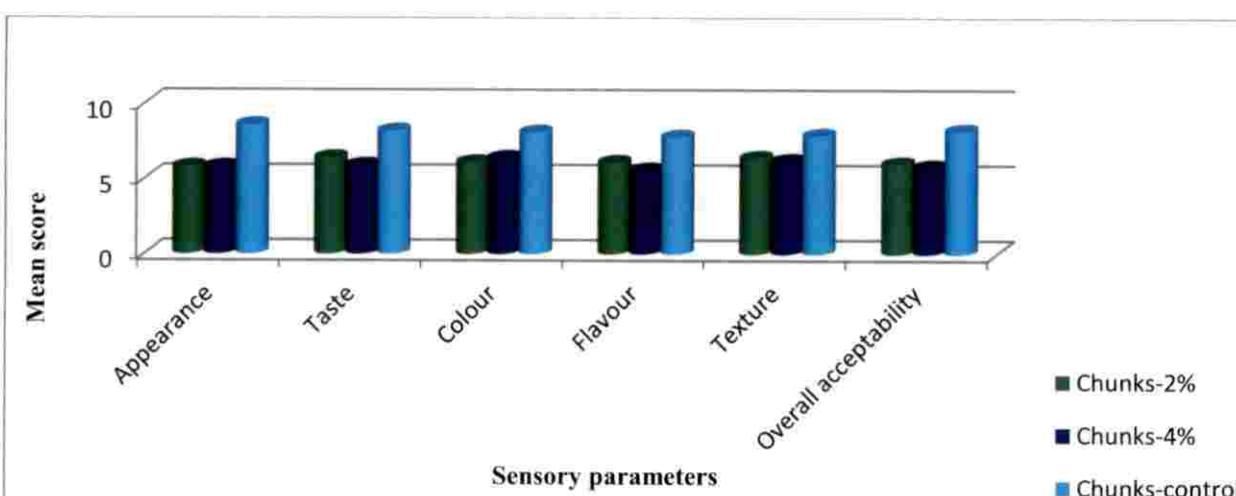


Fig.3. Effect of binding agent (corn starch) on sensory qualities of osmo dehydrated red banana

and reduced its acceptability due to the adhered corn starch powder over the surface of dehydrated red banana slices.

5.2 STORAGE STUDIES OF OSMO DEHYDRATED RED BANANA SLICES

Evaluation of mass transfer, biochemical, physical and sensory qualities of ring, round and chunk shaped osmo dehydrated red banana were conducted and three best treatments with the highest acceptability from each shape (ring at 80°Brix for 180 min, round at 80°Brix for 180 min and chunks at 80°Brix for 180 min) were selected for storage studies. The osmo dehydrated red banana packed in polypropylene (200 gauge) were kept at room temperature and analysed for biochemical, sensory and microbial parameters at monthly interval for a period of four months.

5.3.1 Biochemical parameters of stored osmo dehydrated red banana slices

During storage, TSS of osmo dehydrated red banana increased from 53.73°Brix to 55.48°Brix (3.26%). In the present study, TSS of osmo dehydrated red banana rings increased from 58.50°Brix to 60.50°Brix and for round shaped red banana increase from 56.19°Brix to 57.45°Brix was observed after four months of storage. An increase in TSS from 46.50°Brix to 48.50°Brix was noticed in osmo dehydrated red banana chunks. Similar findings were reported by Chavan *et al.* (2010) in banana, Khan *et al.* (2014) in strawberry, Mahesh *et al.* (2017) in pineapple and Gamit (2015) in pomegranate arils which might be due to the reduction in moisture content during storage (Chavan *et al.*, 2010).

Total sugar of osmo dehydrated red banana rings increased from 54.87% to 56.88% and it was from 53.65% to 56.32% in round shaped osmo dehydrated red banana and 52.65% to 55.41% in osmo dehydrated red banana chunks (Fig.4). Similar results of increase in total sugar during storage was reported by Khan *et al.* (2014) in storage study of osmo dehydrated strawberry and Mahesh *et al.* (2017) during storage of osmo dehydrated pineapple slices. Increase in total sugar

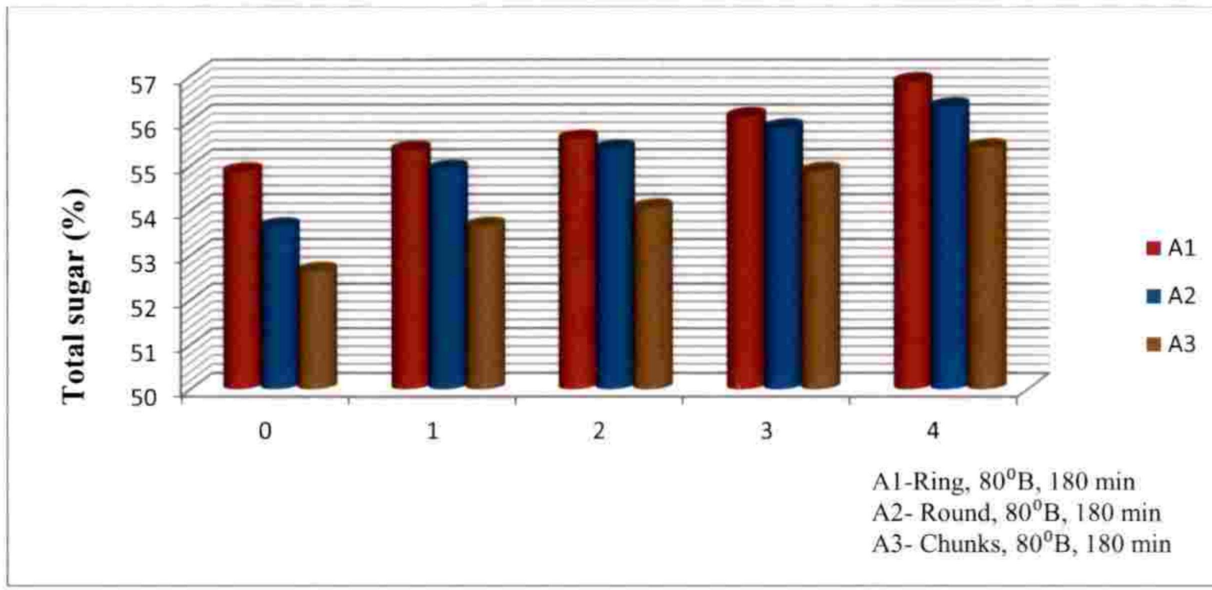


Fig.4. Effect of storage on total sugar (%) of osmo dehydrated red banana

during storage of osmo dehydrated product may be attributed to the loss in moisture content (Chavan *et al.,* 2010).

Reducing sugar of osmo dehydrated red banana rings increased from 37.13% to 39.92% during storage (6.70%). When round shape is considered, increase in reducing sugar from 38.22% to 40.44% was noticed and it was 36.55% to 39.05% in osmo dehydrated red banana chunks. Increase in reducing sugars might be due to hydrolysis of total sugars into reducing sugars and total sugar increase during storage was a mass reduction effect due to loss in moisture content (Chavan *et al.,* 2010). Similar results of increase in reducing sugar during storage was reported by Gamit (2015) during storage study of pomegranate arils, Khan *et al.* (2014) in osmo dehydrated strawberry and Mahesh *et al*. (2017) in osmo dehydrated pineapple slices.

Acidity showed decreasing trend irrespective of the treatments. Acidity decreased from 0.62% at the time of storage to 0.30% after four months of storage (51.61%). Decrease in acidity during storage was reported in osmo dehydrated strawberry (Khan *et al*., 2014), pomegranate arils (Gamit, 2015), pineapple (Mahesh *et al*., 2017; Rahim *et al.,* 2018) and carrot (Selvakumar and Tiwari, 2018). Acidity of osmo dehydrated red banana rings decreased from 0.65% to 0.32% whereas a decrease from 0.59% to 0.28% was observed for round shaped osmo dehydrated red banana and acid loss of 0.61% to 0.30% was observed for osmo dehydrated red banana chunks. The loss of acid in the samples during storage might be due to utilization of acids for conversion of non reducing sugars to reducing sugars and in non enzymatic browning reactions as reported by Sharma *et al.* (2004).

Ascorbic acid showed decreased trend irrespective of the treatments during storage. Ascorbic acid of osmo dehydrated red banana rings decreased from 9.03 mg $100g^{-1}$ at the time of storage to 8.33 mg $100g^{-1}$ after four months of storage. A decrease from 10.80 mg $100g^{-1}$ to 9.70 mg $100g^{-1}$ was observed for round shaped osmo dehydrated red banana and it was 8.93 mg $100g^{-1}$ at the time of storage for osmo dehydrated red banana chunks which decreased to 7.82 mg $100g^{-1}$ at the end of storage. Decrease in ascorbic acid during storage may be due to loss of ascorbic acid by the oxidation of ascorbic acid to dehydro ascorbic acid during storage (Chavan *et al.*, 2010). The result is in conformity with the findings of Chavan *et al.* (2010) in banana and Khan *et al.* (2014) in strawberry.

Carotenoid content of osmo dehydrated red banana decreased during the storage period of four months. Osmo dehydrated red banana rings exhibited a decrease from 6.01 μg $100g^{-1}$ to 4.42 μg $100g^{-1}$ whereas in round shaped slices, decrease from 9.61 μg $100g^{-1}$ to 7.54 μg $100g^{-1}$ was observed and it was from 6.94 μg $100g^{-1}$ to 4.15 μg $100g^{-1}$ in osmo dehydrated red banana chunks. Similar trend was observed by Selvakumar and Tiwari (2018) during storage of osmo dehydrated carrot slices where carotenoids exhibited a decreasing trend with storage. Main cause of carotenoid degradation is oxidation and further stimulation by presence of light, enzymes and co-oxidation of carotene, which later isomerise to form mutachrone (Sagar and Kumar, 2008). The loss of carotenoids content in processed samples was reported mainly due to oxidation as well as thermal degradation (Selvakumar and Tiwari, 2018).

Osmo dehydrated red banana showed a decreasing trend for antioxidant activity during storage. Antioxidant activity decreased from 94.98% to 92.94% in osmo dehydrated red banana rings, 93.68% to 90.88% in round shaped osmo dehydrated red banana and a decrease from 92.88% to 89.68% was observed in case of osmo dehydrated red banana chunks during storage period of four months. Similar trend of decrease in antioxidant activity with storage period was reported by Piasecka *et al.* (2011) during storage of osmo dehydrated apples, sour cherries and blackcurrants when stored for a period of 12 months.

5.3.2 Sensory attributes of stored osmo dehydrated red banana slices

Sensory attributes *viz.* appearance, taste, colour, flavour, texture and overall acceptability of selected osmo dehydrated red banana (ring, 80°Brix, 180 min; round, 80°Brix, 180 min and chunks, 80°Brix, 180 min) were analysed at monthly interval for a period of four months and the results revealed a slight reduction in sensory mean score for all the sensory parameters towards the end of storage period.

Colour of the product is the key to success of a processed product in market. Colour is often associated with the quality of the product and may be taken as the indicator of level of natural deterioration of fresh foods (Krokida *et al.*, 2000). Colour score of fruit slices decreased during storage which may be due to absorption of atmospheric moisture and oxygen which influenced compositional status and also caramelization of sugar present in the product caused browning (Krokida *et al.*, 2000). Mean scores for appearance decreased from 7.91 to 7.45, taste (8.27 to 7.73), colour (8.36 to 7.91), flavour (8.45 to 7.82), texture (8.18 to 7.73) and overall acceptability (8.36 to 7.55) for osmo dehydrated red banana rings. For round shaped osmo dehydrated red banana, decrease in sensory mean scores for appearance (7.09 to 6.73), taste (7.18 to 6.63), colour (7.36 to 6.91), flavour (7.64 to 7.00), texture (7.18 to 6.64) and overall acceptability (7.36 to 6.73) was observed. Similar trend of decrease in sensory scores for appearance (7.36 to 7.00), taste (7.82 to 7.27), colour (8.00 to 7.55), flavour (8.27 to 7.64), texture (7.73 to 7.36) and overall acceptability (8.00 to 7.27) was noticed for osmo dehydrated red banana chunks (Fig.5). Reduced mean score during storage for colour, flavour, taste and over all acceptability was supported by Khan *et al.* (2014) in strawberry, Gamit (2015) in pomegranate arils, Mahesh *et al.* (2017) in pineapple, Priyanka *et al.* (2018) in banana, Selvakumar and Tiwari (2018) in carrot slices and Gurumeenakshi and Varadharaju (2018) in mango.

On analyzing the mean scores for various sensory parameters *viz.*, appearance, taste, colour, flavour, texture and overall acceptability of osmo dehydrated red banana for a period of four months, osmo dehydrated ring shaped red banana immersed in osmotic concentration of 80°Brix for an immersion time of 180 min (A_1) was the most accepted treatment followed by osmo dehydrated red banana chunks immersed in osmotic concentration of 80°Brix for an immersion time of 180 min (A_3) and round shaped red banana in 80°Brix for 180 min (A_3) secured the lowest sensory scores for all the sensory attributes (Fig.6). Even though during storage sensory mean score for all sensory attribute decreased, but it was within the range of consumer acceptance.

5.3.3 Evaluation of microbial load during storage

The osmo dehydrated red banana fruits were analysed for yeast, bacteria and fungi during the storage of four months.

No microbial growth was observed for osmo dehydrated red banana rings, round shaped osmo dehydrated red banana and osmo dehydrated red banana chunks during the entire storage period of four months and were microbiologically safe. This could probably because of the addition of KMS, citric acid in osmotic solution and high concentration of sugar in osmo dehydrated red banana. The combination of low pH and water available for microbial growth significantly reduced the incidence of microbial spoilage (Tiganitas *et al.,* 2009). Osmo dehydrated fruit slices pretreated with ascorbic acid, KMS and citric acid retained highly acceptable qualities throughout the entire storage period. (Gurumeenakshi and Varadharaju, 2018). The results of the present study were supported by other researchers where no apparent microbial spoilage was observed during storage of banana (Ehabe *et al.,* 2006 and Chavan *et al.*, 2010), pomegranate arils (Gamit, 2015) and banana figs (Priyanka *et al.*, 2018).

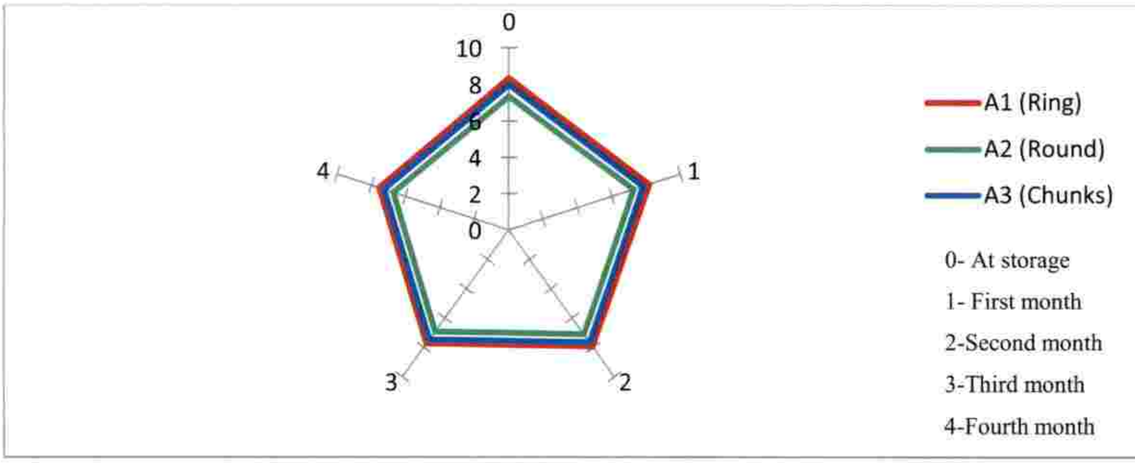


Fig.5. Overall acceptability of osmo dehydrated red banana during storage

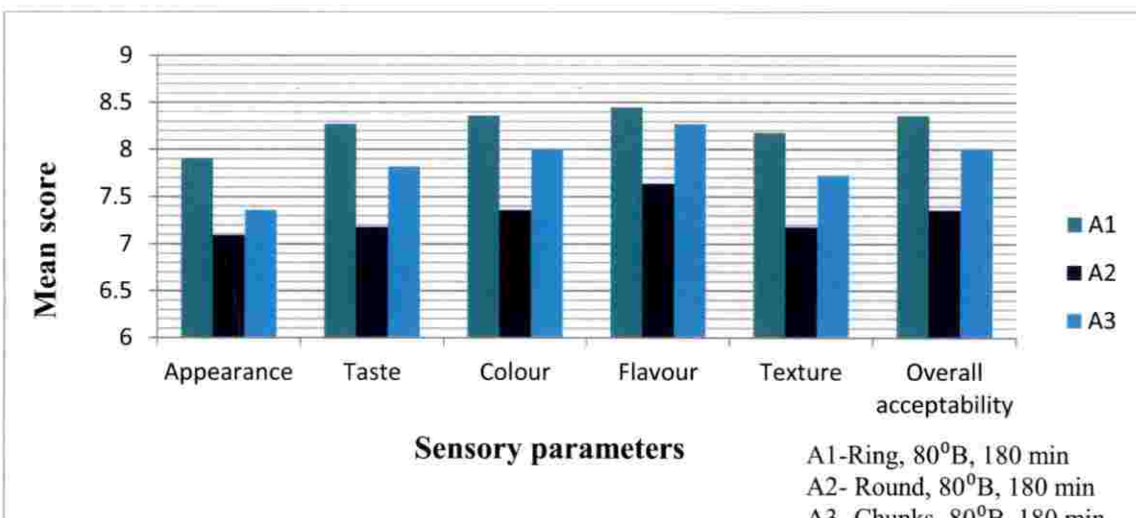


Fig.6. Consumer acceptance of osmo dehydrated red banana

Summary

6. SUMMARY

The present study entitled "Development of osmo dehydrated Red Banana (*Musa* spp.)" was carried out at Department of Post Harvest Technology, College of Agriculture, Vellayani during the period 2017-2019 with the objective to standardize different process variables *viz*., fruit slice shape, osmotic concentration and immersion time for osmo dehydration of red banana and to assess the storage stability.

The experiment was conducted as two separate parts

1. Development of osmo dehydrated red banana
2. Storage stability studies of osmo dehydrated red banana

The main findings of the study are summarized as below.

Good quality uniform sized, optimally ripened red banana sliced into three shapes *viz.* ring, round and chunks of thickness 5 mm, were osmosed in sugar syrup of 40°Brix, 60°Brix and 80°Brix concentration with an immersion time of 60, 120 and 180 minutes. After the osmotic treatments, the samples were analysed for different mass transfer characters. The osmosed red banana slices were finally dehydrated in a cabinet drier at 50°C till the product attained a moisture content of 17$\pm$1% and analysed for biochemical characters (TSS, total sugar, reducing sugar, acidity, ascorbic acid, carotenoids and antioxidant activity), physical characters (yield, rehydration ratio, textural quality and colour) and sensory quality attributes.

Mass transfer characters *viz.,* water loss, solid gain, percentage weight reduction and water loss to solid gain were recorded for three shapes of osmo dehydrated red banana and observed that mass transfer characters increased with increase in osmotic solution concentration and immersion time in all the treatments irrespective of the shapes. Osmo dehydrated red banana chunks immersed in osmotic solution concentration of 80°Brix and immersion time of

180 minutes recorded the highest solid gain (8.90%), water loss (9.59%) and weight reduction (10.00%) with a water loss to solid gain ratio of 1.07.

Biochemical characters *viz.*, TSS, total sugar and reducing sugar increased with increase in osmotic concentration and immersion time whereas acidity, ascorbic acid, antioxidant activity and carotenoid content decreased with increase in osmotic concentration and immersion time. TSS of osmo dehydrated red banana rings varied from 39.33°Brix to 59.49°Brix and it was from 43.57°Brix to 56.13°Brix for round shaped osmo dehydrated red banana and it varied between 29.17°Brix and 46.76°Brix in osmo dehydrated red banana chunks. Total sugar ranged from 37.83% to 52.27% in osmo dehydrated red banana rings whereas in round shaped slices, it was 35.89% to 54.15% and 30.61% to 53.87% in osmo dehydrated red banana chunks. Acidity of osmo dehydrated red banana rings decreased from 1.28% to 0.68% and it was 1.14% to 0.61% in round shaped osmo dehydrated red banana and 1.04 to 0.63% in osmo dehydrated red banana chunks. Carotenoid content of osmo dehydrated red banana exhibited a decreasing trend with increase in osmotic concentration and immersion time. Carotenoid content of osmo dehydrated red banana rings ranged between 24.00 μg $100g^{-1}$ to 6.00 μg $100g^{-1}$ while it was from 33.58 μg $100g^{-1}$ to 9.50 μg $100g^{-1}$ and 25.83 μg $100g^{-1}$ to 6.09 μg $100g^{-1}$ for round shaped osmo dehydrated red banana and osmo dehydrated red banana chunks respectively. Antioxidant activity of osmo dehydrated red banana rings ranged from 90.67% to 94.54% whereas it was from 94.22% to 93.88% in round shaped osmo dehydrated red banana and 93.96% to 89.00% in osmo dehydrated red banana chunks.

Osmo dehydrated red banana rings recorded a TSS of 59.49°Brix, total sugar of 52.27%, reducing sugar of 36.63%, 8.33 mg $100g^{-1}$ ascorbic acid, 0.68% acidity, 94.54% antioxidant activity and 6.00 μg $100g^{-1}$ carotenoid content at 80°Brix and 180 min immersion time. Similarly in round shaped osmo dehydrated red banana, osmotic concentration of 80°Brix and 180 min immersion time recorded a TSS of 56.13°Brix, total sugar of 54.15%, reducing sugar of 37.82%, 10.71 mg $100g^{-1}$ ascorbic acid, 0.61% acidity, 93.88% antioxidant activity and 9.50 μg $100g^{-1}$ carotenoids. Osmo dehydrated red banana chunks recorded a TSS of 46.76°Brix, total sugar of 53.87%, reducing sugar of 36.63%, 8.33 mg $100g^{-1}$ ascorbic acid, 0.63% acidity, 89.00% antioxidant activity and 6.09 μg $100g^{-1}$ carotenoids.

The physical characters *viz.,* yield, rehydration ratio, browning index and textural quality of osmo dehydrated red banana were recorded and observed the highest yield (31.75%) was for osmo dehydrated red banana chunks at 80°Brix and 180 minutes immersion time and it was 30.37% and 29.58% for ring and round sliced osmo dehydrated red banana respectively. The lowest hardness (1.24 kg) and cutting energy (0.72 kg s) was noticed in osmo dehydrated red banana chunks at 80°Brix and 180 minutes immersion time. The osmotic treatment at 80°Brix and 180 minutes immersion time recorded a rehydration ratio of 1.31 in osmo dehydrated red banana rings and it was 1.28 and 1.33 in round shaped osmo dehydrated red banana and osmo dehydrated red banana chunks respectively.

Sensory evaluation of osmo dehydrated red banana ring, round and chunk shaped slices were conducted and kruskal wallis test confirmed significant difference among the treatments for sensory attributes. Osmo dehydrated red banana rings recorded the highest mean score for appearance (8.09), taste (8.36), colour (7.91), texture (6.91) and overall acceptability (8.00) at 80°Brix for an immersion time of 180 min. Similar trend of highest mean score for appearance (8.30), taste (7.60), colour (8.10), texture (7.10) and overall acceptability (7.90) in round shaped osmo dehydrated red banana. The highest mean sensory score for appearance (8.60), taste (8.00), colour (8.10), flavour (7.50), texture (7.90) and overall acceptability (8.10) was observed at osmotic concentration of 80°Brix and immersion time of 180 min for osmo dehydrated red banana chunks.

Based on the mass transfer, biochemical, physical and sensory analysis, three best treatments; one from each shape *viz.,* osmo dehydrated red banana ring at 80°Brix, 180 min; round slices of osmo dehydrated red banana at 80°Brix, 180 min and osmo dehydrated red banana chunks at 80°Brix, 180 min were selected for future studies. The best treatments selected were subjected to 2% and 4% cornstarch treatment and compared with untreated samples for sensory qualities. The results revealed that all sensory parameters of appearance, taste, colour, flavour, texture and overall acceptability, the sensory mean score was higher for osmo dehydrated red banana slices without corn starch treatment.

The three selected osmo dehydrated red banana rings, round slices and chunks packed in 200 gauge polypropylene and stored at room temperature were subjected to biochemical, microbial and sensory quality analysis at monthly interval for four months. For biochemical characters *viz.,* TSS, total sugar, reducing sugar, acidity, ascorbic acid, carotenoid content and antioxidant activity were analysed and found increase in TSS (53.73°Brix to 55.48°Brix), total sugar (53.72% to 56.20%) and reducing sugar (37.30% to 39.80%) where as acidity (0.62% to 0.30%), vitamin C (9.59 mg $100g^{-1}$ to 8.62 mg $100g^{-1}$), antioxidant activity (93.85% to 91.17%) and carotenoid content (7.52 µg $100g^{-1}$ to 5.37 µg $100g^{-1}$) decreased. Sensory analysis revealed that all the three osmo dehydrated red banana treatments were safe and acceptable throughout the storage period and among all the three shapes, osmo dehydrated red banana rings recorded the highest acceptance with a mean score of 7.91 for appearance, 8.27 for taste, 8.36 for colour, 8.45 for flavour, 8.18 for texture and 8.36 for overall acceptability followed by osmo dehydrated red banana chunks with a mean score of 7.36 for appearance, 7.82 for taste, 8.00 for colour, 8.27 for flavour, 7.73 for texture and 8.00 for overall acceptability and round shaped osmo dehydrated red banana recorded a mean score of 7.09 for appearance, 7.18 for taste, 7.36 for colour, 7.64 for flavour, 7.18 for texture and 7.36 for overall acceptability. Sensory qualities of the product decreased slightly with the advancement of storage period and no microbial growth was found till the end of storage.

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Abstract

DEVELOPMENT OF OSMO DEHYDRATED RED BANANA (*Musa* spp.)

by

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ABSTRACT

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ABSTRACT

The present study entitled "Development of osmo dehydrated Red Banana (*Musa* spp.)" was carried out at the Department of Post Harvest Technology, College of Agriculture, Vellayani during the period 2017-2019 with the objectives to standardize different process variables *viz.*, fruit slice shape, osmotic concentration and immersion time for osmo dehydration of red banana and to assess the storage stability of osmo dehydrated product.

Good quality uniform sized, fully ripe red banana were sliced into three shapes *viz.,* ring, round and chunks of thickness 5 mm and osmosed in sugar syrup of 40°Brix, 60°Brix and 80°Brix concentration with an immersion time of 60, 120 and 180 minutes. After the osmotic treatments, the samples were analysed for different mass transfer characters. The osmosed red banana slices were finally dehydrated in a cabinet drier at 50°C till the product attained a moisture content of 17($\pm$1)% and analysed for biochemical, physical and sensory quality parameters.

Mass transfer characters *viz.*, solid gain, water loss and percentage weight reduction increased with increase in osmotic concentration and immersion time irrespective of fruit shapes. Maximum solid gain (8.90%), water loss (9.59%) and weight reduction (10.00%) with a water loss to solid gain ratio of 1.07 was observed in osmo dehydrated red banana chunks at an osmotic concentration of 80°Brix with 180 minutes immersion time. Biochemical characters *viz.*, TSS, total sugar and reducing sugar increased with increase in osmotic concentration and immersion time whereas acidity, vitamin C, antioxidant activity and carotenoid content decreased. Osmo dehydrated red banana rings recorded a TSS of 59.49°Brix, total sugar of 52.27%, reducing sugar of 36.63%, 8.33 mg $100g^{-1}$ vitamin C, 0.68% acidity, 94.54% antioxidant activity and 6.00 µg $100g^{-1}$ carotenoids and it varied with shapes. Physical characters *viz.*, yield, rehydration ratio, textural quality and colour were analysed. The highest yield (31.75%) was observed for osmo dehydrated red banana chunks at 80°Brix and 180 minutes immersion time and it was 30.37% and 29.58% for ring and round slices

respectively. The lowest hardness (1.24 kg) and cutting energy (0.72 kg s) was noticed in osmo dehydrated red banana chunks at 80°Brix and 180 minutes immersion time.

Sensory evaluation of osmo dehydrated ring, round and chunk shaped slices were conducted and kruskal wallis test confirmed significant difference among the treatments for sensory attributes. Osmo dehydrated red banana rings, rounds and chunks recorded the highest acceptance for all the sensory attributes at 80°Brix for an immersion time of 180 min. Based on the mass transfer, biochemical, physical and sensory analysis, three best treatments; one from each shape were selected (ring, 80°Brix, 180 min; round, 80°Brix, 180 min and chunks, 80°Brix, 180 min). The best treatments selected were subjected to 2% and 4% corn starch treatment and sensory analysis revealed that corn starch treated samples were not acceptable when compared with untreated samples.

The three selected osmo dehydrated red banana were packed in 200 gauge polypropylene and stored at room temperature were analysed for biochemical, microbial and sensory qualities at monthly interval for four months. During storage, 3.26% increase in TSS (53.73°Brix to 55.48°Brix), 4.62% increase in total sugar (53.72% to 56.20%) and 6.70% increase in reducing sugar (37.30% to 39.80%) were observed whereas a decrease of 51.61% in acidity (0.62% to 0.30%), 10.11% in vitamin C (9.59 mg $100g^{-1}$ to 8.62 mg $100g^{-1}$), 2.86% in antioxidant activity (93.85% to 91.17%) and 28.59% reduction in carotenoid content (7.52 µg $100g^{-1}$ to 5.37 µg $100g^{-1}$) was observed. Sensory qualities of the product decreased slightly with the advancement of storage period and osmo dehydrated red banana rings recorded the highest consumer acceptance followed by chunks and round shaped slices. No microbial growth was found till the end of storage.

In the present study, process variables were standardised for the development of osmo dehydrated red banana. Sugar syrup as osmotic solution at a concentration of 80°Brix with an immersion time of 180 min was recorded as the best treatment for osmo dehydration for all the three shapes of red banana slices *viz.,* ring, round and chunks. Better consumer acceptability was recorded for osmo dehydrated red banana rings followed by chunks and round slices. Storage stability studies revealed that osmo dehydrated red banana packed in 200 gauge polypropylene could be stored for four months at room temperature without loss in quality.

Appendices

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APPENDIX I

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Post Harvest Technology

Title: Development of osmo dehydrated Red banana (*Musa spp.*)

Score card for assessing the organoleptic qualities of osmo dehydrated red banana

Sample: Osmodehydrated red banana

Instructions: You are given 9 osmodehydrated red banana samples. Evaluate them and give scores for each criteria

Criteria	Scores								
	1	2	3	4	5	6	7	8	9
Appearance									
Taste									
Colour									
Flavour									
Odour									
Texture (Hard/Firm/Soft)									
Overall acceptability									

<u>Score</u>

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

Date:

Name:

Signature:

APPENDIX II

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Post Harvest Technology

Title: Development of osmo dehydrated Red banana (*Musa spp.*)

Score card for assessing the organoleptic qualities of osmo dehydrated red banana treated with corn starch

Sample: Osmodehydrated red banana

Instructions: You are given 6 osmodehydrated red banana samples. Evaluate them and give scores for each criteria

Criteria	Scores					
	1	2	3	4	5	6
Appearance						
Taste						
Colour						
Flavour						
Odour						
Texture (Hard/Firm/Soft)						
Overall acceptability						

Score

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

Date:

Name:

Signature:

APPENDIX III

COLLEGE OF AGRICULTURE, VELLAYANI

Department of Post Harvest Technology

Title: Development of osmo dehydrated Red banana (*Musa spp.*)

Score card for assessing the organoleptic qualities of stored osmo dehydrated red banana

Sample: Osmodehydrated red banana

Instructions: You are given 3 osmodehydrated red banana samples. Evaluate them and give scores for each criteria

Criteria	Scores		
	1	2	3
Appearance			
Taste			
Colour			
Flavour			
Odour			
Texture (Hard/Firm/Soft)			
Overall acceptability			

Score

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

Date: Name:

Signature: