Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)

KEERTHISHREE M

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THESIS

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DECLARATION

I, hereby declare that the thesis entitled **"Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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Keerthishree, M

Dedicated to my beloved
Appaji

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LIST OF ABBREVIATIONS

%	-	Percentage
cm	-	Centimeter
SG	-	Solid Gain
WL	-	Water Loss
TSS	-	Total Soluble Solids
N	-	Newton
Ns	-	Newton seconds
WL/SG	-	Ratio of Water Loss to Solid Gain
BI	-	Browning Index
CD	-	Critical Difference
et al	-	And others
Fig.	-	Figure
g	-	Gram
kg	-	kilogram
mg	-	milligram
^0C	-	Degree Celsius
^0B	-	Degree Brix
i.e.	-	That is
viz.,	-	Namely
RSM	-	Response Surface Methodology
CRD	-	Completely Randomized Block Design
CV	-	Critical Value
NS	-	Non Significant
KMS	-	Potassium metabisulphite
PP	-	Polypropylene

Introduction

1. INTRODUCTION

Banana is one of the largely consumed tropical fruits in the world and is a major fruit crop of Kerala. It is well known for its high nutritional value, being rich in starch, sugar, vitamin A, C and minerals such as potassium, phosphorus, calcium and, magnesium. Banana being a tropical fruit is highly susceptible to huge postharvest losses and ripe banana has a short shelf life. Processing of banana into diverse products with longer shelf life has been proposed as a way of absorbing seasonal surpluses to reduce postharvest losses thus increasing and stabilizing farmer's income (Balasooriya *et al.*, 2006). In India processing of banana is less than 6.3 per cent and there is a vast potential for product development (Pedapathi and Tiwari, 2014).

Drying and dehydration are the most widely used methods in processing of fruits. Banana is processed mainly into products like powder, chips, fig etc. Osmotic dehydration is an operation used for partial removal of water from plant tissues by immersion in an osmotic solution. This is a useful technique to decrease energy cost of processing and to extend the shelf life. It also helps to improve sensorial, nutritional and organoleptic properties of food. Dehydration techniques, including osmotic dehydration induce significant changes in the dehydrated material and have an impact on dietary value (Torreggiani and Bertolo, 2001). Osmotic dehydration techniques not only enable the storage of fruits for a longer period, but also preserve flavour, nutritional characteristics and prevent microbial spoilage. Through dehydration, problems of marketing, handling and transport becomes much simpler and banana could be made available to consumer throughout the year.

Partially dehydrated fruits through osmo dehydration can be added to food such as desserts, yogurt, ice-cream, confectionery and bakery products and after additional drying, they can also be used as components of cereals or snacks for direct consumption (Lenart, 1996; Torreggiani and Bertolo, 2001).

Nendran is the most popular variety of Kerala and 'chips' is the major value added product. Dehydrated products from nendran banana through osmotic dehydration can help in product diversification with nutritional benefits. New osmotically dehydrated products and industrial applications require appropriate manufacturing procedures. Fundamental parameters for mass transfer during osmotic dehydration need to be standardised for the industrialisation of the technology (Rastogi *et al.*, 2002). Thus, an understanding of factors affecting mass transfer during osmotic dehydration is required for the process optimization (Phisut *et al.*, 2012).

Hence, the present investigation "Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)" was carried out with the objective to standardize different process variables like shape of fruit slice, thickness, concentration of osmotic solution and immersion time for osmo-air dehydration of Nendran banana and to optimise the conditions suitable for better mass transfer kinetics.

Review of literature

2. REVIEW OF LITERATURE

Osmotic dehydration (OD) is an operation used for the partial removal of water from plant tissues by immersion in a hypertonic solution of sugar and salt solution, to reduce the moisture content of food before actual drying process. The present study focus on optimization of process variables for osmo-air dehydrated nendran banana. A brief review of literature relating to conversion of fruits into safe, stable, nutritious product using OD is presented in this chapter. Therefore, available literature on OD of other fruits has also been reviewed.

Osmotic dehydration technique is a partial dehydration process to give the product an improvement in quality over the conventional drying. It is affected by several factors such as osmotic agent, osmotic concentration, temperature, time, size, shape, and tissue compactness of material, agitation and solution/sample ratio. It can be done to enhance the mass transfer rate or to shorten the drying time. Quality of osmotically dehydrated products is better and shrinkage is considerably lower as compared to products from conventional drying process (Akbarian *et al.*, 2014).

2.1. OSMOTIC DEHYDRATION: A NOVEL TECHNOLOGY

Osmotic dehydration of fruits result in increased shelf life with less loss of aroma in dried and semidried food stuffs (Petrotos and Lazarides, 2001). It is used with other drying methods such as freezing and deep fat frying to make better quality final product (Torreggiani and Bertolo, 2001). OD is one of the most important complementary treatment and food preservation technique in processing of dehydrated food, since it reduces the damage of heat to flavour, colour and inhibits browning and decreases energy costs (Alakali *et al.*, 2006 and Torres *et al.*, 2006). Water loss between 2 and 9 h from the beginning of osmotic process was higher at 1:10 ratio than at 1:15 ratio, probably due to high concentration of sucrose in the fruit's outer layer, which acts as an additional resistance to water transfer between fruits and solution (Teles *et al.*, 2006). Andres *et al.* (2007) and

Lombard *et al*. (2008) reported that OD can be used as a pre-treatment for tropical fruits for obtaining high quality dried products.

Mafoonazad (2010) defined OD as a 'dewatering and impregnation soaking process a combination of dehydration and impregnation which can modify the functional properties of food materials, thereby creating new products. Chavan (2012) reported that OD has received greater attention in recent years as an effective method for preservation of fruits and vegetables and stated that increase in solid gain and water loss with increased solute concentration was due to the high rate of diffusion of solute and water exchange. OD removed about 30 to 70% of water from fruits and were used as snacks (Akbarian *et al*., 2014).

2.2. MASS TRANSFER CHARACTERS DURING OSMOSIS

In OD, fruits are immersed or soaked in sugar solution which resulted in three types of counter mass transfer phenomenon; removal of water during osmotic process mainly by diffusion and capillary flow, whereas solute uptake or leaching is only by diffusion (Rahman, 2007). Osmotic dehydration is a process of water removal from fruits, because cell membrane is semi-permeable and allow water to pass through them more rapidly than sugar. The driving force for water removal is the concentration gradient between the solution and intracellular fluid (Chavan *et al*., 2010). In osmosis three processes occurs; first water flow out from the food tissue to the osmotic solution, second, a solute transfer from the osmotic solution to the food tissue, third, a leaching out of the food tissue's own solutes (sugar, organic acids, minerals, vitamins) into the osmotic solution which is meagre (Tortoe, 2010).

Mass transfer and final product quality of OD products depend on several factors, such as, tissue properties (Saurel, 1994; Raoult-Wack, 1994; Lenart, 1996); syrup concentration (Heng *et al*., 1990; Park *et al*., 2002; Fernandes *et al*., 2006); format and dimension of the fruit pieces (Lerici *et al*., 1985; Panagiotou *et al*., 1998); process time Videv *et al*. (1990) and Araujo (2005). The effect of solution concentration on mass transfer rates (water loss, solids gain and weight reduction) during OD, using sucrose as dehydrating agent, has been studied for a numbers of fruits such as pear (Park *et al.*, 2002), carrot (Rastogi *et al.*, 2002), pineapple (Rastogi and Raghavarao, 2002) and melon (Lima *et al.*, 2006).

Water loss from fruits during OD took place in first two hours and maximum sugar gain was found with in 30 minutes was reported by Conway *et al.* (1983). Mauro and Menegalli (1995) reported that moisture loss in banana during OD at temperatures lower than 40°C, water loss was very slow and at temperatures higher than 50°C, flavour and texture affected. The amount of water loss during initial period was high and as dehydration period advanced, the rate of water loss decreased and rate of solute gain increased (Ertekin and Cakaloz, 1996). Also for removing 30-40% moisture, it took 3h to 3 days for OD of fruits and vegetables (Islam and Flink 1982; Grabowski *et al.*, 1994; Welti *et al.*, 1995; Ertekin and Cakaloz, 1996; Sagar, 2001). OD reduced up to 50% weight of fresh vegetables and fruits (Yetenayet and Hosahalli, 2010).

Water loss increased with increase in surface area of fruit pieces by Rastogi and Raghavararo (1997). Panagiotou *et al.* (1998) observed that the size of fruit samples had a negative effect on water loss during osmotic treatment and the distribution coefficient of water decreased with increase in temperature. In general, a sample size of 3 mm to a maximum of 10 mm in rectangle, ring or cube shape was suggested for the use in OD process (Aoquar *et al.*, 2006). Borquez *et al.* (2010) showed that in osmotic dewatering of raspberry fruit using a pressure of 1.33 MPa for a period of 8 min the water loss was approximately 3-4 times higher than the mass gain.

Studies conducted by George, (1994) on OD for palayankodan banana revealed that 70 °B sugar solution at 60 °C with 60 minutes immersion time was found superior. Lazarides (1994) studied OD on apples and found that higher concentration of sugar solution, showed a faster water loss and much greater uptake of sugar solids. Saurel (1994) reported that a dense solute-barrier layer formed at the surface of the food material when the osmotic solution concentration increased which enhances the dewatering effect and reduced the loss of nutrients during the process. Silveira *et al.* (1996) studied the effect of temperature (30°, 40° and 50°C) and sucrose concentration (50°, 60° and 70°B) on OD of commercial size pineapple rings, at an initial ratio of 1:4 fruit: sucrose solution and found that rate of water loss from pineapple varied with both osmotic solution concentration and temperature. The highest mass transfer in OD of pineapple was found in sucrose at concentration of 70%, temperature 50°C and 9 h of immersion time (Saputra, 2001). El-Aouar *et al.* (2006) and Corzo and Gomez (2004) observed that the water loss increased with processing time in melon.

Giraldo *et al.* (2003) studied the mass transfer during OD of mango and reported that water transfer rate increased with the concentration of sucrose up to 45 °B, whereas, this effect did not appear between 55 °B and 65 °B. The rate was constant being slightly greater for the treatment at 55 °B which could be due to case hardening effect. Osmotic pre-treatment of banana slices with 60 °B sugar syrup for 24 h was found best for Robusta slices which rated significantly superior over Ney Poovan (Thipanna, 2005). Effect of OD on mass transfer properties of banana was studied by Nowakunda *et al.* (2004) and revealed that treating the slices at temperatures not more than 30°C using osmotic solutions at 55° or 65°B was beneficial. Anusuya *et al.* (2006) conducted study of OD of grapes and found 40% sugar solution as the best for dehydration. Isadoram *et al.* (2006) reported that a moderate to high sucrose concentration of 55 to 65°B was suitable for OD of banana. Falade *et al.* (2007) monitored the mass transfer during OD of watermelon slabs under three different sucrose concentrations of 40 °B, 50 °B and 60 °B and observed increased water loss and solid gain with increase in osmotic solution concentration. Sagar and Kumar (2007) studied OD of guava slices and found that higher sugar concentration (60 °B) and temperature (60 °C) increased water loss from the produce and solid gain into the osmosed guava slices. Singh (2008) did OD of pineapple reported that the optimum dehydration parameters as 62°B sucrose, 30°C temperature, 6 h immersion time and 1:6 fruit to solution ratio to obtain water loss of 48.41%, solid gain of 10.9%, WL/SG ratio of 4.4% and weight reduction of 37.0%.

The mass transfer during OD of apricot was studied by Ispir and Togrul (2009) and reported that increase in sucrose concentration resulted in an increase in osmotic pressure gradients and hence higher water loss and solid gain uptake values throughout the osmotic period. Mercali *et al.* (2010) found that sugar and salt concentration and temperature of osmotic solution affected mass transfer kinetics during OD of banana. Nores *et al.* (2010) suggested that OD usually used as a pretreatment for other dehydration process and reported that water loss and solid gain were higher at the beginning of osmosis and treatment at 65 °B and 1:2 ratio achieved highest water loss and solid gain for guava fruits. Low concentration sucrose solution caused minimal water loss culminating in lower water loss and solid gain ratios (Tortoe, 2010). Mundada *et al.* (2011) studied effect of sucrose concentration on mass transfer during OD of pomegranate arils and found increased water loss and solid gain with increase of osmotic solution concentration to 60 °B as compared to 40° and 50° B. OD is influenced by several factors like nature of fruits, pre-treatments, concentration of osmotic solution, agitation, immersion time, temperature, and fruit to osmotic solution ratio (Naknean *et al.*, 2012).

During extended osmotic treatment, increase of solute concentrations resulted in increase of water loss and solid gain rates (Phisut *et al.*, 2012). Sugar as osmotic solution had been reported to be more effective for OD Banana (Renu, 2012) and stated that most efficient water loss occurred between 60 to 90 minutes of immersion time indicating that it may not be necessary to carry out the osmotic treatment step for longer hours. However, moisture loss, solid gain and weight reduction increased with longer time of treatment. The results also suggested that for bananas, osmotic treatment need not to be done at extreme conditions of temperature and concentration due to its soft texture and suggested that treating the slices at temperatures not more than 40 °C using osmotic solutions at 45° or 50° B as ideal. Fasogbon *et al.* (2013) investigated the influence of two osmotic conditions (50°B sugar and 47:3% w/w sugar/salt solutions) on mass transfer and drying characteristics (dry-matter loss, rehydration capacity) of pineapple slices and reported that pineapple slices, osmotically dehydrated at 4 h 50 °B sugar syrup enhanced solid gain, water loss, and rehydration capacity. Khanom (2014) reported that water loss, solid gain, weight reduction and TSS during OD of pineapple slices (10 mm thick) in different concentration of sugar (40%, 50% and 60%) up to 6 hours at room temperature and found increased rate of water loss with increase in concentration and rapid rate of water loss, sugar gain, weight reduction was recorded for first four hour of the osmotic process. In OD of guava, Pedapathi and Tiwari (2014) observed increased solid gain, water loss, weight reduction with increase in the osmotic concentration increased from 30 to 45 °B and suggested that for optimal OD, the sugar concentrations should be in the range of 40-50°B.

In OD, size and shape of the produce had great influence on drying factors (Lerici *et al*., 1985). Several researchers reported that the kinetics of OD is affected by the shape and size of the samples due to different specific surface area or surface to thickness ratio and different forms of samples can be selected on the basis of end use of product after further processing. (Islam and Flink, 1982; Lerici *et al*., 1985; Sankat *et al*., 1996; Rastogi *et al*., 2002). Different species and different varieties of the same species at different maturity levels had been found to give substantially different response to OD (Singh, 1995). Pineapple cylinders of 2 cm in diameter and 1 cm thick were immersed in sucrose and observed that water loss and solids gain increased linearly with temperature and concentration and optimum corresponded to 58°-63°B sugar concentration for 6 mm slice thickness rather than 3 and 9mm thickness was reported by Kumar and Devi (2011) and also stated that temperature affected mostly the water loss while the concentration of the solution affected mostly the solids gain. Dhingra *et al.* (2013) carried out OD of pineapple slices of 6, 9 and 12 mm thickness using aqueous solutions of sucrose of different concentrations (40, 50 and 60 % w/w) as osmotic media, and found that water loss and solid gain were more intensive at higher sucrose concentration and lower slice thickness. The volume of pear slices was significantly affected by the interaction between temperature and osmosis time and high temperature favoured the mass transfers, resulted in more extensive shrinkage (Nadia *et al.,* 2013). Sutar and Sutar (2013) reported that the tissues at different locations in the same fruit respond differently to OD and the inner and outer parenchyma tissue of Grany Smith variety of apple showed different water loss and solid gain at the same OD conditions. The interconnectivity and pore spaces of two kinds of tissues showed different mass transfer due to different pathways of transport.

2.2.1. Optimizing OD Process Through Response Surface Methodology

Azoubel (2000) studied OD of banana in sucrose solution as influenced by temperature (30–50^{o}C), immersion time (60–150 minutes) and solution concentration (40–60% w/ w) through response surface methodology and found that responses of water loss and solid gain were fitted to polynomials, with multiple correlation coefficients ranging from 0.72 to 0.95. The fitted functions were optimised for maximum water loss and minimised incorporation of solids in order to obtain a product resembling non-processed fruit. Optimum conditions to obtain water removal >25% with solid uptake lower than 6% could be obtained using a 44% (w / w) sucrose solution concentration, temperatures up to 38 ^{o}C and immersion time up to 80 minutes. For studying OD of pomegranate arils, a mathematical model was developed to quantify the responses of water loss, weight reduction and solute gain using response surface methodology by Abdul and Hasnain (2010). Under the experimental conditions, water loss was 15-32%, whereas 6-13% solids were gained. Optimisation of the model with the goal of maximum water loss and minimum solute gain resulted in 24.5% and 9.6% values, respectively, whereas, with the goal of minimum water loss and maximum solute gain resulted in 15.6% water loss and 13.8% solute gain. Analysis by response surface methodology (RSM) was used to optimize the OD process of kiwifruit by Rodriguez (2010) and a second order polynomial model was fitted by a multiple linear regression method for describing and predicting the values of WR, WL and SG, hardness and colour change and results indicated that, to obtain a maximal WL (22.77%), SG (8.538%) and hardness (63.32N) and a minimal WR

(16.864 %) and colour character (2.326), dehydration should be performed with an osmotic solution of xylitol at 47.5 °B, with a time of 6 h at 32 °C temperature.

Kumar and Devi (2011) reported response surface methodology with four factors on three levels to find out the optimum osmotic concentration, temperature, slice thickness and KMS concentration for better OD of pineapple slices. The slices of various thickness (3, 6, 9 mm) were dipped into various sugar concentration (50°B, 60°B, 70°B) with temperature (35°C, 45°C, 55°C) for six hours with addition of KMS (0.025%, 0.05%, 0.075%) response surfaces, contour plot and ANOVA revealed that WL and SG increased linearly with the increase in sugar concentrations and temperatures of the solution and slice thickness and KMS percentage had least effect on mass transfer characters and optimum OD corresponded to 58-63 °B, 55°C temperature, 6 mm slice thickness and 0.05 - 0.065% KMS concentration. Sridevi and Genitha (2012) used response surface methodology for quantitative investigation of water loss, solid gain and weight reduction during OD of pineapple in sugar syrup and optimum conditions were found to be temperature 38.2°C, processing time 128.7 minutes and sugar concentration 44.05°B. At these optimum values, water loss, solid gain and weight reduction were found to be 30.092%, 13.363% and 20.377% respectively. Khatir *et al.* (2013) observed response surface methodology to determine the optimum processing conditions that yield maximum water loss and weight reduction and minimum solid gain during OD orange pieces (Valencia Late) in sugar solution. The independent process variables for OD process were temperature (40, 50, 60 °C), processing time (60, 120, 240 min) and sugar concentrations (45, 55, 65 % w/w) and optimal conditions for maximum water loss, weight reduction and solid gain correspond to temperature of 50 °C, processing time of 240 minutes, sugar concentration of 65 % in order to obtain water loss 60.83 % (g/100 g fresh sample), solid gain of 46,48 % (g/100 g fresh sample) and weight reduction of 57.42 (g/100 g fresh sample).

Gupta *et al.* (2014) proved combined effects of temperature (40 - 60°C), sugar concentration (40 - 60°B) and duration (60 - 240 minutes) and were modelled in osmotic drying of guava with water loss and sugar gain as response variables and found that highest water loss, solid gain, weight reduction, yield, moisture loss was obtained for guava slices treated at 70° B for 24 h. Patil *et al.* (2013) studied water loss and sugar transfer during OD of sapota slices using response surface methodology with the temperature (40–60 °C), processing time (120 - 240 minutes), sugar concentrations (40–60°B) and keeping solution-to-sample ratio as constant (5:1) being the independent process variables and found that concentration of sugar solution and temperature were the most significant factors affecting the water loss and sugar gain during OD and effect of temperature and time were more pronounced for SG than the concentration of sugar solution. Effect of sucrose concentrations (40 to 65°B), temperature (30 to 50 °C) and time of immersion (0 to 180 minutes) were studied for diced mango cubes of 2 cm^3 dimensions by Duduyemi *et al.* (2015) and variables of water loss, solute gain and performance ratio were modelled and optimised using the modified distance approach of the response surface methodology.

2.2.2. Change in biochemical parameters of osmosed fruits

Geetha *et al.* (2006) studied osmotic concentration kinetics on aonla preserve and reported that total sugar and TSS increased with the increase in sugar syrup concentration and temperature, while moisture and ascorbic acid decreased. Dionello *et al.* (2009) evaluated OD of sliced fruit of two cultivars of pineapple, Pearl and Smooth Cayenne in invert sugar syrup and found that an increase of about three times TSS of the pineapple slices and no significant differences due to cultivar and temperature of dehydration was noticed.

Total titratable acidity decreased independently of the pre-treatment time, in apricot cubes pretreated in sucrose (Riva *et al.*, 2005). In general, dried fruits pre-treated with sucrose, inverted sugar or de-acidified fruit juice had a predominantly sweet taste, while those treated with concentrated apple juice had high acidity (Konopacka *et al.*, 2009). Product saltiness or sweetness increased during osmotic process and the acidity decreased which is not desirable in some cases and this could be avoided by controlling the solute diffusion and optimising the process to improve the sensory properties of the product (Tortoe, 2010). Sagar and Kumar (2009) reported that reducing sugar and total sugar were found higher in osmosed mango slices than in unosmosed slices. According to Chong (2010) fruit with high amount of reducing sugar and polypheol oxidase substrates should apply low temperature drying technique.

Ascorbic acid intake increased with the pre-treatment time (Riva *et al.*, 2005). The ascorbic acid content decreased with increase in processing time, osmotic concentration and temperature for osmodehydrated apples were observed by Devic *et al.* (2010) and might be due to diffusion from the fruit tissue into the osmotic solution during dehydration and losses due to chemical degradation during processing. A change of temperature of the sucrose solution from 20 to 60 ^{0}C had impact on ascorbic acid content and was lost due to heat sensitive reactions, mainly oxidation (Nadia *et al.*, 2013).

2.2.3. Physical Parameters of Osmo-air Dehydrated Fruits

Conway *et al.* (1983) and Lenart (1992) reported that increase in osmotic solution concentration resulted in corresponding increase in water loss to equilibrium level and drying rate. Thippanna (2005) in banana and Pedapathi and Tiwari (2014) in guava reported that, osmotic treatment of fruit slices at 70^{0}B syrup for 24 h resulted in highest yield and lowest drying rate.

The osmotic step, both in sucrose and sorbitol, increased initial drying rate of apricot cubes in the first falling rate phase probably due to 60 min soaking loosening the surface cellular structure, which was observed in strawberry Chiralt *et al.* (2001). The combined osmotic and microwave drying resulted in more homogeneous heating of the mushroom by modification of its dielectric properties, slightly reduced drying time, reduced shrinkage, higher final porosity and improved rehydration characteristics. Higher rate of evaporation from the surface of jackfruit samples at higher temperatures which lead to higher mass transfer rate during drying (Demir *et al.*, 2004). The moisture ratio of osmotically drehydrated fruits reduced exponentially as the drying time increased (Doymaz, 2007). Premi *et al.* (2010) also reported the reduction in drying rate at the end of drying of drumstick leaves due to reduction in moisture availability with advancement of drying.

Rehydration is a complex process aimed at the restoration of raw material properties when dried material is in contact with water. During rehydration, absorption of water into the tissue and leaching out of product solutes (sugar, acids, minerals, vitamins etc.) into the medium both occur concurrently. Dry material, subjected to rehydration, undergoes many chemical and physical changes owing to the property of water imbibition and solute loss and rate depended on porosity of the material which is related to drying and the predrying processes involved. Factors of interest during rehydration includes, drying material, pretreatments, temperature, the chemical composition of the product, drying techniques and conditions, composition of the rehydrating medium, etc. (Fasogbon *et al.*, 2013). The quality of osmotically dehydrated products is usually assessed by rehydration characteristics, colour, shrinkage and density, texture, chemical quality and sensory characteristics (Sutar and Sutar, 2013).

Rehydration cannot be simply treated as the reverse process to dehydration (Sanjuan *et al.*, 1999). Rehydration can be considered as a measure of the injuries to the material caused by drying and treatments preceding dehydration (Lewick, 1998). Dehydrated products need to be rehydrated before consumption or further processing (Nayak *et al.*, 2006). Rehydration is a process of moistening dry material (Femina *et al.*, 2000). Rehydration is usually carried out by soaking the dry material in large amounts of water (Garcia *et al.*, 2005).

Mainly porosity of the material had influence on mass transfer and phenomena of shrinkage as well as ratio of rehydration affected by size and shape of the produce area to volume ratio of the material with solution. Lerici *et al.* (1985) and Torreggiani (1993). Chaudhari *et al.* (1993) and Ghosh *et al.* (2004) reported that in terms of final product characteristics, sugar uptake affected both rehydration and flavour retention. Bhuvaneswari *et al.* (1999) reported that rehydration ratio of osmotically treated peas was higher than those of untreated samples. Generally osmo dehydrated products resulted in to low rehydration ratio due to increased solid gain and the solid loss by dissolution in to water during rehydration and this effect could not be counted as loss of original solids of the products (Sutar and Prasad, 2005) and they also reported that final product showed much lower rehydration rate, lower hygroscopicity and better textural quality after rehydration in comparison to other dehydration technique.

The rehydration values of osmotically dehydrated pineapples in sugar/salt solution (52.32 %-70.07%) were higher than that of osmotically dehydrated in sugar solution (40.50%-54.40%) at 90°C was observed by Fasogbon *et al.* (2013). The rehydration ratio determines the ability of the sample to regain the water without disintegration, which can be taken as a quality parameter. The highest rehydration ratio (0.43) was observed in jackfruit dried at 50°C whereas least (0.40) was observed in samples dried at 70 °C and this might be due to the fact that a higher drying temperature caused decrease in water content at a faster rate and brought more physico-chemical changes in products, which led to decreased rehydration ratio (Pragathi and Sharma, 2014). The rehydration ratio showed an increasing trend as osmotic concentration increased in cranberries and drying rate was initially constant and latter decreased with the time in osmotically pretreated craneberries (Grabowski *et al.*, 2015).

Fruits and vegetables undergo volumetric changes upon water loss which is expressed as shrinkage. Such modifications occurring during drying process affect the moisture transport properties as well as structure of the product Raghavan and Silveira (2001). Maximum shrinkage during drying of fruit material decreased as its solid increased (Lazano *et al.*, 1983) and structural collapse was shown to decrease when fruit was impregnated with sugar prior to air drying (Witrow *et al.*, 1995; Dellvalle *et al.*, 1998; Nieto *et al.*, 1998; Reppa *et al.*, 1999; Riva *et al.*, 2001). Raghavan and Silveira (2001) reported that the shrinkage of strawberries had a linear relation with moisture ratio and equivalent diameter had a reciprocal logarithmic function with moisture ratio. Hatamipour and Mowla (2002) reported that during drying, the volume change is expressed as shrinkage and shrinkage affects the physical properties of materials such as bulk density and porosity. Changes in shape and size during drying modify both the dimensions and transport properties of individual particles and also thickness and porosity of packed bed in dryer (Karathanos and Saravacos, 1993; Ratti, 1994). OD overcomes several disadvantages of other drying methods creating negative impact on product shrinkage and density. Due to solid gain during OD, the final product exhibit less shrinkage as well as it helps in maintaining proper level of density due solid uptake. The shrinkage as a negative quality determining parameter, recorded relatively more at lowest concentration and increased concentration of sugar in hypertonic solution increased net penetration of sugar in to slices occupying empty spaces rendered due to removal of moisture reported (Kaleemullah and Kailappan, 2002).

Enzymatic browning during air dehydration of apricots was due to phenolase activity, which had been decreased rapidly with increase in soluble solids content (Pointing *et al.*, 1966 and McBean *et al.*, 1971) and colour parameters showed slight change after the osmotic step; a* and b* maintain their original values (no browning), whereas L* values show a little decrease (darkening) and lower darkening for osmodehydrated samples. These results are in accordance with those obtained on apple and, banana and Tan *et al.* (2001) on pineapple. OD of banana helped in reducing the browning of fruits during air drying (Krokida *et al.*, 2000). Perera *et al.* (2010) also observed a decrease in color due to browning reaction (millard) that occurred throughout storage in pineapple juice. A decrease in color intensity was recorded in pineapple slices and mango chips due to osmodehydration (Kumar and Devi, 2011). Fructose is one of the major carbohydrates in promoting color degradation during processing while sucrose stabilizes anthocyanin level in fruits like strawberry (Zou *et al.*, 2013).

Aboubakar *et al.* (2008) reported that jackfruit samples dried at 60 ^{0}C were found better as compared to sample obtained at 50 and 70 ^{0}C in terms of 'a' and 'b' value and sugar impregnation maintained luminosity, resulted in a final product very close to the fresh fruit. Longer osmotic concentration and time resulted in higher loss of phytonutrients, mainly due to the leaching into sucrose solution and negative influence of oxygen (Nadia *et al.*, 2013). Patil *et al.* (2013)

conducted an experiment to study the suitability of seven banana varieties (Grand Naine, Rajapuri, Yanagambi KM-5, Monthan, Yalakkibale, Kothia and Bluggoe) for making osmo-dehydrated banana crisps. The variety Yalakkibale recorded higher recovery (57.49%) of crisps and lower dehydration ratio (1.74) and it was due to higher TSS, low moisture and high dry matter content than the other varieties. Jesulin and Manimehala (2014) reported that textural qualities like cutting force and cutting energy decreased in case of osmotically dehydrated papaya slices and it may be due to water loss.

2.2.4. Biochemical Parameters of Osmo-air Dehydrated Fruits

Dehydrated papaya slices prepared by steeping in 70 °B syrup with 1000 ppm SO_2 gave the best product as assessed by chemical parameters like acidity (0.36 %), carotenoids (1.05mg/100g), reducing sugar (32.70 %), total sugar (72.30 %), SO_2 (500 ppm) and moisture (17.6%). About 50 per cent of the initial value (1.05 mg from 2.0 mg/100g) of caotenoids was retained (Mehta and Tomar, 1980). Madamba and Lopez (2002) reported that reducing sugar and total sugar was higher in osmotically dehydrated mango slices and increased concentration resulted in increased reducing sugar and total sugar. Elbeltagy *et al.* (2008) reported that reducing sugar and total sugar at 65 ^{o}B was higher than compared to 50 and 45 ^{o}B during osmo-air dehydration of strawberries.

During OD, a high osmotic rate would make the process of moisture removal more efficiently and studies had focused on rapid and effective removal of desired amount of water from fruits by adjusting process variables (El-Aouar *et al.*, 2006; Moreira *et al.*, 2007; Ispir and Togrul, 2009; Devic *et al.*, 2010; Bchir *et al.*, 2011; Mundada *et al.*, 2011). Shedame *et al.* (2008) studied the process of OD followed by tray drying on grapes for raisin preparation and found that acidity and ascorbic acid decreased with increase in syrup concentration, temperature of solution and time of concentration while total, reducing and non-reducing sugar increased with increase in syrup concentration, temperature of solution and time of immersion.

Dehydration of foodstuffs by immersion in osmotic solutions before convective air-drying improved the quality of final product since it prevented oxidative browning, loss of volatile flavouring constituents, and reduced fruit acidity (Yetenayet and Hosahalli, 2010) and reduction in acidity level reduced the characteristic taste of some products and solute uptake and leaching of valuable product constituents often lead to substantial modification of the original product composition with a negative impact on sensory characteristics and nutritional profile (Chaudhari *et al.*, 1993 and Ghosh *et al.*, 2004). Lower total acidity, vitamin C and phenolic compound in sample produced by slow OD were observed as compared to fast OD. Leaching of natural solutes such as acids, vitamins and small molecules of phenolic compound into the osmotic solution could take place during OD process and induced a higher loss of natural solutes in prolonged OD process (Vijayakumari *et al.*, 2007 and Devic *et al.*, 2010). Reduction in total acidity was detected in all osmo-dried cantaloupes compared to fresh cantaloupe which is reported due to leaching of acids into the medium during OD process. Vitamin C was also found lower in OD fruits than fresh cantaloupes and could be due to leaching and chemical degradation which was enhanced by drying temperature (Devic *et al.*, 2010).

Sugar uptake resulted in development of a concentrated solids layer under the surface of the fruit, upsetting osmotic pressure gradient across the fruit interface and decreased the driving force for water flow and sugar uptake affected both rehydration and flavour retention (Chaudhari *et al.*, 1993 and Ghosh *et al.*, 2004). Assous *et al.* (2012) evaluated the effect of OD of guava and results indicated that total sugar, ascorbic acid and phenolic contents of osmo air-dried guava slices were higher than that of air dried guava slices.

In osmotic treatment, solute transference to the fruit caused an increase of soluble solid content of the fruit which decreased phenolase activity and hence reduced the susceptibility of fruit to enzymatic browning during air dehydration and limited the decrease of vitamin C (Pointing *et al.*, 1966; McBean *et al.*, 1971; Vial *et al.*, 1991). During the OD, water and small amount of natural solutes (vitamin C) were transferred from fruit to the solution and the solute was transferred from the osmotic solution to the fruit in a countercurrent manner (Park *et al.*, 2002).

Decrease in vitamin C was observed in OD Kiwi by Vial *et al.* (1991). Pizzocaro *et al.* (1993) stated that colour and ascorbic acid changes were related, and was a decrease of ascorbic acid, whose chemical action is to reduce the o-quinones formed by polyphenoloxidase to colourless dihydroxyphenols. Azoubel and Murr (2003) reported that ascorbic acid losses during OD of kiwi fruits might be due to leaching of vitamin from the product to the osmotic solution during osmotic process. For evaluating the varieties of banana suitable for OD by Rasheed (2005) reported that nendran banana was found more suitable with good shelf life and nutritive value. The quality traits and nutritional value of osmodried fruits can be modified depending on the parameters of the dehydration process and osmotic agent used (Chiralt and Talens, 2005 and Mandala *et al.*, 2005). Singh *et al.* (2007) evaluated osmotically dehydrated aonla fruit segments and reported that OD showed better vitamin C retention, less acidity and tannin content than in whole fruit preserve. Aonla fruit segments steeped in 60°B sugar syrup showed less vitamin C loss than in 70°B syrup and reducing and total sugar in the product increased with increase in sugar syrup concentration and steeping time. El-beltagy *et al.* (2008) investigated the surface area exposed and retention of vitamin C during solar drying of strawberries and found that increase in surface area accelerated the vitamin loss during the drying which might be due to high sensitivity of vitamin C to light. Santos and Silva (2008) reported that vitamin C can be easily degraded, depending on many variables such as pH, temperature, light, and presence of enzymes, oxygen, and metallic catalyzers. Thus, many studies on food processing take vitamin C as a quality indicator. Ascorbic acid of content of osmo dehydrated pear slice decreased with increase in processing time, osmotic concentration and temperature and losses during osmo-dehydration might be by diffusion from the fruit tissue into the osmotic solution during dehydration and losses due to chemical degradation during processing (Nadia *et al.*, 2013).

2.2.5. Sensory Evaluation of Osmo-air Dehydrated Fruits

Forni *et al.* (1997) proved that as the osmotic concentration increased from 50 to 60 °B, colour of the redness and yellowness also increased in apricots. Loss of cell turgidity, deformation or cell wall rupture, splitting and degradation of the middle lamella, cellular collapse, plasmolysis and tissue shrinkage are indicated as the main effects of OD on the cellular structure of plant tissues (Lewicki and Porzecka, 2005). Riva *et al.* (2005) reported that osmo-dehydrated apricot cubes with 60°B sucrose had lowest structure collapse and better superficial appearance. Incorporation of sugar improved colour stability during air dehydration which lead to higher sensory score. Falade *et al.* (2007) observed darker colour in osmo-dried watermelon due to increase in pigment content during OD and drying process and decrease in L* value and an increase in a* values could be a result of browning reactions occurred during hot-air drying.

Structural changes noticed in OD product texture, were due to osmotic process (Sormani *et al.*, 1999; Mastrangelo *et al.*, 2000; Pereira *et al.*, 2007). Azoubel and Murr (2003) reported that cashew apple pretreated in sucrose solution and dried at 60°C temperature had the highest sensory score regarding colour, taste and flavour. Konopacka *et al.* (2009) studied effect of OD of sour cherries and blackcurrants using different osmotic treatments on sensory quality and fruits impregnated with fructo-oligosaccharide were characterised with good texture properties as well as an acceptable sweetness intensity that resulted in high quality acceptance. Alam and Singh (2010) found that aonla flakes of 2 mm thickmess in 70°B sugar solution with 60°C osmotic solution temperature for 72 minutes immersion time recorded maximum possible overall acceptability. Chavan *et al.* (2010) found that osmo dehydrated banana slices of (8 mm thickness) prepared by soaking in 60 °B sugar solution for 16 h resulted in highest score for all sensory attributes like colour, appearance, flavour, texture, taste and, overall acceptability.

Osmotic Dehydration promotes stabilization of colour parameters, reducing non-enzymatic browning reactions and often improves fruit product colour (Krokida *et al.*, 2000). Jalalli *et al.* (2008) reported that round sliced osmodehydrated banana was preferred with highest sensory score than longitudinal slices. Naikwadi *et al.* (2010) revealed that sensory quality parameters of dehydrated figs showed excellent organoleptic characteristics for fructose sugar syrup (50°B) treatment for colour, appearance, texture, taste and overall acceptability. Farzaneh *et al.* (2011) found that coated carboxy methyl cellulose apple rings on OD followed by freeze drying had best flavour, texture, and acceptability in sensory analysis. Sakhale and Pawar (2011) reported that mango slice of 10 mm thickness treated with 2% calcium chloride solution for 10 minutes followed by dipping into sugar syrup of 60 °B with mechanical drying showed superiority in sensorial quality attributes in OD of mango slices. Campos *et al.* (2012) revealed that blanching of the star-fruit in 0.75% citric acid was effective in maintaining the color of the osmotically dehydrated fruit which resulted in better sensory acceptance. In general, fruit size of 3 mm to a maximum of 10 mm in rectangle, ring or cube shape of pineapple was suggested for the use in OD (Chavan and Amarowicz, 2012). Nadia *et al.* (2013) reported that color parameter significantly increased along the osmotic process, denoting color intensification in pear fuits. Naknean *et al.* (2012) found that sensory attributes of osmo-dried cantaloupe were found to be better in 50 °B osmotic solution of sorbitol- and maltitol-treated samples and dried in hot air oven at 60°C with higher score for colour, texture and overall acceptability. Nieto *et al.* (2013) reported that osmotically dehydrated apples became soft, extensible and lost crispness and hardness.

Phisut *et al.* (2012) reported that browning index was found between sample produced by fast OD and slow OD. Slow OD could maintain the shape and present texture, resulting in higher mean score of appearance as evaluated by consumers. In an experiment conducted by Patil *et al.* (2013) to study banana varieties for making osmo-dehydrated banana crisps revealed that the variety Yalakkibale recorded highest overall acceptability score compared to other varieties. Kedarnath *et al.* (2014) reported that sapota slices were immersed in a solution 50 °B for 1 h recorded good sensory attributes. Kaushal and Sharma (2014) reported that osmotically pre-treated jack fruit with 15 % salt solution and dried at 60 °C had best quality based on sensory characteristics, which might be due to degradation of colour at a faster rate at higher temperatures or when exposed to lower temperature for a longer period of time. Kumar and Sagar (2014) found that sensory score of osmo dehydrated mango, guava and aonla segments were superior with respect to colour, taste , flavour and overall acceptability when suspended in sugar concentration (60°B) followed by vacuum drying. Shrikanth *et al.* (2014) reported that sensory evaluation of dehydrated ripe Jackfruit bulbs revealed that 40 °B OD, 60 °C drying had maximum score for colour, flavour, texture and overall acceptability.

Surendar *et al.* (2014) carried out OD of guava slices with 4 mm thickness using three different concentrations of sugar solution (40, 50 and 60 %) with 0.2 % potassium metabisulphite (KMS) and found that 60 °B solution gave best sensory quality parameters of colour, appearance and overall acceptability. Thippanna and Tiwari (2015) revealed that osmotically dehydrated 'Robusta' slices were significantly superior over 'Ney Poovan' with regard to sensory score and highest total sensory score was recorded for osmo dehydrated slices in pre-treated with 60°B sugar syrup for 24 h.

2.3. STORAGE STUDIES OF OSMO DEHYDRATED FRUITS

2.3.1. Physical Parameters of Stored Dehydrated Fruits

Polythene and polypropylene are the best packaging material of dried products (Balasubramanyam, 1995). Sagar *et al.* (1998) studied the influence of storage temperature and period of storage on the quality of dehydrated ripe mango slices and reported that dehydrated ripe mango slices could be stored at low temperature (7 °C) up to 6 months and 4 months at room temperature (33-33.5 °C) without losing their colour, flavour and texture. Ahemed and Choudhary (1995) used high density polyethylene pouches for storage of osmo-dried papaya which gave a shelf life of six months at ambient conditions. Storage studies of osmodehydrated banana slices in polypropylene covers by Chavan and Amarowicz (2012) reported a shelf life of six months under ambient conditions.

Prakash (2004) reported that stored samples showed decreased rehydration ratio in osmotically dehydrated carrot. Grzegory *et. al*. (2013) reported that vacuum dried strawberries stored for about 360 days at ambient temperature showed decreasing trend in rehydration ratio, but the differences were not statistically significant which might be due to increase in moisture during storage. Singh and Sharma (2015) reported that stored samples showed decreased rehydration ratio in osmotically dehydrated pineapple that might be due absorption of moisture from environment.

Illeperuma and Jayanthuge (2001) in kolikuttu banana revealed that texture of the dehydrated product was affected by slice thickness where 0.5mm thickness resulted in crispy product. Farnis *et al*. (2008) and Rizzolo *et al*. (2015) in apple reported that texture of the stored samples mainly depended on the absorption of moisture from storage atmosphere.

2.3.2. Biochemical Parameters of Stored Dehydrated Fruits

Moisture content of pre-treated and dehydrated pineapple slices during 18 weeks storage revealed that there was continuous reduction in moisture content during the early weeks of storage and, after 9 weeks of storage, the moisture content increased (Levi *et al*., 1980).

Reduction in acidity during storage was observed by Sagar and Kumar (2006) in dehydrated aonla shreds, mango and guava slices and in tamarind by Lakshmi *et al*. (2005). Evaluation of banana varieties suitable for OD by Rasheed (2005) found that nendran banana was more suitable with good shelf life and nutritive value upto 6 months of storage. Sumitha *et al*. (2015) observed decreased acidity in osmotically dehydrated aonla segments during storage.

Sharma *et al*. (2005) observed reduction of total soluble solids, acidity and ascorbic acid, increase in reducing sugar and moisture content but decrease in total sugar during six months of storage of osmo air dehydrated apricot. The decrease of acidity was due to utilization of acid for hydrolysis of non-reducing sugar which is responsible for increase of reducing sugar. The moisture content and acidity showed significant increase during storage of osmodehydrated while reducing sugar showed non-significant increase (Hafiza *et al.*, 2008). Kumar *et al.* (2008) reported increase in moisture content, reducing sugar and total sugar but decrease in acidity, ascorbic acid and carotenoids in osmo-vac dehydrated longitudinal mango slices during storage of six months in HDPE package and suggested that carotenoid loss might be due to oxidation and exposure of product to light during storage. Sagar and Kumar (2009) reported that, in osmo dehydrated mango slices, moisture content, reducing sugar and total sugar increased while ascorbic acid and acidity got decreased at six months of storage and were acceptable for six months storage at ambient conditions. Storage study of osmodried banana standardized by Chavan *et al.* (2010) showed that there was marginal decrease in moisture content and increase in TSS, total sugar and reducing sugar content during storage period of six months which might be due to hydrolysis of sugar and mass reduction effect due to loss in moisture content.

Naikwadi *et al.* (2010) found a gradual decrease in moisture, acidity and ascorbic acid but increase in sugar content of dehydrated fig during storage period of six months and rate of decrease or increase was faster at ambient than at cool storage conditions. Acidity of the dehydrated jackfruit bulb was found to increase gradually as a result of acid – hydrolysis during storage was reported by Shrikanth *et al.* (2014). During storage of dehydrated jack fruit there was increasing trend in reducing sugar and total sugar, which might be attributed due to breakdown of polysaccharides into monosaccharides as a result of acid hydrolysis. Sumitha *et al.* (2015) revealed that aonla segments prepared by using osmo dehydration, packed in PET jar and stored at low temperature retained highest ascorbic acid and acidity and lower non enzymatic browning values. Furthermore, there was an increase in reducing sugar, total sugar, and partial reduction in non-reducing sugar and acidity of the product during storage.

There was a gradual decrease in acidity content in OD aonla during 6 months of storage at room temperature as compared to the initial and samples stored at low temperature had less reduction in acidity than at room temperature which might be due to limitation in conversion of carbohydrates and proteins into other fractions and also, oxygen free micro-environment might have prevented the oxidation reduction reaction. The decrease in acidity might be due to acid hydrolysis of polysaccharides and non-reducing sugar to their simpler components where acid is utilized for converting them to hexose sugar or complexes in the presence of metal ions as reported by Kumar *et al.* (1993). Reduction in acidity during storage was observed in dehydrated aonla shreds (Sagar and Kumar, 2006), Kumar and Sagar (2008) in mango and guava, Lakshmi *et al.* (2005) in flavoured tamarind ready to serve beverages and in ready to serve bael-guava beverage by Nidhi *et al.* (2008).

Similar results for increase in reducing sugar content during storage were observed by (Kumar and Sagar, 1998) in mango and by Sagar *et al.* (1998) in dehydrated ripe mango slices. Magnitude of increase was comparatively less in the samples stored under low temperature. It might be due to reduced availability of fruit acid at low temperature, which, in turn affected the hydrolysis of polysaccharides.

Decline in ascorbic acid content was observed in dehydrated aonla by Gajanan (2002), dehydrated mango powder by Hymavathi and Vijaya (2005). Osmotically dehydrated aonla segments showed reduction in ascorbic acid content during storage and this might be due to the effect of storage temperature and catalytic activity of fructose. Thermal degradation during processing and subsequent oxidation and light reaction were the other possible causes of reduction in ascorbic acid content (Singh *et al.*, 2007). Similar observations were reported by Kumar and Sagar (2009) in pineapple.

The increase in total sugar during storage was due to the breakdown of polysaccharides, and conversion of starch into sugar (Wills *et al.* 1989).

Joshi *et al.* (2005) reported that total sugar is an indication of per cent reducing sugar and treatment combination of 60 ^{o}B, 9 hours of immersion time with potassium meta bisulphate as preservative showed highest total sugar content of osmotically dehydrated guava slices. Chavan *et al.* (2010) reported that reducing sugar contents gradually increased during six months of storage which might be due to hydrolysis of total sugar into reducing sugar. Palve (2007) reported similar results in osmo-dried apple candy and figs on storage.

2.3.3. Sensory Parameters During Storage of Osmo-air Dried Nendran Banana

Osmotically dehydrated banana products can be preserved up to one year or more depending upon the storage conditions and packaging materials used. Storage studies on osmo-dehydrated mango slices showed that the keeping relative humidity between 64.8 to 75.5 per cent would be conducive for the retention of colour, flavour, texture and taste (Bongirwar and Sreenivasan, 1977).

Ahemed and Choudhary (1995) reported a shelf life of 6 months of room temperature for osmo-dried papaya. Pereira *et al.* (2004) found that guava slices dipped in 60 °B sucrose solution at 40 °C for 2 hours then packed in polyethylene terephthalate containers retained colour and better sensory attributes. In order to prevent absorption of moisture from atmosphere and to prevent spoilage due to contamination, air tight containers of good quality food grade could be used to store osmotically dried foods and aluminum foil, laminated polypropylenepouches are suggested as ideal packing materials (Sagar *et al.* 1999). Hussain *et al.* (2005) reported that best sensory score for osmotically dehydrated banana at 45 °B.

Studies conducted by Illeperuma and Jayanthuge (2001) on osmo-air dehydration of overripe 'Kolikuttu' banana resulted in ready to eat product with good organoleptic property and storability up to 8 months in polypropylene bags. Sharma *et al.* (2005) reported that osmo air dehydrated apricots of 70°B sugar solution stored in polyethylene, laminated pouches and glass jars for six months, observed maximum retention of sensory attributes in laminated pouches stored product with minimal chemical changes. Kumar *et al.* (2008) found that osmo-vac dehydrated longitudinal mango slices immersed in 70 °B sugar solution, packed in HDPE stored at 7°C recorded best sensory attributes for six months.

Anand and Genitha (2011) found no significant change in colour of banana slices after osmotic treatment and were acceptable for a period of one month after storage in LDPE polyethylene bags. Ripe jackfruit bulbs dipped in 40 °B solution and dried at 60 °C recorded high sensory scores during 12 months storage period (Shrikanth *et al.*, 2014). Sumitha *et al.* (2015) reported that OD aonla segments stored at low temperature (15 °C) had superior score for sensory values and products were found to be highly acceptable even after 6 months of storage shelf life of osmodehydration.

2.3.4. Microbial Quality of OD Fruits During Storage

Osmotic dehydration reduced the water activity of the food and makes an unfavorable environment for the microbial growth (Alzamora *et al.*, 1995). The main objective of drying is to remove moisture to a level that prevents microbial growth in order to extend shelf life while maintaining product quality (Changrue and Orsat, 2009). Illeperuma and Jayanthuge (2001) reported that osmotically dehydrated kolikuttu banana was found safe up to 8 months of storage. As per the recommended microbiological standards the maximum limits for mesophilic yeast and moulds for OD fruits are 104 CFU/g and 102 CFU/g respectively (Casetello *et al.*, 2009). Chavan *et al.* (2010) reported that OD banana was microbiologically safe and sensorily acceptable up to 6 months storage at ambient condition. Zapata *et al.* (2011) reported that osmotically dehydrated pineapple slices, at 70 ^{o}B recorded lowest microbial count than compared to 60 ^{o}B and also found that the product was microbiologically safe up to 6 months of storage. Rahman *et al.* (2012) reported that microbial count of osmotic dehydrated jackfruits of various sugar concentrations was nil initially and increased slightly during storage. Osmotic dehydrated jackfruit prepared by 50 ^{o}B sugar solution and 45 ^{o}B sugar solution showed lowest microbial count than that prepared by 35^{o} and 40^{o} B sugar solution during storage in high density polyethylene at ambient condition.

Materials and Methods

3. MATERIALS AND METHODS

The materials used and methodologies adopted during the present investigation "Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)' conducted with the objective to standardize different process variables like fruit slice shape and thickness, osmotic solution concentration and immersion time for osmo-air dehydration of Nendran banana and to optimize the conditions suitable for better mass transfer kinetics are described in this chapter.

3.1. PREPARATION OF OSMO-AIR DEHYDRATED PRODUCT FROM NENDRAN BANANA

The experiment was conducted at Department of Processing Technology, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram during the year 2013-2015.

3.1.1. Selection of Fruits

Nendran banana cv Kaliethan of uniform size, maturity, free from pests, diseases and mechanical damages were procured from the Instructional Farm, Vellayani.

3.1.2. Fruit Slices Preparation

Optimally ripened uniform sized Nendran banana (cv Kaliethan) were peeled and edible fruit portion was made into slices of 5 mm, 10 mm, 15 mm thickness in three shapes *viz.*, longitudinal (5 cm long), round and ring.

3.1.3. Osmotic Treatments

Sugar syrup (sucrose) of three different concentrations *viz.* 50, 60, 70 ^{0}B were prepared. Potassium metabisulphite (0.1%), citric acid (0.1%), and ascorbic acid (0.2%), were added to the osmotic solution.

Prepared nendran banana slices of one kg each were osmosed in 50, 60 and 70 ^{0} B sugar syrup for different immersion time of 40, 60 and 80 minutes. At the end of osmotic treatment for a particular shape, thickness, concentration and osmotic duration, the fruit slices were taken out of the osmotic solution and were rinsed quickly with distilled water in order to remove the sugar adhering to the surface and were blotted to remove moisture. These osmosed banana slices were used for the determination of various mass transfer characters (Plate 1).

Shape of slices : 3

Thickness of slices : 3

Osmotic concentration: 3

Immersion time : 3

Total treatments : 81 (3X3X3X3)

Design : RSM

3.1.3.1. ***Mass Transfer Characters of Osmosed Nendran Banana Slices***

Mass transfer describes the transport of mass from one point to another and is one of the main pillars in transport phenomena of osmotic dehydration. Mass transfer characters *viz.* solid gain (SG), water loss (WL), weight reduction (WR) and ratio of water loss to solid gain (WL/SG) were determined and optimised values were calculated.

3.1.3.1.a. ***Solid Gain*** **(SG)**

Solid gain (%) was determined using the procedure followed by Chavan *et al.* (2010).

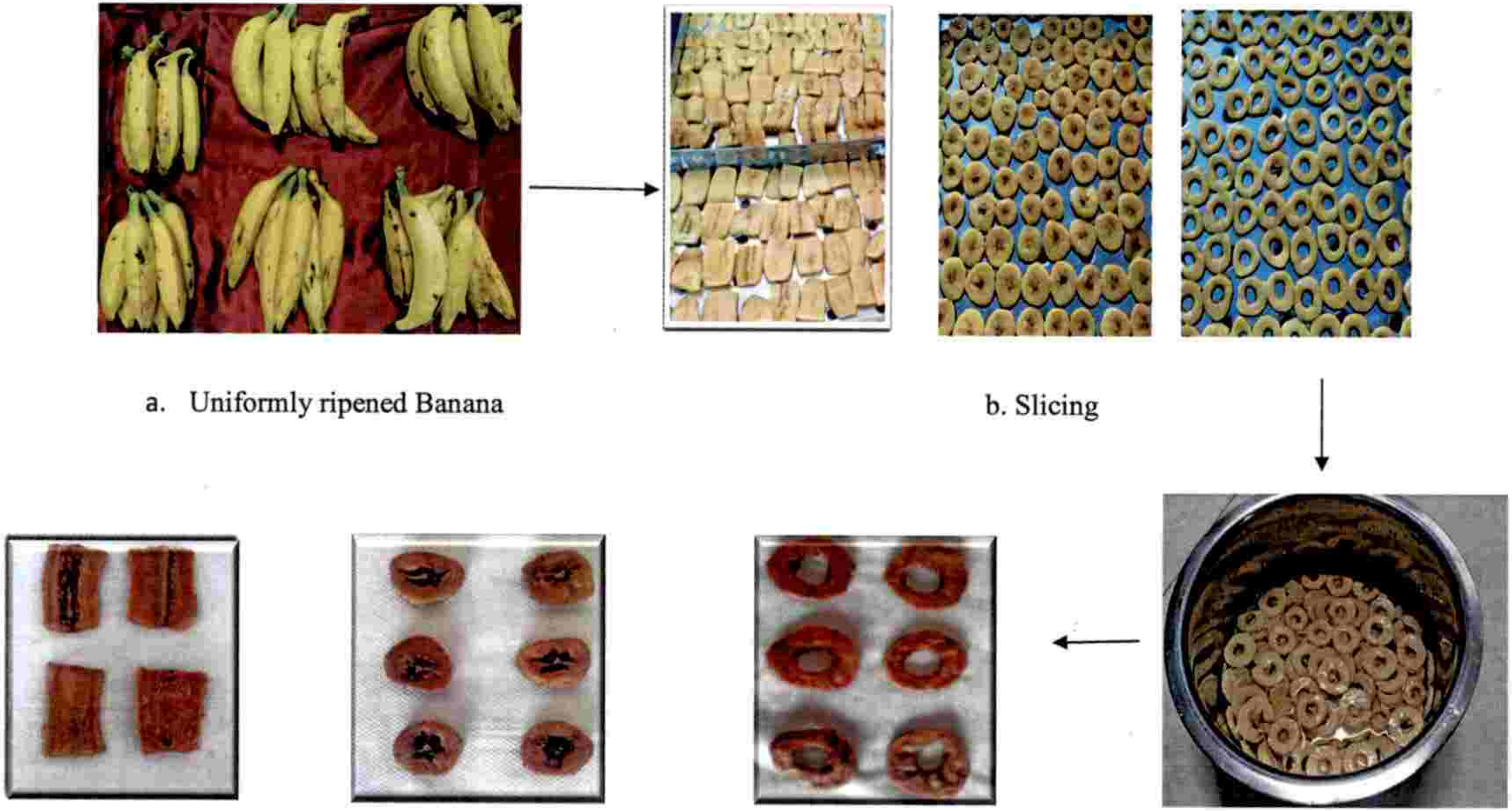
$$SG(\%) = \frac{m - mo}{mo} \times 100$$

where, m = Dry mass of fruit after osmosis, m_0 = Initial dry mass of fresh fruit prior to osmosis

3.1.3.1.b. ***Water Loss*** **(WL)**

Weight of fresh fruit prior to osmosis and 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

$$WL(\%) = \frac{(Wo - Wt) + (St - So)}{Wo} \times 100$$



a. Uniformly ripened Banana

b. Slicing

c. Osmotic treatment

d. Air drying

Plate 1. Osmo-air dehydration of nendran banana

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

3.1.3.1.c. *Weight Reduction* (WR)

Weight reduction 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)

3.1.3.1.d. *Ratio of Water Loss to Solid Gain* (WL/SG)

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

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

3.1.3.2. *Biochemical Parameters of Osmosed Nendran Banana Slices*

Biochemical parameters like TSS, titratable acidity, reducing sugar, total sugar, vitamin C were analysed.

3.1.3.2.a. *Total Soluble Solids* (^{o}B)

Total Soluble Solids (TSS) was recorded by using digital refractometer (Atago - 0 to 53%) and expressed in ^{0} Brix.

3.1.3.2.b. *Titratable Acidity* (%)

The method described by Ranganna (1986) was follwed to measure titratable acidity. The titratable acidity was expressed in terms of per cent citric acid equivalent using following formula.

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

3.1.3.2.c. *Reducing Sugar*

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

$$\text{Reducing sugar} = \frac{\text{Glucose Eq.(0.05) X Total volume made up (ml)}}{\text{Titre value X Weight of the pulp (g)}} \text{ X 100}$$

3.1.3.2.d. *Total Sugar*

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

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

3.1.3.2.e. *Vitamin C (mg/100g)*

The titrimetric method described by Ranganna (1986) was adopted using 2,6 dichlophenol Indophenol method.

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

3.2. DEHYDRATION OF OSMOSED NENDRAN BANANA SLICES

3.2.1. Physical Parameters of Osmo-air Dehydrated Nendran Banana Slices

Known weight of osmosed slices of banana were kept in a cabinet tray drier (Gallen Kamp hot box) (Plate 2). Banana slices were air dried at 55-60 ^{0}C temperature till the fruit slices reached 17$\pm$1% moisture content.

3.2.1.*a. Water Loss*

Water loss after dehydration was calculated as per the procedure described in 3.1.3.1.b.

3.2.1.*b. Weight Reduction*

Weight reduction after dehydration was calculated as per the 3.1.3.1.c.

3.2.1.*c. Yield*

Weight of product prepared from known fresh banana slices, were recorded in an electronic balance (Cyber Lab-0.01mg to 1000mg) and yield was calculated.

$$\text{Yield} = \frac{\text{Weight of product after drying}}{\text{Weight of product before drying}} \times 100$$

3.2.1.*d. Drying Rate (DR)*

Time required for drying the product to optimum moisture was recorded in different treatments and the drying rate was calculated by Mahendran and Prasannath (2004).

$$\text{DR} = \frac{\text{Amount of moisture removed}}{\text{Time taken X } \frac{\text{Final weight}}{100}}$$

3.2.1.*e. Rehydration*

Five gram of dehydrated 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).

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

3.2.1.*f. Shrinkage*

Sample thickness and diameter before and after drying were measured with a steel caliper. Measurements were made at six different places on each sample and total surface area was calculated before and after drying. Area measurements were done in triplicates and mean value is taken for calculation of shrinkage (%) using the procedure followed by Akonor and Tortoe (2010).

Plate 2. Cabinet drier

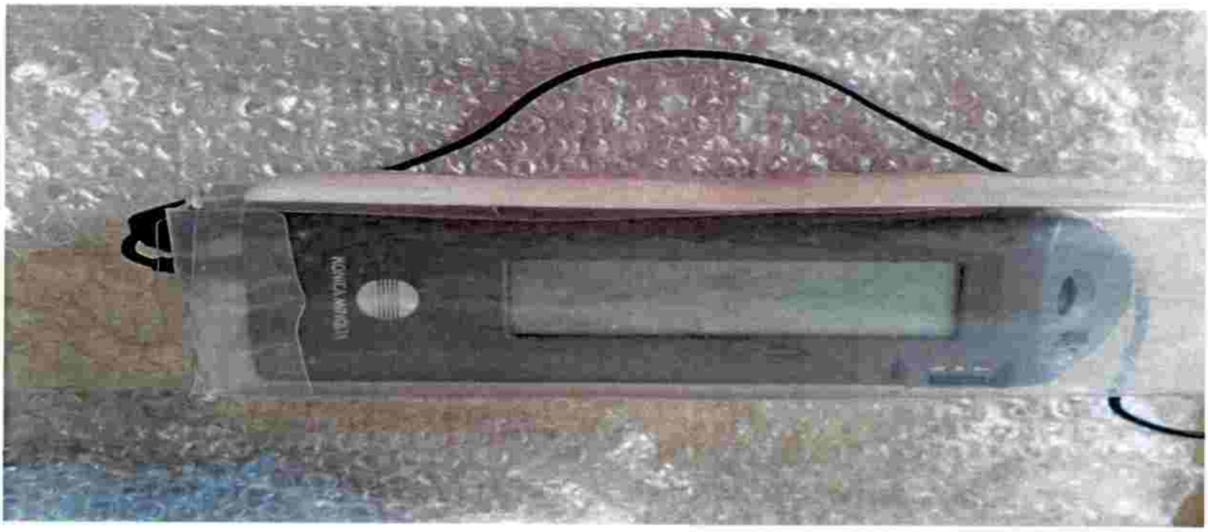


Plate 3. Konica Manolita colourimeter

$$Shrinkage = \frac{Ao - At}{Ao} \times 100$$

Where, Ao is the area of banana slice before drying and At is the diameter of prepared product.

3.2.1.*g*. *Browning Index (BI)*

Colour of the dehydrated product was recorded using Konica Minolta colourimeter (Plate 3) 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.

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

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

3.2.1.*h*. *Textural Properties*

Textural properties of the dried slices were measured using a texture analyzer TA–HD® (Stable Micro systems, Surrey, England). Following conditions/settings were adopted for the experiments, mode-force/cutting: option-return to start, prespeed = 1.5 mm/s; speed = 1 mm/s; post speed = 10 mm/s; distance = 20 mm; trigger force = 0.02 kg; acquisition rate (pps) = 20. The 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 (Plate 4). Cutting force (N) was measured by cutting the samples by fixing a HDP/BSK blade set with knife provided along with the instrument and cutting energy (Ns) of the samples was measured as area from the graph plotted with force and time as Y and X axis (Sajeev *et al.*, 2011).

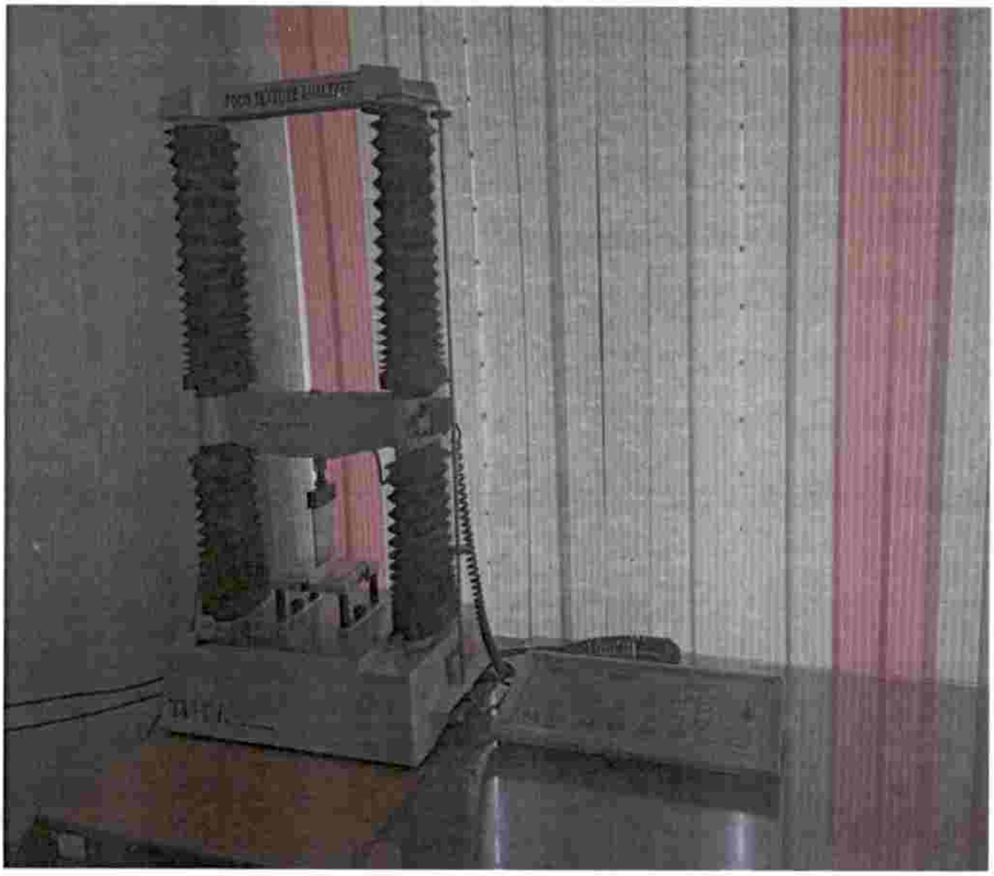


Plate 4. Food Texture analyser

Plate 5. Moisture Analyser

3.2.2. Biochemical Parameters of Osmo-air Dehydrated Nendran Banana Slices

3.2.2.a. *Titratable Acidity*

Titratable acidity after dehydration was calculated as described in 3.1.3.2.b

3.2.2.b. *Reducing Sugar*

Reducing sugar after dehydration was calculated as described in 3.1.3.2.c

3.2.2.c. *Total Sugar*

Total sugar after dehydration was calculated as described in 3.1.3.2.d

3.2.2.d. *Vitamin C*

Vitamin C after dehydration was calculated as described in 3.1.3.2.e

3.2.3. Sensory Parameters for Osmo-air Dehydrated Nendran Banana Slices

Osmo-air dehydrated banana slices prepared by different treatments were evaluated for sensory characteristics *viz.*, appearance, colour, flavour, taste, texture and overall acceptability by 40 members. Each attribute was given score from 1 to 9 according to Hedonic rating (Ranganna, 1986). Sensory analysis was carried out in different steps to obtain best ten treatments from total 81 treatments. From osmo-air dehydrated longitudinal slices of nendran banana, sensory analysis was done separately for different treatments with 5 mm, 10 mm and 15 mm thickness. The score was statistically analysed using Kruskall-Wallis test (chi-square value) and ranked (Shamrez *et al.*, 2013). From nine treatments of 5 mm thickness, best three treatments were selected and the same procedure was followed for 10 and 15 mm thickness. The best nine treatments obtained from the three thickness groups were pooled and sensory analysis was again conducted and scores were statistically analysed and best four treatments were selected for further sensory analysis. Similarly best four treatments from round and ring sliced osmo-air dehydrated nendran banana were also selected. Thus sensory analysis of selected 12 samples from the three shapes with different thickness and osmotic treatments were again conducted using hedonic scale and scores were analysed statistically and best ten treatments were selected for further storage studies.

3.3. STORARAGE STUDIES OF OSMO-AIR DEHYDRATED NENDRAN BANANA

3.3.1. Packaging and Storage

Storage potential of ten best osmo-air dehydrated banana treatments was studied. Osmo- air dried banana (50 g) packaged in PP covers (200 gauge) were sealed and labelled as per the treatments and were stored at room temperature (25 to 30^0C and RH 80 to 85%) and analysed at monthly interval for a period of 6 months in three replications.

Treatments : 10

Replication : 3

Design: CRD

3.3.2. Physical Parameters of Stored Nendran Banana Slices

3.3.2.*a*. *Rehydration Ratio*

Rehydration ratio during storage was calculated as described in 3.2.1.e

3.3.2.*b*. *Browning Index*

Browning index during storage was calculated as described in 3.2.1.g

3.3.2.*c*. *Textural Properties*

Cutting force and cutting force during storage was calculated as described in 3.2.1.h at an interval of three months.

3.3.3. Biochemical Parameters of Stored Nendran Banana Slices

3.3.3.a. *Moisture*

Moisture is measured using digital moisture meter (Plate. 5.)

3.3.3.b. *Titratable Acidity*

Titratable acidity after storage was calculated as described in 3.1.3.2.b

3.3.3.c. *Reducing Sugar*

Reducing sugar after storage was calculated as described in 3.1.3.2.c

3.3.3.d. *Total Sugar*

Total sugar after storage was calculated as described in 3.1.3.2.d

3.3.3.e. *Vitamin C*

Vitamin C after storage was calculated as described in 3.1.3.2.e

3.3.4. Evaluation of Microbial Counts During Storage

The quantitative assay of the micro flora in stored samples was carried out by serial dilution spread plate techniques. Nutrient agar and Rose Bengal agar medium were used for the enumeration of bacterial and fungal population of slices respectively.

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

3.3.5. Statistical Design

Mass transfer characters and biochemical parameters of osmosed nendran banana slices and physical and biochemical parameters of osmo-air dehydrated nendran banana slices of different treatments were recorded and analysed using RSM. Second order response surface design was fitted using SAS software (9.30 ver.). The coefficient of multiple determination was estimated and quadratic regression equation models were developed for all responses with $R^2 > 90\%$. The X_1, X_2, X_3 in the equation were uncoded as $X_1=5x$, $X_2=40+10x$, $X_3=20+20x$. Practically useful estimation of (thickness, concentration, time) for setting maximum and minimum values for various parameters was worked out.

Sensory parameters were statistically analysed using Kruskall - Wallis Chisquare test. Based on mean scores, ranking has been given and top 10 best treatments were selected for further storage studies for six months. Physical and biochemical parameters were analysed by Completely Randomized Design.

Results

4. RESULTS

The experimental data collected from the investigation on "Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)" were analysed and the results are presented in this chapter under following headings.

4.1. Osmo-air dehydration of longitudinally sliced Nendran banana

4.2. Osmo-air dehydration of round sliced Nendran banana

4.3. Osmo-air dehydration of Nendran banana rings

4.4. Storage studies on osmo-air dehydrated Nendran banana

Mass transfer characters and biochemical parameters of osmosed nendran banana slices and physical and biochemical parameters of osmo-air dehydrated nendran banana slices of different shape and thickness were recorded and second order response surface design was fitted using SAS software (9.30 ver.). The coefficient of multiple determination was estimated and quadratic regression equation models were developed for all responses with $R^2 > 90\%$. The X_1, X_2, X_3 in the equation were uncoded as X_1=5x, X_2=40+10x, X_3=20+20x. Practically useful estimation of (thickness, concentration, time) for setting maximum and minimum values for various parameters were worked out and given in the tables.

4.1. OSMO-AIR DEHYDRATION OF LONGITUDINALLY SLICED NENDRAN BANANA

4.1.1. Mass Transfer Characters of Osmosed Longitudinally Sliced Nendran Banana

Mass transfer describes the transport of mass from one point to another and is one of the main pillars in the subject of transport phenomena of osmotic dehydration. Mass transfer characters *viz.* solid gain (SG), water loss (WL), weight reduction (WR) and ratio of water loss to solid gain (WL/SG) were determined and depicted in Table 1 and optimised values are given in Table 1.1.

4.1.1.a. *Solid Gain (SG)*

Linear effect of thickness (X_1) and interaction effect of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$SG=2.29+2.08X_1-0.42X_2-0.07X_3-0.18X_{11}+0.10X_{22}-0.003X_{33}+0.16X_1X_2+0.12X_1X_3+0.13X_2X_3$$

Minimum solid gain of 4.65 % was recorded for 5.1 mm thick slices osmosed in 58.3 ^{0}B concentration for an immersion time of 57.4 minutes and maximum solid gain of 8.78 % was obtained for slices with thickness 14.25 mm, concentration 64.26 ^{0}B and immersion time of 65.6 minutes.

4.1.1.b. *Water Loss (WL)*

Linear effect of thickness (X_1), concentration (X_2) and quadratic effects of thickness and thickness(X_{11}), concentration and concentration (X_{22}) and interaction effect of concentration and time (X_2X_3) showed significance. The predictive model is

$$WL = -7.01+8.77X_1+6.52X_2+3.57X_3-0.91X_{11}-0.89X_{22}+0.03X_{33}+0.20X_1X_2+0.29X_1X_3-0.68X_2X_3$$

Minimum water loss (15.14 %) was recorded for 5.54 mm thick slices osmosed in 56.94 ^{0}B concentration for an immersion of time 53.26 minutes and maximum water loss of 29.38 % was obtained for slices with thickness 14.09 mm, concentration 62.38 ^{0}B and immersion time of 70.41 minutes.

4.1.1.c. *Weight Reduction (WR)*

Linear effect of thickness (X_1), concentration (X_2) and interaction effect of concentration and time (X_2X_3) showed significance. The predictive model for

Table 1. Regression equation coefficients for mass transfer characters of osmosed longitudinal nendran banana slices

Model	Solid Gain (SG)	Water Loss (WL)	Weight Reduction (WR)	WL/SG
Intercept	2.29**	-7.01*	-9.31**	0.33NS
Linear				
X_1 (Thickness)	2.08**	8.77**	6.69**	0.53NS
X_2 (Concentration)	-0.42NS	6.52**	6.95**	1.41**
X_3 (Time)	-0.07NS	3.57NS	3.64NS	0.76NS
Quadratic				
X_{11} (Thickness*Thickness)	-0.18NS	-0.91*	-0.73NS	-0.05NS
X_{22} (Concentration*Concentration)	0.10NS	-0.89*	0.04NS	-0.18NS
X_{33} (Time*Time)	-0.003NS	0.03NS	0.04NS	0.03NS
Interaction effect				
X_1X_2 (Thickness*concentration)	0.16*	0.20NS	0.04NS	-0.07NS
X_1X_3 (Thickness*Time)	0.12NS	0.29NS	0.17NS	-0.08NS
X_2X_3 (Concentration*Time)	0.13NS	-0.68*	-0.81*	-0.23**
R^2	98.65%	98.09%	95.81	95.17%
CV	3.68	4.72	7.45	8.49

Table 1.1. Optimization of mass transfer characters for osmosed longitudinal nendran banana slices

Solid Gain (SG) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	4.63	5.1	58.3	57.4
Maximum	8.78	14.25	64.26	65.6
Water Loss (WL) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	15.14	5.54	56.94	53.26
Maximum	29.38	14.09	62.38	70.41
Weight Reduction (WR) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	10.38	5.88	56.11	51.72
Maximum	20.73	13.83	61.56	72.42
WL/SG		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	2.92	9.02	52.51	47.32
Maximum	3.68	9.31	57.78	79.30

$WR= -9.31+6.69X_1+6.95X_2+3.64X_3-0.73X_{11}+0.04X_{22}+0.04X_{33}+0.04X_1X_2+ 0.17 X_1X_3- 0.81X_2X_3$

Minimum weight reduction of 10.38 % was recorded for 5.88 mm thick slices osmosed in 56.11 ^{0}B concentration for an immersion time of 51.72 minutes and maximum (20.73 %) was obtained for slices with thickness 13.83 mm, concentration 61.56 ^{0}B and immersion time of 72.42 minutes.

4.1.1.d. *Ratio of Water Loss to Solid Gain*

Linear effect of concentration (X_2) and interaction effect of concentration and time (X_2X_3) showed significance. The predictive model for

$WL/SG = 0.33+0.53X_1+1.41X_2+0.76X_3-0.05X_{11}-0.18X_{22}+0.03X_{33}-0.07X_1X_2-0.08X_1X_3-0.23X_2X_3$

Minimum ratio of water loss to solid gain (2.92 %) was recorded for 9.02 mm thick slices osmosed in 52.51 ^{0}B concentration for an immersion time of 47.32 minutes and maximum was 3.68 % was obtained for slices with thickness 9.31 mm, concentration 57.78 ^{0}B and immersion time of 79.30 minutes.

4.1.2. Biochemical Parameters of Osmosed Longitudinally Sliced Nendran Banana

Biochemical parameters analysed after osmosis of longitudinally sliced nendran banana is depicted in Table 2 and optimised values are given in Table 2.1.

4.1.2.a. *TSS*

Linear effect of concentration (X_2), time (X_3) and quadratic effects of concentration and concentration (X_{22}), time and time(X_{33}), and interaction effect of concentration and time (X_2X_3) showed significance. The predictive model for

$TSS=59.53+0.38X_1+4.32X_2+2.06X_3+0.05X_{11}-0.45X_{22}-0.25X_{33}+0.10X_1X_2+ 0.08X_1X_3 -0.15X_2X_3$

Minimum TSS (67.46 ^{0}B) was recorded for 8.85 mm thick slices osmosed in concentration 50.86 ^{0}B for an immersion time of 53.24 minutes and maximum of 73.10 ^{0}B was obtained for slices with thickness 12.59 mm, concentration 67.93 ^{0}B and immersion time of 66.34 minutes.

4.1.2.b. ***Acidity***

Linear effect of thickness (X_1), concentration (X_2) and quadratic effect of concentration and concentration (X_{22}) showed significance. The predictive model for

Acidity = $3.01-0.04X_1-0.15X_2+0X_3+0.003X_{11}+0.02X_{22}-0.006X_{33}-0.005X_1X_2-0.0008X_1X_3-0.004X_2X_3$

Minimum acidity of 2.56 % was recorded for 12.43 mm thick slices osmosed in 66.61 ^{0}B concentration for an immersion time of 71.4 minutes and maximum of 2.76 % was obtained for slices with thickness 8.58 mm, concentration 50.67 ^{0}B and immersion time of 55.48 minutes.

4.1.2.c. ***Reducing Sugar***

Linear effect of concentration (X_2) and quadratic effect of concentration and concentration (X_{22}), and interaction effect of concentration and time (X_2X_3) showed significance. The predictive model for

$RS=37.91+0.23X_1-1.20X_2+0.43X_3+0.07X_{11}+0.45X_{22}+0.01X_{33}+0.02X_1X_2-0.02X_1X_3+0.455X_2X_3$

Minimum reducing sugar (39.07 %) was recorded for 8.31 mm thick slices osmosed in 54.80 ^{0}B concentration for an immersion time of 44.28 minutes and maximum of 43.43 % obtained was for slices with thickness 10.86 mm, concentration 68.15 ^{0}B and immersion time of 71.04 minutes.

4.1.2.d. ***Total Sugar***

Table 2. Regression equation coefficients for biochemical parameters of osmosed longitudinal nendran banana slices

Model	TSS	Acidity	Reducing Sugar	Total Sugar	Vitamin C
Intercept	59.53**	3.01**	37.91**	54.73**	42.1**
Linear					
X_1 (Thickness)	0.38NS	-0.04**	0.23NS	-0.22NS	0.42NS
X_2 (Concentration)	4.32**	-0.15**	-1.20**	-9.04**	-2.38**
X_3 (Time)	2.06**	0NS	0.43NS	-4.24**	-1.11*
Quadratic					
X_{11} (Thickness*Thickness)	0.05NS	0.003NS	0.07NS	0.06NS	0.002NS
X_{22} (Concentration* Concentration)	-0.45**	0.02**	0.45**	2.17**	0.09NS
X_{33} (Time*Time)	-0.25**	-0.006NS	0.013NS	0.66NS	0.01NS
Interaction effect					
X_1X_2 (Thickness*concentration)	0.10NS	-0.005NS	0.02NS	0.48NS	-0.01NS
X_1X_3 (Thickness*Time)	0.08NS	-0.0008NS	-0.02NS	0.13NS	0.04NS
X_2X_3 (Concentration*Time)	-0.15**	-0.004NS	0.45**	1.77**	0.03NS
R^2	99.58%	99.29%	99.12%	96.79%	99.38%
CV	0.26	0.32	0.51	1.94	0.49

Table 2.1. Optimization of biochemical parameters for osmosed longitudinal nendran banana slices

TSS (^{0}B)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	67.46	8.85	50.86	53.24
Maximum	73.10	12.59	67.93	66.34
Acidity (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	2.56	12.43	66.61	71.4
Maximum	2.76	8.58	50.67	55.48
Reducing sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	39.07	8.314	54.803	44.28
Maximum	43.43	10.86	68.152	71.04
Total sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	46.19	6.49	54.59	50.7
Maximum	56.33	10.87	68.81	68.76
Vitamin C (mg/100g)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	34.5	8.76	68.66	68.66
Maximum	38.98	11.03	51.04	52.1

Linear effect of concentration (X_2), time(X_3), quadratic effect of concentration and concentration (X_{22}) and interaction effect of concentration and time (X_2X_3) showed significance. The predictive model for

$$TS = 54.73-0.22X_1-9.04X_2-4.24X_3+0.06X_{11}+2.17X_{22}+0.66X_{33}+0.48X_1X_2+0.13X_1X_3+1.77X_2X_3$$

Minimum total sugar of 46.19 % was recorded for 6.49 mm thick slices osmosed in 54.59 ^{0}B concentration for an immersion time of 50.7 minutes and maximum total sugar of 56.33 % was obtained for slices with thickness 10.87 mm, concentration 68.81 ^{0}B and immersion time of 68.76 minutes.

4.1.2.e. *Vitamin C*

Linear effect of concentration (X_2) and time(X_3) showed significance. The predictive model for

$$\text{Vitamin C} = 42.1+0.42X_1-2.38X_2-1.11X_3+0.002X_{11}+0.09X_{22}+0.01X_{33}-0.01X_1X_2+0.04X_1X_3+0.03X_2X_3$$

Minimum vitamin C (34.5 mg/100g) was recorded for 8.76 mm thick slices osmosed in 68.66 ^{0}B concentration for an immersion time of 68.66 minutes and maximum of 38.98 mg/100g was obtained for slices with thickness 11.03 mm, concentration 51.04 ^{0}B and immersion time of 52.1 minutes.

4.1.3. Physical Parameters of Osmo-air Dehydrated Longitudinally sliced Nendran Banana

Physical parameters *viz.* water loss, weight reduction, yield, drying rate, rehydration ratio, shrinkage, browning index and texture were analysed and given in Table 3. and optimised values are depicted in Table 3.1.

4.1.3.a. *Water Loss (WL)*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) and interaction effect of thickness and concentration (X_1X_2), thickness and time (X_1X_3) showed significance. The predictive model for

$$WL = 63.318-5.865X_1-2.795X_2-1.480X_3+0.574X_{11}+0.533X_{22}+0.004X_{33}-0.521X_1X_2-0.444X_1X_3+0.302X_2X_3$$

Minimum water loss of 39.27 % was recorded for 14.47 mm thickslices osmosed in 62.25 ^{0}B concentration for an immersion time of 67.72 minutes and maximum of (51.08 %) was obtained for slices with thickness 5.13 mm, concentration 58.83 ^{0}B and immersion time of 55.96 minutes.

4.1.3.b. *Weight Reduction (WR)*

Linear effect of thickness, quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}), interaction effect of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$WR=44.578-12.267X_1-2.934X_2-1.076X_3+1.967X_{11}+1.213X_{22}-0.091X_{33}-0.914X_1X_2-0.137X_1X_3+0.482X_2X_3$$

Minimum weight reduction (17.36 %) was recorded for 14.69 mm thick slices osmosed in 59.27 ^{0}B concentration for an immersion time of 66.74 minutes and maximum of 30.82 % was obtained for slices with thickness 5.14 mm, concentration 62.32 ^{0}B and immersion time of 59.03 minutes.

4.1.3.c. *Yield*

Linear effect of thickness (X_1), quadratic effects of thickness and thickness(X_{11}), concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$Y=55.414+12.267X_1+2.948X_2+1.073X_3-1.963X_{11}-1.224X_{22}+0.094X_{33}+0.911X_1X_2+0.143X_1X_3-0.487X_2X_3$$

Minimum yield (69.17) was recorded for 5.14 mm thick slices osmosed in 62.32 ^{0}B concentration for an immersion time of 59.02 minutes and maximum yield of 82.63 was obtained for slices with thickness 14.69 mm, concentration 59.27 ^{0}B and immersion time of 66.74 minutes.

4.1.3.d. *Drying Rate*

Minimum drying rate of 1.57 was recorded for 12.39 mm thick slices osmosed in 52.29 ^{0}B concentration for an immersion time of 51.54 minutes and maximum of 2.07 was obtained for slices with thickness 5.01 mm, concentration 59.83 ^{0}B and immersion time of 61.56 minutes.

4.1.3.e. *Rehydration Ratio*

Linear effect of thickness (X_1), concentration (X_2), time (X_3) showed significance. The predictive model for

$$RR = 2.999-0.105X_1-0.081X_2-0.103X_3-0.004X_{11}-0.014X_{22}+0.002X_3+0.009X_1X_2+0.0008X_1X_3+0.001X_2X_3$$

Minimum rehydration ratio (2.24) was recorded for 12.9 mm thick slices osmosed in 66.42 ^{0}B concentration for an immersion time of 69.94 minutes and maximum (2.58) was obtained for slices with thickness 6.97mm, concentration 54.27^{0}B and immersion time of 48.92 minutes.

4.1.3.f. *Shrinkage*

Minimum shrinkage of 58.58 % was recorded for 5.38 mm thick slices osmosed in 56.23 ^{0}B concentration for an immersion of time 61.68 minutes and maximum of 70.37 % was obtained for slices with thickness 12.45 mm, concentration 58 ^{0}B and immersion time of 43.06 minutes.

4.1.3.g. *Browning Index*

Browning index shows the colour changes towards the brownness of the product. Linear effect of concentration (X_2), quadratic effects of concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

BI = $133.787+1.342X_1-4.198X_2+1.577X_3-0.277X_{11}+1.033X_{22}+0.301X_{33}+0.757X_1X_2-0.351X_1X_3+0.036X_2X_3$

Minimum browning index (134.67) was recorded for 6.95 mm thick slices osmosed in 57.7 ^{0}B concentration for an immersion time of 44.68 minutes and maximum of 140.70 was obtained for slices with thickness 11.48 mm, concentration 67.77 ^{0}B and immersion time of 71.08 minutes.

4.1.3.h. *Texture*

Linear effect of thickness (X_1), concentration (X_2), time (X_3) quadratic effects of thickness and thickness (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

cutting force = $-1.122+18.477X_1+2.664X_2+2.177X_3-2.151X_{11}+0.253X_{22}-0.188X_{33}-0.797X_1X_2-0.151X_1X_3-0.151X_2X_3$

Minimum cutting force (22.30 N) was recorded for 5.11 mm thick slices osmosed in 58.03 ^{0}B concentration for an immersion time 58.4 minutes and maximum 38.67 N was obtained for slices with thickness 14.71 mm, concentration 63.03 ^{0}B and immersion time of 62.82 minutes.

Linear effect of concentration (X_2) and quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) showed significance. The predictive model for

cutting energy = $31.367-0.931X_1-3.172\ X_2+1.357X_3+1.008X_{11}+0.972X_{22}-0.171X_{33}+0.207X_1X_2+0.041X_1X_3-0.087X_2X_3$

Minimum cutting energy 30.95 Ns was recorded for 5.45 mm thick slices osmosed in 57.91^{0}B concentration for an immersion time of 52.78 minutes and maximum cutting energy of 38.54 Ns was obtained for slices with thickness 14.76 mm, concentration 62.90 ^{0}B and immersion time of 61.88 minutes.

Table 3. Regression equation coefficients for physical parameters of osmo-air dehydrated longitudinal nendran banana slices

Model	Water Loss (WL)	Weight Reduction (WR)	Yield	Drying Rate	Rehydration Ratio	Shrinkage	Browning Index	Texture	
								Cutting Force	Cutting Energy
Intercept	63.318**	44.578**	55.414**	0.547**	2.999**	26.901**	133.787**	-1.122NS	31.367**
Linear									
X_1 (Thickness)	-5.865**	-12.267**	12.267**	-0.094**	-0.105**	22.681**	1.342NS	18.477**	-0.931NS
X_2 (Concentration)	-2.795**	-2.934NS	2.948NS	0.088**	-0.081*	20.647**	-4.198**	2.664**	-3.172*
X_3 (Time)	-1.480NS	-1.076NS	1.073NS	0.073**	-0.103**	-5.507NS	1.577NS	2.177**	1.357NS
Quadratic									
X_{11} (Thickness*Thickness)	0.574**	1.967**	-1.963**	0.017*	-0.004NS	-2.955**	-0.277NS	-2.151**	1.008**
X_{22} (Concentration*Concentration)	0.533**	1.213*	-1.224*	-0.016**	-0.014NS	-3.742**	1.033**	0.253NS	0.972**
X_{33} (Time*Time)	0.004NS	-0.091NS	0.094NS	-0.008NS	0.002NS	1.277NS	0.301NS	-0.188NS	-0.171NS
Interaction effect									
X_1X_2 (Thickness*concentration)	-0.521**	-0.914*	0.911*	0.007NS	0.00NS	-3.055**	0.757**	-0.797**	0.207NS
X_1X_3 (Thickness*Time)	-0.444**	-0.137NS	0.143NS	-0.001NS	0.0008NS	-0.212NS	-0.351NS	-0.151NS	0.041NS
X_2X_3 (Concentration*Time)	0.302NS	0.482NS	-0.487NS	-0.016**	0.001NS	-0.357NS	0.036NS	-0.151NS	-0.087NS
R^2	99.09%	96.89%	96.89%	89.07%	98.87%	86.18%	95.30%	99.83%	97.08%
CV	1.27	5.22	1.66	2.34	0.78	3.98	0.49	1.13	1.97

Table 3.1. Optimization of physical parameters for osmo-air dehydrated longitudinal nendran banana slices

Water loss (WL) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	39.27	14.47	62.25	67.72
Maximum	51.08	5.13	58.83	55.96
Weight reduction (WR) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	17.36	14.69	59.27	66.74
Maximum	30.82	5.14	62.32	59.03
Yield		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	69.17	5.14	62.32	59.02
Maximum	82.63	14.69	59.27	66.74
Drying rate		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	1.57	12.39	52.29	51.54
Maximum	2.07	5.015	59.83	61.56
Rehydration ratio		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	2.24	12.9	66.42	69.94
Maximum	2.58	6.97	54.27	48.92
Shrinkage		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	58.58	5.38	56.23	61.68
Maximum	70.37	12.45	58	43.06
Browning index		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	134.67	6.95	57.7	44.68
Maximum	140.70	11.48	67.77	71.08
Cutting force (N)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	22.30	5.11	58.03	58.4
Maximum	38.67	14.71	63.03	62.82
Cutting energy (Ns)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	30.95	5.45	57.91	52.78
Maximum	38.54	14.76	62.90	61.88

4.1.4. Biochemical Parameters of Osmo-air Dehydrated Longitudinally Sliced Nendran Banana

Biochemical parameters analysed after osmo-air dehydration of longitudinally sliced nendran banana is depicted in Table 4 and optimised values are given in Table 4.1.

4.1.4.a. *Acidity*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of thickness and thickness (X_{11}) and interaction effects of thickness and concentration (X_{22}) showed significance. The predictive model for

Acidity = $2.12-0.148X_1-0.123X_2-0.033X_3+0.031X_{11}+0.0083X_{22}-0.0033X_{33}-0.015X_1X_2-0.0016X_1X_3+0.0091X_2X_3$

Minimum acidity (1.50 %) was recorded for 12.09 mm thick slices osmosed in 68.7 ^{0}B concentration for an immersion time of 64.94 minutes and maximum acidity of 1.75 % was obtained for slices with thickness 7.15, concentration 52.2 and immersion time of 54.8 minutes.

4.1.4.b. *Reducing Sugar*

Linear effect of thickness (X_1), quadratic effects of thickness and thickness (X_{11}) and interaction effects of thickness and time (X_1X_3) showed significance. The predictive model for

RS = $44.57+0.75X_1-0.13X_2-0.34X_3-0.17X_{11}+0.052X_{22}+0.076X_{33}+0.078X_1X_2+0.213X_1X_3-0.01X_2X_3$

Minimum reducing sugar (45.24 %) was recorded for 5.09 mm thick slices osmosed in 58.69 ^{0}B concentration for an immersion time of 57.26 minutes and maximum of 46.91 % was obtained for slices with thickness 13.33 mm, concentration 63.29 ^{0}B and immersion time of 73.38 minutes.

Table 4. Regression equation coefficients for biochemical parameters of osmo-air dehydrated longitudinal nendran banana slices

Model	**Acidity**	**Reducing Sugar**	**Total Sugar**	**Vitamin C**
Intercept	2.12**	44.57**	49.13**	23.79**
		Linear		
X_1 (Thickness)	-0.148**	0.75**	-0.27NS	3.60**
X_2 (Concentration)	-0.123**	-0.13NS	1.42**	2.33**
X_3 (Time)	-0.033NS	-0.34NS	0.574NS	0.362NS
		Quadratic		
X_{11} (Thickness*Thickness)	0.031**	-0.17**	0.217*	-0.34**
X_{22} (Concentration* Concentration)	0.0083NS	0.052NS	-0.036NS	-0.071NS
X_{33} (Time*Time)	-0.0033NS	0.076NS	-0.036NS	0.018NS
		Interaction effect		
X_1X_2 (Thickness*concentration)	-0.015**	0.078NS	-0.311**	-0.51**
X_1X_3 (Thickness*Time)	-0.0016NS	0.213**	-0.017NS	-0.0008NS
X_2X_3 (Concentration*Time)	0.0091NS	-0.01NS	0.0133NS	-0.015NS
R^2	98.46%	97.07%	93.71%	99.04%
CV	0.98	0.31	0.43	0.52

Table 4.1. Optimization of biochemical parameters for osmo-air dehydrated longitudinal nendran slices

Acidity (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	1.50	12.09	68.7	64.94
Maximum	1.75	7.15	52.2	54.8
Reducing sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	45.24	5.09	58.69	57.26
Maximum	46.91	13.33	63.29	73.38
Total sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	51.04	9.21	51.42	5.18
Maximum	52.76	7.44	67.61	67.94
Vitamin C (mg/100g)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	30.60	6.009	54.19	56.80
Maximum	33.87	12.6	67.07	69.44

4.1.4.c. *Total Sugar*

Linear effect of concentration (X_2), quadratic effects of thickness and thickness(X_{11}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$TS = 49.13-0.27X_1+1.42X_2+0.574X_3+0.217X_{11}-0.036X_{22}-0.036X_{33}-0.311X_1X_2-0.017X_1X_3+0.0133X_2X_3$$

Minimum total sugar of 51.04 % was recorded for 9.21 mm thick slices osmosed in 51.42 ^{0}B concentration for an immersion time of 5.18 minutes and maximum total sugar of 52.76 % was obtained for slices with thickness 7.44 mm, concentration 67.61 ^{0}B and immersion time of 67.94 minutes.

4.1.4.d. *Vitamin C*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of thickness and thickness (X_{11}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$\text{Vitamin C} = 23.79+3.60X_1+2.33X_2+0.362X_3-0.34X_{11}-0.071X_{22}+0.018X_{33}-0.51X_1X_2-0.0008X_1X_3-0.015X_2X_3$$

Minimum vitamin C (30.60 mg/100g) was recorded for 6.009 mm thick slices osmosed in 54.19 ^{0}B concentration for an immersion time of 56.80 minutes and maximum of 33.87 mg/100g was obtained for slices with thickness 12.6 mm, concentration 67.07 ^{0}B and immersion time of 69.44 minutes.

4.1.5. Evaluation of Sensory Parameters for Osmo-air Dehydrated Longitudinal Nendran Banana Slices

Sensory parameters were statistically analysed using Kruskall - Wallis test and found that the treatments showed significant difference in organoleptic qualities and acceptability (Table 5)

Table 5. Evaluation of sensory parameters for osmo-air dehydrated longitudinal nendran banana slices

Treatments	Appearance		Taste		Colour		Flavour		Texture		Overall acceptability	
	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_1	8.4	1	8.53	1	8.2	1	8.53	1	8.16	1	8.4	1
T_2	3.2	5	3.63	5	3.26	5	3.56	5	3.36	5	3.26	5
T_3	4.63	4	4.9	4	4.66	4	4.83	4	4.533	4	4.66	4
T_4	7.9	2	7.9	2	7.8	2	8	2	7.8	2	7.9	2
T_5	3.03	6	3.26	6	3.06	6	3.3	6	3.3	6	3.06	6
T_6	2.73	8	2.86	7	2.86	8	3.13	8	2.96	7	2.76	8
T_7	7.66	3	7.66	3	7.5	3	7.8	3	7.56	3	7.66	3
T_8	2.86	7	2.8	8	2.7	7	3.23	7	2.93	8	2.8	7
T_9	2.46	9	2.66	9	2.36	9	2.56	9	2.53	9	2.43	9
Chisquare (KW test)	21.38**		21.29**		20.24**		19.68**		17.38**		21.87**	
T_{10}	7.56	3	7.63	3	7.16	3	7.56	3	7.46	3	7.56	3
T_{11}	8.5	1	8.73	1	8.33	1	8.53	1	8.63	1	8.53	1
T_{12}	4.76	6	4.8	6	4.3	6	4.66	6	4.53	6	4.66	6
T_{13}	5.66	5	5.86	5	5.76	5	5.76	5	5.9	4	5.76	5
T_{14}	8.43	2	8.66	2	8.3	2	8.43	2	8.2	2	8.43	2
T_{15}	2.8	8	2.96	8	2.73	8	2.7	8	2.6	8	2.7	8
T_{16}	5.96	4	6.33	4	6.26	4	6.06	4	5.76	5	6.06	4
T_{17}	3.03	7	3.13	7	3.1	7	3	7	2.8	7	3	7
T_{18}	2.36	9	2.5	9	2.56	9	2.36	9	2.46	9	2.36	9
Chisquare (KW test)	16.25**		17.64**		18.86**		21.37**		20.39**		22.48**	
T_{19}	5.8	4	6.26	4	5.933	4	5.8	4	5.9	4	5.8	4
T_{20}	8.23	1	8.5	1	8.13	1	8.23	1	8.13	1	8.23	1
T_{21}	4.23	7	4.5	7	4.13	7	4.23	7	4.3	7	4.23	7
T_{22}	5.63	5	5.6	5	5.36	6	5.63	5	5.76	5	5.63	5
T_{23}	7.83	2	8.23	2	7.83	2	7.83	2	7.73	2	7.83	2
T_{24}	7.2	3	7.63	3	7.2	3	7.2	3	7	3	7.2	3
T_{25}	5.46	6	5.86	6	5.23	5	5.46	6	5.36	6	5.46	6
T_{26}	2.1	8	2.3	8	2.23	9	2.1	8	2.43	8	2.1	8
T_{27}	2	9	2.1	9	2.26	8	2	9	2.2	9	2	9
Chi-square (KW test)	20.18**		21.37**		22.64**		24.52**		26.37**		20.25**	

Table 5.1. Selected treatments with highest acceptability for osmo-air dehydrated longitudinal nendran banana slices

Treatments	Appearance		Taste		Colour		Flavour		Texture		Overall acceptability	
	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_1	8.2	1	8.5	1	8.7	1	8.46	1	8.06	1	8.8	1
T_4	7.96	2	8.23	2	8	2	7.76	2	7.86	2	8.5	2
T_7	6.23	9	6.5	9	6.43	9	6.33	9	6.13	9	6.63	9
T_{10}	7.4	4	7.7	4	7.3	4	7.3	4	7.3	4	7.66	4
T_{11}	7.63	3	7.9	3	7.8	3	7.73	3	7.76	3	7.96	3
T_{14}	6.83	7	6.9	7	6.7	7	6.8	7	6.7	7	7.26	7
$T_{[illegible]}$	7.06	6	7.6	6	7	6	7.16	6	6.93	6	7.33	6
$T_{[illegible]}$	7.16	5	7.46	5	7.46	5	7.2	5	7.26	5	7.5	5
$T_{[illegible]}$	6.5	8	6.7	8	6.36	8	6.4	8	6.4	8	7.13	8
Chi-square (KW test)	19.96**		21.37**		22.56**		21.69**		23.67**		21.25**	

Evaluation of organoleptic qualities for osmo-air dehydrated longitudinal slices of 5 mm thickness (T_1 to T_9) showed highest mean score for appearance, taste, colour, flavour, texture and overall acceptability for the treatment T_1(8.4) followed by T_4(7.9) and T_7(7.66). Among the treatments of 10 mm thickness slices (T_{10} to T_{18}), the highest mean score was for T_{11} (8.53) followed by T_{14} (8.43) and T_{10} (7.56). Highest acceptability mean score for the treatments with 15 mm thickness treatments (T_{19} to T_{27}) was recorded by T_{20} (8.23) followed by T_{23} (7.83) and T_{24} (7.2) (plate 6).

Considering the highest scored 3 treatments from each group of thickness (5mm, 10mm, 15 mm) 9 top ranked treatments of longitudinal nendran slices were selected for further sensory analysis. Organoleptic evaluation of these treatments .(Table 5.1.) recorded significant difference in acceptability and the treatments T_1 (5mm,50 ^{0}B,40 minutes) recorded the highest overall acceptability mean score (8.8) followed by T_2 (5mm,50 ^{0}B,60 minutes), T_{11} (7.96). These 3 treatments (T_1, T_2 and T_{11}) from osmo-air dried longitudinal slices were selected for further sensory analysis studies.

4.2. OSMO-AIR DEHYDRATION OF ROUND SLICED NENDRAN BANANA

4.2.1. Mass Transfer Characters of Osmosed Round Sliced Nendran Banana

Mass transfer characters of round sliced nendran banana were determined and depicted in Table 6 and optimised values are given in Table 6.1.

4.2.1.a. *Solid Gain (SG)*

Linear effect of concentration (X_2), quadratic effects of concentration and concentration (X_2X_2) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$SG=1.83+0.54X_1-1.38X_2+0.50X_3-0.18X_{11}+0.4X_{22}-0.08X_{33}+0.18X_1X_2+0.0016X_1X_3+0.05X_2X_3$$

Minimum solid gain of 2.10 % was recorded for 7.14mm thick slices osmosed in 55.68 ^{0}B concentration for an immersion time of 46.03 minutes and maximum of 3.86 % was obtained for slices with thickness 10.88 mm, concentration 69.66 ^{0}B and immersion time of 63.78 minutes.

4.2.1.b. ***Water Loss (WL)***

Linear effect of thickness (X_1), quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$WL = -1.44+4.91X_1-1.48X_2+2.12X_3-0.86X_{11}+0.84X_{22}+0.19X_{33}+0.94X_1X_2-0.085 X_1X_3-0.30X_2X_3$$

Minimum water loss of 7.65 % was recorded for 5.83 mm thick slices osmosed in 56.32 ^{0}B concentration for an immersion time of 51.7 minutes and maximum of 18.03 % was obtained for slices with thickness 12.49mm, concentration 68.05 ^{0}B and immersion time of 66.40 minutes.

4.2.1.c. ***Weight Reduction** (WR)*

Linear effect of thickness (X_1),quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$WR = -3.27+4.37X_1-0.10X_2+1.62X_3-0.68X_{11}+0.43X_{22}+0.27X_{33}+0.76X_1X_2-0.08 X_1X_3-0.36X_2X_3$$

Minimum weight reduction (5.52 %) was recorded for 5.76 mm thick slices osmosed in 56.44 ^{0}B concentration for an immersion time of 52.10 minutes and maximum (14.35 %) was obtained for slices with thickness 12.90 mm, concentration 67.25 ^{0}B and immersion time of 67.37 minutes.

Table 6. Regression equation coefficients for mass transfer characters of osmosed round sliced nendran banana

Model	Solid Gain (SG)	Water Loss (WL)	Weight Reduction (WR)	WL / SG
Intercept	1.83*	-1.44NS	-3.27NS	-1.40NS
Linear				
X_1 (Thickness)	0.54NS	4.91**	4.37**	1.76**
X_2 (Concentration)	-1.38**	-1.48NS	-0.10NS	2.44**
X_3 (Time)	0.50NS	2.12NS	1.62NS	0.70NS
Quadratic				
X_{11} (Thickness*Thickness)	-0.18NS	-0.86*	-0.68*	-0.06NS
X_{22} (Concentration* Concentration)	0.40**	0.84**	0.43NS	-0.40**
X_{33} (Time*Time)	-0.08NS	0.19NS	0.27NS	0.096NS
Interaction effect				
X_1X_2 (Thickness*concentration)	0.18**	0.94**	0.76**	-0.16NS
X_1X_3 (Thickness*Time)	0.0016NS	-0.085NS	-0.08NS	-0.10NS
X_2X_3 (Concentration*Time)	0.05NS	-0.30NS	-0.36NS	-0.256*
R^2	92.91%	97.98	97.78%	91.22%
CV	8.74	5.90	6.82	7.68

Table 6.1. Optimization of mass transfer characters for osmosed round sliced nendran banana

Solid Gain (SG) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	2.10	7.14	55.68	46.03
Maximum	3.86	10.88	69.66	63.748
Water Loss (WL) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	7.65	5.83	56.32	51.7
Maximum	18.03	12.49	68.05	66.40
Weight Reduction (WR) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	5.52	5.76	56.44	52.10
Maximum	14.35	12.90	67.25	67.37
WL/SG		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	3.65	5.68	56.4	52.88
Maximum	5.79	14.40	58.30	68.64

4.2.1.d. *Ratio of Water Loss to Solid Gain*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of concentration and concentration (X_{22}) and interaction effects of concentration and time (X_1X_3) showed significance. The predictive model for

$$WL/SG = -1.40+1.76X_1+2.44X_2+0.70X_3-0.06X_{11}-0.40X_{22}+0.096X_{33}-0.16X_1X_2-0.10X_1X_3-0.256X_2X_3$$

Minimum ratio of water loss to solid gain 3.65 was recorded for 5.68 mm thick slices osmosed in 56.4 ^{0}B concentration for an immersion time of 52.88 minutes and maximum of 5.79 was obtained for slices with thickness 14.40 mm, concentration 58.30 ^{0}B and immersion time of 68.64 minutes.

4.2.2. Biochemical Parameters of Osmosed Round Sliced Nendran Banana

Biochemical parameters analysed after osmosis of round sliced nendran banana is depicted in Table 7 and optimised values are given in Table 7.1.

4.2.2.a. *TSS*

Linear effect of thickness (X_1), concentration (X_2), time (X_3) and quadratic effects of concentration and concentration (X_{22}) showed significance. The predictive model for

$$TSS = 58.30+0.805X_1+3.73X_2+0.78X_3+0X_{11}-0.36X_{22}+0.033X_{33}+0.025X_1X_2+0.066X_1X_3+0.075X_2X_3$$

Minimum TSS (65.12 ^{0}B) was recorded for 8.61 mm thick slices osmosed in 50.93^{0}B concentration for an immersion time of 53.6 minutes and maximum 71.01^{0}B was obtained for slices with thickness 12 mm, concentration 67.59 ^{0}B and immersion time of 70.2 minutes.

4.2.2.b. *Acidity*

Linear effect of thickness (X_1), concentration (X_2), time (X_3) and quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) showed significance. The predictive model for

Acidity = $3.15-0.07X_1-0.19X_2-0.036X_3+0.006X_{11}+0.025X_{22}-0.0016X_{33}+0X_1X_2+0.00083X_1X_3-0.0016X_2X_3$

Minimum acidity (2.57 %) was recorded for 12.25 mm thick slices osmosed in 66.9 ^oB concentration for an immersion time of 71.08 minutes and maximum 2.80 % was obtained for slices with thickness 8.36 mm, concentration 50.97 ^oB and immersion time of 54.40 minutes.

4.2.2.c. *Reducing Sugar*

Interaction effect of concentration and time (X_2X_3) showed significance. The predictive model for

RS = $34.21+0.165X_1+0.80X_2+0.621X_3+0.21X_{11}+0.218X_{22}+0.278X_{33}+0.015X_1X_2-0.15X_1X_3-0.27X_2X_3$

Minimum reducing sugar of 37.04 % was recorded for 7.80 mm thick slices osmosed in 53.05 ^0B concentration for an immersion time of 48.58 minutes and maximum of 40.30 % was obtained for slices with thickness 12.4 mm, concentration 67.3 ^0B and immersion time of 69.42 minutes.

4.2.2.d. *Total Sugar*

Linear effect of thickness (X_1), time (X_3), quadratic effects of concentration and concentration(X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

TS = $35.12+2.57X_1-0.56X_2+2.70X_3-0.057X_{11}+1.20X_{22}-0.153X_{33}-0.36X_1X_2+0.083X_1X_3+0.038X_2X_3$

Minimum total sugar of 43.33 % was recorded for 5.85 mm thick slices osmosed in 56.1 ^0B concentration for an immersion time of 51.8 minutes and

Table 7. Regression equation coefficients for biochemical parameters of osmosed round sliced nendran banana

Model	TSS	Acidity	Reducing sugar	Total Sugar	Vitamin C
Intercept	58.30**	3.15**	34.21**	35.12**	37.26**
Linear					
X_1 (Thickness)	0.805*	-0.07**	0.165NS	2.57**	0.087NS
X_2 (Concentration)	3.73**	-0.19**	0.80NS	-0.56NS	-0.193NS
X_3 (Time)	0.78*	-0.036**	0.621NS	2.70**	-0.67NS
Quadratic					
X_{11} (Thickness*Thickness)	0NS	0.006*	0.21NS	-0.057NS	0.06NS
X_{22} (Concentration* Concentration)	-0.36**	0.025**	0.218NS	1.20**	-0.35*
X_{33} (Time*Time)	0.033NS	-0.0016NS	0.278NS	-0.153NS	-0.097NS
Interaction effect					
X_1X_2 (Thickness*concentration)	0.025NS	0NS	0.015NS	-0.36*	0.069NS
X_1X_3 (Thickness*Time)	0.066NS	0.00083NS	-0.15NS	0.083NS	0.043NS
X_2X_3 (Concentration*Time)	0.075NS	-0.0016NS	-0.27*	0.038NS	0.029NS
R^2	99.61%	99.62%	94.48%	98.85%	97.25%
CV	0.27	0.27	1.06	1.08	0.90

Table 7.1. Optimization of biochemical parameters for osmosed dehydrated round sliced nendran banana

TSS (^{0}B)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	65.12	8.61	50.93	53.6
Maximum	71.01	12	67.59	70.2
Acidity (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	2.57	12.25	66.9	71.08
Maximum	2.80	8.36	50.97	54.40
Reducing Sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	37.04	7.80	53.05	48.58
Maximum	40.30	12.4	67.3	69.42
Total Sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	43.33	5.85	56.1	51.8
Maximum	52.97	11.13	69.05	67.16
Vitamin C (mg/100g)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	32.62	8.72	68.6	68.4
Maximum	36.23	11.95	53.1	47.86

maximum of 52.97 % was obtained for slices with thickness 11.13 mm, concentration 69.05 ^{0}B and immersion time of 67.16 minutes.

4.2.2.e. *Vitamin C*

Quadratic effects of concentration and concentration (X_{22}) showed significance. The predictive model for

Vitamin C = $37.26+0.087X_1-0.193X_2-0.67X_3+0.06X_{11}-0.35X_{22}-0.097X_{33}+0.069X_1X_2+0.043X_1X_3+0.029X_2X_3$

Minimum vitamin C of 32.62 mg/100g was recorded for 8.72 mm thick slices osmosed in 68.6 ^{0}B concentration for an immersion time of 68.4 minutes and maximum of 36.23 mg/100g was obtained for slices with thickness 11.95 mm, concentration 53.1 ^{0}B and immersion time of 47.86 minutes.

4.2.3. Physical Parameters of Osmo-air Dehydrated Round sliced Nendran Banana

Physical parameters *viz.* water loss, weight reduction, yield, drying rate, rehydration ratio, shrinkage, browning index and texture were analysed and given in Table 8. and optimised values are depicted in Table 8.1.

4.2.3.a. *Water Loss (WL)*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

WL = $61.167-3.742X_1+2.904X_2-1.251X_3+0.684X_{11}-0.889X_{22}+0.127X_{33}-0.653X_1X_2-0.081X_1X_3+0.09X_2X_3$

Minimum water loss of 50.55 was recorded for 12.66 mm thick slices osmosed in 68.31 ^{0}B concentration for an immersion time of 63.04 minutes and maximum of 57.46 was obtained for slices with thickness 5.19 mm, Concentration 57.93 ^{0}B and immersion time of 56.26 minutes.

4.2.3.b. *Weight Reduction (WR)*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

WR = $43.843-10.981X_1+5.212X_2+1.041X_3+1.648X_{11}-1.187X_{22}-0.036X_{33}-0.637X_1X_2-0.216X_1X_3+0.244X_2X_3$

Minimum weight reduction (28.79 %) was recorded for 14.24 mm thick slices osmosed in 64.81 ^{0}B concentration for an immersion time of 55.68 minutes and maximum of 41.50 % was obtained for slices with thickness 5.04 mm, concentration 60.31 ^{0}B and immersion time of 62.46 minutes.

4.2.3.c. *Yield*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

Yield = $55.493+10.357X_1-4.741X_2+0.327X_3-1.587X_{11}+1.061X_{22}-0.421X_3X_3+0.637X_1X_2+0.384X_1X_3-0.249X_2X_3$

Minimum yield (58.93) was recorded for 5.07mm thick slices osmosed in 60.32^{0}B concentration for an immersion time of 63.4 minutes and maximum of 71.52 was obtained was for slices with thickness 14.34mm, concentration 64.62^{0}B and immersion time of 56.52minutes.

4.2.3.d. *Drying Rate*

Linear effect of thickness (X_1), concentration (X_2), quadratic effects of concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$DR = 0.654-0.067X_1+0.066X_2+0.012X_3-0.0001X_{11}-0.014X_{22}-0.005X_{33}+0.007X_1X_2+0.0007X_1X_3-0.001X_2X_3$$

Minimum drying rate (0.57) was recorded for thickness 14.04 mm, 54.24 ^{0}B concentration and immersion time 62.32 minutes and maximum of 0.67 was obtained for slices with thickness 5.07 mm, concentration 60.92 ^{0}B and immersion time of 56.94 minutes.

4.2.3.e. *Rehydration Ratio*

Linear effect of thickness (X_1) and time (X_3) showed significance. The predictive model for

$$RR = 2.002-0.146X_1-0.044X_2-0.127X_3+0.013X_{11}-0.017X_{22}+0.005X_{33}-0.006X_1X_2-0.0008X_1X_3+0.009X_2X_3$$

Minimum rehydration ratio (1.26) was recorded for 12.84 mm thick slices osmosed in 66.91 ^{0}B concentration for an immersion time of 68.8 minutes and maximum rehydration ratio of 1.58 was obtained for slices with thickness 6.53 mm, concentration 55.23 ^{0}B and immersion time of 49.14 minutes.

4.2.3.f. *Shrinkage*

Minimum shrinkage (48.00 %) was recorded for 9.04 mm thick slices osmosed in 50.21 ^{0}B concentration for an immersion time of 58.28 minutes and maximum of 48.40 % was obtained for slices with thickness 5.73 mm, concentration 65.23 ^{0}B and immersion time of 59.6 minutes.

4.2.3.g. *Browning Index*

Linear effect of time (X_3), quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$BI=128.04+0.585X_1+0.56X_2+2.276X_3+0.513X_{11}+0.853X_{22}-0.169X_{33}-0.391X_1X_2-0.068X_1X_3+0.127X_2X_3$$

Minimum browning index (134.58) was recorded for 7.72 mm thick slices osmosed in 68.75 ^{0}B concentration for an immersion time of 63.96 minutes and maximum browning index of 143.15 was obtained for slices with thickness of 11.52 mm, concentration 57.61 ^{0}B and immersion time of 78.42 minutes.

4.2.3.h. ***Texture***

Linear effect of thickness (X_1), quadratic effects of thickness and thickness (X_{11}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$\text{cutting force} = 22.727+3.451X_1-1.654X_2+0.841X_3+1.513X_{11}+0.418X_{22}-0.138X_{33}+0.735X_1X_2-0.015X_1X_3+0.221X_2X_3$$

Minimum force of 29.40 N was recorded for 5.81 mm thick slices osmosed in 63.14 ^{0}B concentration for an immersion time of 68.96 minutes and maximum force of 51.69 N was obtained for slices with thickness 8.3 mm, Concentration 52.16 ^{0}B and immersion time of 49.58 minutes.

Linear effect of thickness (X_1) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$\text{cutting energy} = 49.885+4.845X_1-0.645X_2+0.953X_3-0.08X_{11}+0.142X_{22}+0.064X_{33}+0.392X_1X_2-0.174X_1X_3+0.05X_2X_3$$

Minimum cutting energy 56.59 Ns was recorded for 5.12 mm thick slices osmosed in 62.64 ^{0}B concentration for an immersion time of 62.22 minutes and

Table 8. Regression equation coefficients for physical parameters of osmo-air dehydrated round sliced nendran banana

Model	Water Loss (WL)	Weight Reduction (WR)	Yield	Drying Rate	Rehydration Ratio	Shrinkage	Browning Index	Texture	
								Cutting Force	Cutting Energy
Intercept	61.167**	43.843**	55.493**	0.654**	2.002**	27.444NS	128.04**	22.727**	49.885**
Linear									
X_1 (Thickness)	-3.742**	-10.981**	10.357**	-0.067**	-0.146**	-13.087NS	0.585NS	3.451**	4.845**
X_2 (Concentration)	2.904**	5.212**	-4.741**	0.066**	-0.044NS	45.994**	0.56NS	-1.654NS	-0.645NS
X_3 (Time)	-1.251NS	1.041NS	0.327NS	0.012NS	-0.127**	-4.636NS	2.276**	0.841NS	0.953NS
Quadratic									
X_{11} (Thickness*Thickness)	0.684**	1.648**	-1.587**	-0.0001NS	0.013NS	7.522NS	0.513**	1.513**	-0.08NS
X_{22} (Concentration*Concentration)	-0.889**	-1.187**	1.061**	-0.014**	-0.017NS	-3.742NS	0.853**	0.418NS	0.142NS
X_{33} (Time*Time)	0.127NS	-0.036NS	-0.421NS	-0.005NS	0.005NS	2.347NS	-0.169NS	-0.138NS	0.064NS
Interaction effect									
X_1X_2 (Thickness*concentration)	-0.653**	-0.637*	0.637**	0.007**	-0.006NS	-9.447**	-0.391**	0.735**	0.392**
X_1X_3 (Thickness*Time)	-0.081NS	-0.216NS	0.384NS	0.0007NS	-0.0008NS	-0.523NS	-0.068NS	-0.015NS	-0.174NS
X_2X_3 (Concentration*Time)	0.093NS	0.244NS	-0.249NS	-0.001NS	0.009NS	-1.789NS	0.127NS	0.221NS	0.05NS
R^2	97.57%	97.82%	98.36%	98.41%	98.57%	66.91%	99.10%	99.77%	99.60%
CV	0.96	2.86	1.26	1.10	1.38	14.35	0.30	1.36	0.54

Table 8.1. Optimization of physical parameters for osmo-air dehydrated round sliced nendran banana

Water loss (WL) (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	50.55	12.66	68.31	63.04
Maximum	57.46	5.19	57.93	56.26
Weight reduction (WR) (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	28.79	14.24	64.81	55.68
Maximum	41.50	5.040	60.31	62.46
Yield		Thickness (mm)	Concentration (°B)	
Minimum	58.93	5.07	60.32	63.4
Maximum	71.52	14.34	64.62	56.52
Drying rate		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	0.57	14.04	54.24	62.32
Maximum	0.675	5.075	60.92	56.94
Rehydration ratio		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	1.26	12.84	66.91	68.8
Maximum	1.58	6.53	55.23	49.14
Shrinkage		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	48.00	9.04	50.21	58.28
Maximum	48.40	5.73	65.23	59.6
Browning index		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	134.58	7.72	68.75	63.25
Maximum	143.15	11.52	57.61	78.42
Cutting force (N)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	29.40	5.814	63.14	68.96
Maximum	51.69	8.3	52.16	49.58
Cutting energy (Ns)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	56.59	5.2102	62.64	62.22
Maximum	66.87	14.84	62.41	60.82

maximum cutting energy of 66.87 Ns was obtained for slices with thickness 14.84mm, concentration 62.41^{0}B and immersion time of 60.82minutes.

4.2.4. Effect of Biochemical Parameters of Osmo-air Dehydrated Round Sliced Nendran Banana

Biochemical parameters analysed after osmo-air dehydration of round sliced nendran banana is depicted in Table 9 and optimised values are given in Table 9.1.

4.2.4.a. *Acidity*

Interaction effects of thickness and time (X_1X_3) showed significance. The predictive model for

$$Acidity = 1.87-0.035X_1-0.013X_2-0.026X_3+0.003X_{11}-0.003X_{22}+0.005X_{33}-0.00083X_1X_2-0.014X_1X_3-0.0058X_2X_3$$

Minimum acidity of 1.57 % was recorded for 13.13 mm thick slices osmosed in 65.23 ^{0}B concentration for an immersion time of 71.54 minutes and maximum acidity of 1.73 % was obtained for slices with thickness 6.55 mm, concentration 55.31 ^{0}B and immersion time of 48.9 minutes.

4.2.4.b. *Reducing Sugar*

Linear effect of concentration (X_2) and interaction effects of concentration and time (X_2X_3) showed significance. The predictive model for

$$RS = 42.64+0.12X_1+1.075X_2+0.621X_3+0.027X_{11}-0.10X_{22}+0.0077X_{33}+0.086X_1X_2-0.015X_1X_3-0.184X_2X_3$$

Minimum reducing sugar (44.82 %) was recorded for 8.23 mm thick slices osmosed in 51.93 ^{0}B concentration for an immersion time of 50.5 minutes and maximum of 46.17 % was obtained for slices with thickness 13.89 mm, concentration 65.82 ^{0}B and immersion time of 64.6 minutes.

4.2.4.c. *Total Sugar*

Table 9. Regression equation coefficients for biochemical parameters of osmo-air dehydrated round sliced nendran banana

Model	Acidity	Reducing Sugar	Total Sugar	Vitamin C
Intercept	1.87**	42.64**	45.60**	23.76**
Linear				
X_1 (Thickness)	-0.035NS	0.126NS	2.45**	1.383*
X_2 (Concentration)	-0.013NS	1.075**	2.15**	1.01NS
X_3 (Time)	-0.026NS	0.621NS	1.076**	0.07NS
Quadratic				
X_{11} (Thickness*Thickness)	0.003NS	0.027NS	-0.448**	-0.0077NS
X_{22} (Concentration* Concentration)	-0.003NS	-0.10NS	-0.23**	0.097NS
X_{33} (Time*Time)	0.005NS	0.0077NS	-0.056NS	0.027NS
Interaction effect				
X_1X_2 (Thickness*concentration)	-0.00083NS	0.086NS	0.124NS	-0.28**
X_1X_3 (Thickness*Time)	-0.014**	-0.015NS	-0.093NS	0.156NS
X_2X_3 (Concentration*Time)	-0.0058NS	-0.184**	-0.117NS	0.075NS
R^2	98.19%	93.66%	98.19%	95.98%
CV	0.68	0.39	0.40	1.17

Table 9.1. Optimization of biochemical parameters for osmo-air dehydrated round sliced nendran banana

Acidity (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	1.57	13.13	65.23	71.54
Maximum	1.73	6.55	55.31	48.9
Reducing sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	44.82	8.23	51.93	50.5
Maximum	46.17	13.89	65.82	64.6
Total sugar (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	51.91	7.11	52.39	54.06
Maximum	54.92	12.14	68.65	65.16
Vitamin C (mg/100g)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	27.30	6.32	53.79	54.46
Maximum	30.53	13.1	65.96	70.18

Linear effect of thickness (X_1), concentration (X_2), time (X_3) and quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) showed significance. The predictive model for

$$TS = 45.60+2.45X_1+2.15X_2+1.076X_3-0.448X_{11}-0.23X_{22}-0.056X_{33}+0.124X_1X_2-0.093X_1X_3-0.117X_2X_3$$

Minimum total sugar of 51.91 % was recorded for 7.11 mm thick slices osmosed in 52.39 ^{0}B concentration for an immersion time of 54.06 minutes and maximum of 54.92 % was obtained for slices with thickness 12.14 mm, concentration 68.65 ^{0}B and immersion time of 65.16 minutes.

4.2.4.d. *Vitamin C*

Linear effect of thickness (X_1) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$\text{Vitamin C} =23.76+1.383X_1+1.01X_2+0.07X_3-0.0077X_{11}+0.097X_{22}+0.027X_{33}-0.28X_1X_2+0.156X_1X_3+0.075X_2X_3$$

Minimum vitamin C of 27.30 mg/100g was recorded for 6.32 mm thick slices osmosed in 53.79 ^{0}B concentration for an immersion time of 54.46 minutes and maximum of 30.53 mg/100g was obtained for slices with thickness 13.1 mm, concentration 65.96 ^{0}B and immersion time of 70.18 minutes.

4.2.5. Evaluation of Sensory Parameters for Osmo-air Dehydrated Round Nendran Banana Slices

Sensory parameters were statistically analysed using Kruskall - Wallis chisquare test and found that the treatments showed significant difference in organoleptic qualities and acceptability (Table 10). Evaluation of organoleptic qualities for osmo-air dehydrated round slices of 5mm thickness (T_{28} to T_{36}) revealed that highest mean score for appearance, taste, colour, flavour, texture and over all acceptability was for the treatments T_{28} (8.16) followed by T_{31} (7.8) and T_{34} (7.76). Among the treatments of 10mm thickness slices (T_{37} to T_{45}), the

Table 10. Evaluation of sensory parameters for osmo-air dehydrated round sliced nendran banana

	Sensory parameters											
	Appearance		Taste		Colour		Flavour		Texture		Overall acceptability	
Treatments	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_{28}	8.16	1	8.6	1	8	1	8.16	1	8.3	1	8.16	1
T_{29}	6.13	6	6.13	6	6.1	6	6.13	6	6.3	6	6.13	6
T_{30}	3.8	7	3.8	7	4.13	7	3.8	7	4	7	3.8	7
T_{31}	7.8	2	8.26	2	7.83	2	7.8	2	7.9	2	7.8	2
T_{32}	6.36	5	6.36	5	6.8	5	6.36	5	6.46	5	6.36	5
T_{33}	6.5	4	7.43	4	6.16	4	6.5	4	6.9	4	6.5	4
T_{34}	7.76	3	8.1	3	7.7	3	7.76	3	7.63	3	7.76	3
T_{35}	2.7	8	3.3	8	2.56	8	2.7	8	3.1	8	2.7	8
T_{36}	2.33	9	2.4	9	2.33	9	2.33	9	2.53	9	2.33	9
Chisquare	**19.64***		**20.35****		**23.64****		**21.34****		**25.67****		**23.97****	
T_{37}	6.3	5	6.93	5	6.2	5	6.3	5	6.56	4	6.3	5
T_{38}	6.13	6	6.9	6	6.66	6	6.13	6	6.13	6	6.13	6
T_{39}	8.3	1	8.73	1	8.3	1	8.3	1	8.63	1	8.3	1
T_{40}	6	7	6.13	7	6.33	7	6	7	7.1	7	6	7
T_{41}	8.03	2	8.3	2	8.23	2	8.03	2	8.2	2	8.03	2
T_{42}	6.5	4	6.96	4	6.23	4	6.5	4	6.4	5	6.5	4
T_{43}	7.93	3	8.2	3	7.9	3	7.93	3	7.83	3	7.93	3
T_{44}	2.36	9	2.6	9	2.6	9	2.36	9	2.23	9	2.36	9
T_{45}	2.53	8	2.83	8	2.43	8	2.53	8	2.76	8	2.53	8
Chi-square	**16.38***		**17.68****		**18.45****		**19.34***		**20.67****		**21.57****	
T_{46}	8.26	1	8.26	1	8.26	1	8.26	1	8.13	1	8.26	1
T_{47}	5.733	7	5.8	7	5.86	7	5.73	7	5.83	7	5.73	7
T_{48}	6.33	5	6.46	5	6.43	5	6.33	5	6.2	5	6.33	5
T_{49}	7.93	2	8.16	2	8.06	2	7.93	2	7.8	2	7.93	2
T_{50}	6.7	4	6.93	4	6.56	4	6.7	4	6.66	4	6.7	4
T_{51}	6.1	6	6.2	6	5.96	6	6.1	6	6.3	6	6.1	6
T_{52}	7.46	3	7.86	3	7.86	3	7.46	3	7.53	3	7.46	3
T_{53}	2.26	9	2.46	9	2.13	9	2.26	9	2.36	9	2.26	9
T_{54}	2.56	8	2.86	8	2.53	8	2.56	8	2.66	8	2.56	8
Chi-square (KW test)	**23.18***		**24.56****		**20.66****		**19.45****		**18.17****		**21.54****	

Table 10.1. Selected treatments with highest acceptability for osmo-air dehydrated round sliced nendran banana

	Sensory parameters											
	Appearance		Taste		Colour		Flavour		Texture		Overall acceptability	
Treatments	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_{28}	8.36	1	8.83	1	8.36	1	8.5	1	8.43	1	8.33	1
T_{29}	7.53	4	7.9	4	7.53	4	7.56	4	7.7	4	7.53	4
T_{34}	7.13	7	7.56	7	7.13	7	7.26	7	7.43	6	7.13	7
T_{39}	8.06	2	8.6	2	8.06	2	8.46	2	8.33	2	8.06	2
T_{40}	7.76	3	8.5	3	7.76	3	8	3	7.76	3	7.76	3
T_{41}	6.73	9	6.73	9	6.73	9	6.6	9	6.6	9	6.73	9
T_{46}	7.2	6	7.63	6	7.2	6	7.33	6	7.33	7	7.2	6
T_{47}	7.4	5	7.6	5	7.4	5	7.4	5	7.56	5	7.4	5
T_{48}	7	8	7.53	8	7	8	6.96	8	7.13	8	7	8
Chi-square	**20.36****		**21.56****		**22.36****		**23.87****		**25.69****		**24.32****	

highest mean score was for T_{39} (8.3) followed by T_{41} (8.03) and T_{43} (7.93). Highest acceptability mean score for the treatments with 15mm thickness (T_{46} to T_{54}) was recorded for T_{46} (8.26) followed by T_{49} (7.93) and T_{52} (7.46). Considering the highest scored 3 treatments from each group of thickness (5mm, 10mm, 15 mm) 9 top ranked treatments of round nendran slices were selected for further sensory analysis are given in Table 10.1. Organoleptic evaluation of these treatments showed significant difference and treatment T_{28} (round, 5mm, 50^0B, 40minutes) recorded the highest overall acceptability mean score (8.33) followed by T_{39} (8.06) and T_{40} (7.76) (plate 7).

4.3. OSMO-AIR DEHYDRATION OF RING SLICED NENDRAN BANANA

4.3.1. Mass Transfer Characters of Osmosed Ring Sliced Nendran Banana

Mass transfer were determined and depicted in Table 11and optimised values are given in Table 11.1.

4.3.1.a. *Solid Gain (SG)*

Linear effect of concentration (X_2), quadratic effects of thickness and thickness (X_{11}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$SG = 0.89+0.33X_1+2.077X_2+1.10X_3+0.29X_{11}-0.06X_{22}-0.05X_{33}-0.36X_1X_2-0.16X_1X_3-0.076X_2X_3$$

Minimum solid gain of 4.94 % was recorded for 7.95 mm thick slices osmosed in 51.7 ^{0}B concentration for an immersion time of 51.8 minutes and maximum of 7.22 % was obtained for slices with thickness 13.45 mm, concentration 66.6 ^{0}B and immersion time of 65.48 minutes.

4.3.1.b. *Water Loss (WL)*

Linear effect of concentration (X_2) and quadratic effects of concentration and concentration (X_{22}) showed significance. The predictive model for

$$WL= -1.26+0.59X_1+6.55X_2+0.82X_3+0.22X_{11}-0.99X_{22}+0.15X_{33}-0.10X_1X_2+0.13X_1X_3+0.025X_2X_3$$

Minimum water loss of 8.45 % was recorded for 8.45 mm thick slices osmosed in concentration 51.09 ^{0}B for an immersion time of 53.28 minutes and maximum of 15.58 % was obtained for slices with thickness 12.95 mm, concentration 64.63 ^{0}B and immersion time of 73.08 minutes.

4.3.1.c. *Weight Reduction (WR)*

Linear effect of concentration (X_2), quadratic effects of concentration and concentration (X_{22}), time and time (X_{33}) and interaction effects of thickness and concentration (X_1X_2), thickness and time (X_1X_3) showed significance. The predictive model for

$$WR = -2.15+0.251X_1+4.47X_2-0.22X_3-0.06X_{11}-0.92X_{22}+0.20X_{33}+0.25X_1X_2+0.29X_1X_3+0.10X_2X_3$$

Minimum weight reduction (3.48 %) was recorded for 8.83 mm thick slices osmosed in 50.77 ^{0}B concentration for an immersion time of 53.28 minutes. Maximum of 8.47 % was obtained for slices with thickness 12.70 mm, concentration 63.92 ^{0}B and immersion time of 74.88 minutes.

4.3.1.d. *Ratio of Water Loss to Solid Gain (WL/SG)*

Linear effect of concentration (X_2) and quadratic effects of concentration and concentration (X_{22}) showed significance. The predictive model for

$$WL/SG = -1.60+0.73X_1+6.68X_2+0.86X_3+0.19X_{11}-1.00X_{22}+0.156X_{33}-0.12X_1X_2+0.13X_1X_3+0.0066X_2X_3$$

Minimum water loss to solid gain of 8.39 was recorded 8.46 mm for thick slices osmosed in 51.09 ^{0}B concentration for an immersion time of 53.28 minutes and maximum of 15.54 was obtained for slices with thickness 12.85 mm, concentration 64.68 ^{0}B and immersion time of 73.34 minutes.

Table 11. Regression equation coefficients for mass transfer characters of osmosed ring sliced nendran banana

Model	Solid Gain (SG)	Water Loss (WL)	Weight Reduction (WR)	WL / SG
Intercept	0.89NS	-1.26NS	-2.15**	-1.60NS
Linear				
X_1 (Thickness)	0.33NS	0.59NS	0.251NS	0.73NS
X_2 (Concentration)	2.077**	6.55**	4.47**	6.68**
X_3 (Time)	1.10NS	0.82NS	-0.27NS	0.86NS
Quadratic				
X_{11} (Thickness*Thickness)	0.29*	0.22NS	-0.06NS	0.19NS
X_{22} (Concentration* Concentration)	-0.06NS	-0.99**	-0.92**	-1.00**
X_{33} (Time*Time)	-0.05NS	0.15NS	0.20*	0.156NS
Interaction effect				
X_1X_2 (Thickness*concentration)	-0.36**	-0.10NS	0.25**	-0.12NS
X_1X_3 (Thickness*Time)	-0.16NS	0.13NS	0.29*	0.13NS
X_2X_3 (Concentration*Time)	-0.076NS	0.025NS	0.10NS	0.0066NS
R^2	93.36%	98.78%	99.04%	98.78%
CV	5.14	3.24	4.21	3.27

Table 11.1. Optimization of mass transfer characters for osmosed ring sliced nendran banana

Solid Gain (SG) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	4.94	7.95	51.7	51.8
Maximum	7.22	13.45	66.6	65.48
Water Loss (WL) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	8.45	8.45	51.09	53.28
Maximum	15.58	12.95	64.63	73.08
Weight Reduction (WR) (%)		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	3.48	8.83	50.77	53.82
Maximum	8.47	12.70	63.92	74.88
WL/SG		Thickness (mm)	Concentration (^{0}B)	Time (minutes)
Minimum	8.39	8.466	51.09	53.28
Maximum	15.54	12.85	64.68	73.34

4.3.2. Biochemical Parameters of Osmosed Ring Sliced Nendran Banana

Biochemical parameters analysed after osmosis of ring sliced nendran banana is depicted in Table 12. and optimised values are given in Table 12.1.

4.3.2.a. *TSS*

Linear effect of thickness(X_1), concentration (X_2), time (X_3), quadratic effects of time and time (X_{33}) and interaction effect of thickness and time (X_1X_3), concentration and time showed significance. The predictive model

$$TSS = 55.12+0.78X_1+2.46X_2+2.11X_3+0.122X_{11}+0.072X_{22}-0.227X_{33}+0.041X_1X_2-0.183X_1X_3+0.108X_2X_3$$

Minimum TSS of 62.26 ^{0}B was recorded for 8.5 mm thick slices osmosed in 51.1^{0}B concentration for an immersion time of 52.76 minutes and maximum TSS of 69.01 ^{0}B was obtained for slices with thickness 11.45 mm, concentration 69.14 ^{0}B and immersion time of 65.48 minutes.

4.3.2.b. *Acidity*

Linear effect of thickness (X_1), quadratic effect of thickness and thickness and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$Acidity = 2.45+0.22X_1+0.037X_2-0.026X_3-0.048X_{11}-0.0016X_{22}-0.0033X_{33}-0.047X_1X_2-0.00083X_1X_3-0.0033X_2X_3$$

Minimum acidity of 2.34 % was recorded for 14.05 mm thick slices osmosed in 65.2 ^{0}B concentration for an immersion time of 64.92 minutes and maximum of 2.58 % was obtained for slices with thickness 9.15 mm, concentration 51.9 ^{0}B and immersion time of 48.58 minutes.

4.3.2.c. *Reducing Sugar*

Linear effect of time (X_3), quadratic effects of thickness and thickness(X_{11}), concentration and concentration (X_{22}) and interaction effects of concentration and time showed significance. The predictive model for

$$RS = 33.15-0.21X_1-0.50+1.22X_3+0.177X_{11}+0.34X_{22}-0.119X_{33}+0.03X_1X_2-0.01 X_1X_3+0.221X_2X_3$$

Minimum reducing sugar of 35.06 % was recorded for 8.6 mm thick slices osmosed in 54.6 ^{0}B concentration for an immersion time of 44.04 minutes and maximum of 38.95 % was obtained for slices with thickness 11.27 mm, concentration 68.33 ^{0}B and immersion time of 69.8 minutes.

4.3.2.d. *Total Sugar*

Linear effect of thickness (X_1), concentration (X_2), time (X_3), quadratic effects of time and time (X_{33}) and interaction effect of concentration and time (X_2X_3) showed significance. The predictive model for

$$TS = 30.43+2.007X_1+3.095X_2+3.056X_3+0.0011X_{11}-0.14X_{22}-0.168X_{33}+0.005 X_1X_2+0.00083X_1X_3-0.241X_2X_3$$

Minimum total sugar of 40.92 % was recorded for 7.36mm thick slices osmosed in 53.8^{0}B concentration for an immersion time of 48.26 minutes and maximum of 47.82 % was obtained for slices with thickness 13.25 mm, concentration 65.6 ^{0}B and immersion time of 70.2 minutes.

4.3.2.e. *Vitamin C*

Quadratic effects of concentration and concentration (X_{22}) showed significance. The predictive model for

$$\text{Vitamin C} = 35.95+0.61X_1+0.068X_2-0.99X_3-0.056X_{11}-0.46X_{22}-0.034X_{33}+ 0.065X_1X_2-0.039X_1X_3+0.11X_2X_3$$

Minimum vitamin C of 31.57 mg/100g was recorded for 8.95 mm thick slices osmosed in 69.07 ^{0}B concentration for an immersion time of 67.32 minutes

Table 12. Regression equation coefficients for biochemical parameters of osmosed ring sliced nendran banana

Model	TSS	Acidity	Reducing Sugar	Total Sugar	Vitamin C
Intercept	55.12**	2.45**	33.15**	30.43**	35.95**
Linear					
X_1 (Thickness)	0.78*	0.22**	-0.21NS	2.007**	0.61NS
X_2 (Concentration)	2.46**	0.037NS	-0.50NS	3.095**	0.068NS
X_3 (Time)	2.11**	-0.026NS	1.22**	3.056**	-0.99NS
Quadratic					
X_{11} (Thickness*Thickness)	0.122NS	-0.048**	0.177*	0.0011NS	-0.056NS
X_{22} (Concentration* Concentration)	0.072NS	-0.0016NS	0.34**	-0.14NS	-0.46**
X_{33} (Time*Time)	-0.227**	-0.0033NS	-0.119NS	-0.168*	-0.034NS
Interaction effect					
X_1X_2 (Thickness*concentration)	0.041NS	-0.047**	0.03NS	0.005NS	0.065NS
X_1X_3 (Thickness*Time)	-0.183**	-0.00083NS	-0.01NS	0.00083NS	-0.039NS
X_2X_3 (Concentration*Time)	0.108*	-0.0033NS	0.221**	-0.241**	0.11NS
R^2	99.76%	97.49%	99.02%	99.73%	97.83%
CV	0.26	0.793	0.53	0.41	0.83

Table 12.1. Optimization of biochemical parameters for osmosed ring sliced nendran banana

TSS (°B)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	62.26	8.5	51.1	52.76
Maximum	69.01	11.45	69.14	65.48
Acidity (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	2.34	14.05	65.2	64.92
Maximum	2.58	9.15	51.9	48.58
Reducing sugar (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	35.06	8.6	54.6	44.04
Maximum	38.95	11.27	68.33	69.8
Total sugar (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	40.92	7.36	53.8	48.26
Maximum	47.82	13.25	65.6	70.2
Vitamin C (mg/100g)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	31.57	8.95	69.07	67.32
Maximum	35.28	11.35	53.6	45.6

and maximum of 35.28 mg/100g was obtained for slices with thickness 11.35 mm, concentration 53.6 ^{0}B and immersion time of 45.6 minutes.

4.3.3. Physical Parameters of Osmo-air Dehydrated Ring Sliced Nendran Banana

Physical parameters *viz.* water loss, weight reduction, yield, drying rate, rehydration ratio, shrinkage. Browning index, cutting force and cutting energy were analysed for ring slices and given in Table 13. and optimised values are depicted in Table 13.1.

4.3.3.a. *Water Loss (WL)*

Minimum water loss of 43.45 % was recorded for 6.61 mm thick slices osmosed in 67.35 ^{0}B concentration for an immersion time of 60.56 minutes and maximum of 58.84 % was obtained for slices with thickness 10.31 mm, concentration 57.56 ^{0}B and immersion time of 40.64 minutes. predicted model is

4.3.3.b. *Weight Reduction (WR)*

Linear effect of thickness (X_1), time (X_3) and quadratic effects of thickness and thickness (X_{11}) showed significance. The predictive model for

$$WR = 32.82+5.01X_1+1.15X_2+2.443X_3-0.503X_{11}-0.037X_{22}-0.162X_{33}-0.094X_1X_2-0.117X_1X_3-0.011X_2X_3$$

Minimum weight reduction of 42.75 % was recorded for 5.65 mm thick slices osmosed in 57.79 ^{0}B concentration for an immersion time of 51.18 minutes and maximum of 48.98 % was obtained for slices with thickness 13.82 mm, concentration 63.08 ^{0}B and immersion time of 71.30 minutes.

4.3.3.c. *Yield*

Linear effect of thickness (X_1), time (X_3) and quadratic effects of thickness and thickness (X_{11}) showed significance. The predictive model for

$$Yield = 67.06-4.84X_1-1.15X_2-2.48X_3+0.46X_{11}+0.059X_{22}+0.184X_{33}+0.095X_1X_2+0.117X_1X_3-0.02X_2X_3$$

Minimum yield of 50.99 was recorded for 13.87 mm thick slices osmosed in 62.95 ^{0}B concentration for an immersion time of 71.14 minutes and maximum of 57.21 % was obtained for slices with thickness 5.68 mm, concentration 57.82 ^{0}B and immersion time of 50.86 minutes.

4.3.3.d. *Drying Rate*

Linear effect of thickness (X_1), concentration (X_2), and quadratic effects of thickness and thickness (X_{11}), concentration and concentration (X_{22}) showed significance. The predictive model for

$$DR=0.796-0.172X_1+0.137X_2-0.0042X_3+0.029X_{11}-0.027X_{22}+0.000044X_{33}-0.0034X_1X_2+0X_1X_3-0.0001X_2X_3$$

Minimum drying rate (0.65) was recorded for 12.06 mm thick slices osmosed in 50.9 ^{0}B concentration for an immersion time of 61.1 minutes and maximum of 0.80 was obtained for slices with thickness 5.05 mm, concentration 61.36 ^{0}B and immersion time of 59.28 minutes.

4.3.3.e. *Rehydration Ratio*

Linear effect of thickness (X_1), time (X_3) and quadratic effects of concentration and concentration (X_{22}) showed significance. The predictive model for

$$RR=1.78-0.131X_1+0.025X_2-0.19X_3+0.01X_{11}-0.026X_{22}+0.018X_{33}-0.0125X_1X_2+0.015X_1X_3+0.004X_2X_3$$

Minimum rehydration ratio 1.05 was recorded for 12.27mm thick slices osmosed in 68.19^{0}B concentration for an immersion time of 66.98 minutes and maximum (1.37) was obtained for slices with thickness7.066 mm, concentration 55.93 ^{0}B and immersion time of 45.98 minutes.

4.3.3.f. *Shrinkage*

Minimum shrinkage was 63.79 % recorded for 5.84 mm thick slices osmosed in 60 ^{0}B concentration for an immersion time of 71.1 minutes and maximum shrinkage of 74.09 % was obtained for slices with thickness 10.65 mm, concentration 50.14 ^{0}B and immersion time of 57.78 minutes.

4.3.3.g. *Browning Index*

Linear effect of thickness (X_1), time (X_3) and interaction effects of thickness and concentration (X_1X_2), thickness and time (X_1X_3), concentration and time (X_2X_3) showed significance. The predictive model for

$$BI = 112.148+5.327X_1-0.034X_2+7.463X_3-0.498X_{11}+0.736X_{22}-0.445X_{33}+0.702X_1X_2-0.979X_1X_3-0.706X_2X_3$$

Minimum browning index (127.74) was recorded for 8.45 mm thick slices osmosed in 62.1 ^{0}B concentration for an immersion time of 78.28 minutes and maximum of 137.65 was obtained for slices with thickness 14.61 mm, concentration 63.8 ^{0}B and immersion time of 60.78 minutes.

4.3.3.h. *Texture*

Minimum cutting force 42.94 N was recorded for 14.95 mm thick slices osmosed in 58.75 ^{0}B concentration for an immersion time of 58.9 minutes and maximum of 54.95 N was obtained for slices with thickness 9.37 mm, concentration 69.84 ^{0}B and immersion time of 57.6 minutes.

Linear effect of thickness (X_1) and quadratic effects of thickness and thickness (X_{11}) showed significance. The predictive model for

$$\text{cutting energy} = 7.161+10.057X_1+0.533X_2+0.857X_3+0.5562X_{11}+0.4566X_{22}+0.168X_{33}+0.25X_1X_2+0.556X_1X_3-0.738X_2X_3$$

Minimum cutting energy was 26.43 Ns recorded for 14.98 mm thick slices osmosed in 59.9 ^{0}B concentration for an immersion time of 59.82 minutes and maximum of 42.68 Ns was obtained for slices with thickness 9.19 mm, concentration 68.48 ^{0}B and immersion time of 49.92 minutes.

4.3.4. Biochemical Parameters of Osmo-air Dehydrated Ring Sliced Nendran Banana

Biochemical parameters analysed after osmo-air dehydration of ring sliced nendran banana is depicted in Table 14 and optimised values are given in Table 14.1.

4.3.4.a. *Acidity*

Linear effect of concentration (X_2), quadratic effects of concentration and concentration (X_{22}) and interaction effects of thickness and concentration (X_1X_2) showed significance. The predictive model for

$$\text{Acidity} = 1.81-0.012X_1-0.035X_2+0.0016X_3-0.0044X_{11}-0.0077X_{22}-0.0061X_{33}-0.0058X_1X_2-0.0008X_1X_3-0.0025X_2X_3$$

Minimum acidity (1.50 %) was recorded for 12.21 mm thick slices osmosed in 68.44 ^{0}B concentration for an immersion time of 66.02 minutes and maximum of 1.69 % was obtained for slices with thickness 7.82 mm, concentration 51.5 ^{0}B and immersion time of 54.06 minutes.

4.3.4.b. *Reducing Sugar*

Linear effect of thickness (X_1), concentration (X_2), time (X_3), quadratic effects of thickness and thickness (X_{11}) and interaction effect of (X_2X_3) significance. The predictive model for

$$RS = 42.16+1.111X_1+0.803X_2+0.606X_3-0.155X_{11}-0.035X_{22}-0.021X_{33}-0.061X_1X_2-0.074X_1X_3-0.079X_2X_3$$

Minimum reducing sugar (44.87 %) was recorded for 6.84 mm thick slices osmosed in 53.52 ^{0}B concentration for an immersion time of 51.46 minutes and

Table 13. Regression equation coefficients for physical parameters of osmo-air dehydrated ring sliced nendran banana

Model	Water Loss (WL)	Weight Reduction (WR)	Yield	Drying Rate (DR)	Rehydration Ratio	Shrinkage	Browning Index (BI)	Texture	
								Cutting Force	Cutting Energy
Intercept	74.05*	32.82**	67.06**	0.796**	1.78**	82.57**	112.148**	20.841**	7.161**
Linear									
X_1 (Thickness)	5.81NS	5.01**	-4.84**	-0.172**	-0.131*	6.026NS	5.327**	3.883**	10.057*
X_2 (Concentration)	-3.52NS	1.15NS	-1.15NS	0.137**	0.025NS	-18.48**	-0.034NS	-2.117**	0.533NS
X_3 (Time)	-21.31NS	2.443**	-2.48**	-0.0042NS	-0.19**	-1.46NS	7.463**	1.152NS	0.857NS
Quadratic									
X_{11} (Thickness*Thickness)	-3.01NS	-0.503**	0.46**	0.029**	0.01NS	-2.27NS	-0.498NS	0.734**	0.556**
X_{22} (Concentration*Concentration)	-2.195NS	-0.037NS	0.059NS	-0.027**	-0.026*	4.06**	0.736NS	0.689**	0.456NS
X33 (Time*Time)	5.15NS	-0.162NS	0.184NS	0.000044NS	0.018NS	-1.63NS	-0.445NS	-0.067NS	0.168NS
Interaction effect									
X_1X_2 (Thickness*concentration)	4.145NS	-0.094NS	0.095NS	-0.0034NS	-0.012NS	-0.17NS	0.702*	0.517**	0.25NS
X_1X_3 (Thickness*Time)	0.016NS	-0.117NS	0.117NS	0NS	0.015NS	2.67*	-0.979**	0.056NS	0.556NS
X_2X_3 (Concentration*Time)	0.006NS	-0.011NS	-0.02NS	-0.0001NS	0.004NS	0.944NS	-0.706*	-0.165NS	-0.738NS
R^2	35.66%	98.78%	98.55%	98.40%	96.85%	57.91%	95.38%	99.73%	88.61%
CV	17.83	0.77	0.71	1.2265	2.36	5.40	0.8203	1.2665	4.5051

Table 13.1. Optimization of physical parameters for osmo-air dehydrated ring sliced nendran banana

Water Loss (WL) (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	43.45	6.61	67.35	60.56
Maximum	58.84	10.31	57.56	40.64
Weight Reduction (WR) (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	42.75	5.65	57.79	51.18
Maximum	48.98	13.82	63.08	71.30
Yield		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	50.99	13.87	62.95	71.14
Maximum	57.21	5.68	57.82	50.86
Drying Rate		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	0.65	12.06	50.9	61.1
Maximum	0.80	5.05	61.36	59.28
Rehydration Ratio		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	1.05	12.27	68.19	66.98
Maximum	1.37	7.066	55.93	45.98
Shrinkage		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	63.79	5.84	60	71.1
Maximum	74.09	10.65	50.14	57.78
Browning Index		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	127.74	8.45	62.61	78.28
Maximum	137.65	14.61	63.8	60.78
Cutting Force (N)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	42.94	14.95	58.75	58.9
Maximum	54.95	9.37	69.84	57.6
Cutting Energy (Ns)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	26.43	14.98	59.9	59.82
Maximum	42.68	9.19	68.48	49.92

Table 14. Regression equation coefficients for biochemical parameters of osmo-air dehydrated ring sliced nendran banana

Model	Acidity	Reducing Sugar	Total Sugar	Vitamin C
Intercept	1.81**	42.16**	46.56**	22.98**
Linear				
X_1 (Thickness)	-0.012NS	1.111**	0.554**	1.915**
X_2 (Concentration)	-0.035*	0.803**	2.067**	0.71NS
X_3 (Time)	0.0016NS	0.606*	0.646**	-0.245NS
Quadratic				
X_{11} (Thickness*Thickness)	-0.0044NS	-0.155**	-0.022NS	-0.354**
X_{22} (Concentration* Concentration)	-0.0077*	-0.035NS	-0.192**	-0.069NS
X_{33} (Time*Time)	-0.0061NS	-0.021NS	-0.036NS	0.033NS
Interaction effect				
X_1X_2 (Thickness*concentration)	-0.0058*	-0.061NS	-0.049NS	0.134NS
X_1X_3 (Thickness*Time)	-0.0008NS	-0.074NS	-0.021NS	0.326**
X_2X_3 (Concentration*Time)	-0.0025NS	-0.079*	-0.054NS	-0.005NS
R^2	99.34%	94.05%	99.27%	96.55%
CV	0.51	0.28	0.20	1.19

Table 14.1. Optimization of biochemical parameters for osmo-air dehydrated ring sliced nendran banana

Acidity (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	1.50	12.21	68.44	66.02
Maximum	1.69	7.82	51.5	54.06
Reducing sugar (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	44.87	6.84	53.52	51.46
Maximum	45.88	11.11	67.14	69.06
Total sugar (%)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	50.21	8.78	50.67	54.62
Maximum	52.59	11.59	68.86	66.72
Vitamin C (mg/100g)		Thickness (mm)	Concentration (°B)	Time (minutes)
Minimum	26.16	5.23	57.12	27.94
Maximum	29.62	13.61	64.64	70.22

maximum of 45.88 % was obtained for slices with thickness 11.11 mm, concentration 67.14 ^{0}B and immersion time of 69.06 minutes.

4.3.4.c. *Total Sugar*

Linear effect of thickness (X_1), concentration (X_2), time (X_3) and quadratic effects of concentration and concentration (X_{22}) showed significance. The predictive model for

$$TS = 46.56+0.554X_1+2.067X_2+0.646X_3-0.022X_{11}-0.192X_{22}-0.036X_{33}-0.049X_1X_2-0.021X_1X_3-0.054X_2X_3$$

Minimum total sugar (50.21 %) was recorded for 8.78 mm thick slices osmosed in 50.67 ^{0}B concentration for an immersion time of 54.62 minutes and maximum of 52.59 % was obtained for slices with thickness 11.59 mm, concentration 68.86 ^{0}B and immersion time of 66.72 minutes.

4.3.4.d. *Vitamin C*

Linear effect of thickness (X_1) quadratic effects of thickness and thickness (X_{11}) and interaction effects of thickness and time (X_1X_3) showed significance. The predictive model for

$$\text{Vitamin C} = 22.98+1.915X_1+0.71X_2-0.245X_3-0.354X_{11}-0.069X_{22}+0.033X_{33}+0.134X_1X_2+0.326X_1X_3-0.005X_2X_3$$

Minimum vitamin C (26.16 mg/100g) was recorded for 5.23 mm thick slices osmosed in 57.12 ^{0}B concentration for an immersion time of 27.94 minutes and maximum of 29.62 mg/100g was obtained for slices with thickness 13.61 mm, concentration 64.64 ^{0}B and immersion time of 70.22 minutes.

4.3.5. Evaluation of Sensory Parameters for Osmo-air Dehydrated Ring sliced Nendran Banana

Sensory parameters were statistically analysed using Kruskall - Wallis chisquare test and found that the treatments showed significant difference in

Table 15. Evaluation of sensory parameters for osmo-air dehydrated ring sliced nendran banana

	Sensory parameters											
	Appearance		Taste		Colour		Flavour		Texture		Overall acceptability	
Treatments	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_{55}	8.36	1	8.56	1	8.23	1	8.36	1	8.46	1	8.36	1
T_{56}	7.96	3	8.1	3	7.83	3	7.96	3	8.2	3	7.96	3
T_{57}	6.43	6	6.43	6	6.53	6	6.43	6	6.53	6	6.43	6
T_{58}	8.03	2	8.2	2	8.2	2	8.03	2	8.4	2	8.03	2
T_{59}	6.56	4	7.93	4	6.76	4	6.86	4	6.73	4	6.86	4
T_{60}	5.83	7	5.7	7	5.73	7	5.83	7	5.73	7	5.83	7
T_{61}	6.66	5	6.86	5	6.7	5	6.66	5	6.53	5	6.66	5
T_{62}	2.13	9	2.43	9	2.06	9	2.13	9	2.2	9	2.13	9
T_{63}	2.36	8	2.53	8	2.3	8	2.36	8	2.33	8	2.36	8
Chi-square(KW test)	22.35**		23.54**		21.36**		20.36**		21.39**		20.18**	
T_{64}	7.86	2	8	2	7.96	2	7.86	2	8	2	7.86	2
T_{65}	7.06	4	7.86	4	6.96	5	7.06	4	7.06	4	7.06	4
T_{66}	6.43	6	6.66	6	6.43	6	6.43	6	6.43	6	6.43	6
T_{67}	8.33	1	8.53	1	8.23	1	8.33	1	8.33	1	8.33	1
T_{68}	6.86	5	7.26	5	7.13	4	6.86	5	6.86	5	6.86	5
T_{69}	5.83	7	5.96	7	5.7	7	5.83	7	5.83	7	5.83	7
T_{70}	7.2	3	7.93	3	7.3	3	7.2	3	7.43	3	7.2	3
T_{71}	2.73	8	3	8	2.63	8	2.73	8	3	8	2.73	8
T_{72}	2.56	9	2.53	9	2.43	9	2.56	9	2.83	9	2.56	9
Chi-square(KW test)	16.38**		19.25**		20.34**		22.49**		23.98**		23.26**	
T_{73}	8.13	1	8.43	1	8.13	1	8.13	1	8.10	1	8.13	1
T_{74}	6.96	4	7.66	4	7.26	4	6.96	4	7.16	4	6.96	4
T_{75}	6.23	7	6.7	7	6.43	7	6.23	7	6.23	7	6.23	7
T_{76}	7.8	2	7.93	2	7.66	2	7.8	2	7.9	2	7.8	2
T_{77}	6.86	5	7	5	7.1	5	6.86	5	7.03	5	6.86	5
T_{78}	6.73	6	6.83	6	6.76	6	6.73	6	6.46	6	6.73	6
T_{79}	7.43	3	8	3	7.53	3	7.43	3	7.56	3	7.43	3
T_{80}	2.56	8	2.9	8	2.8	8	2.56	8	2.4	8	2.56	8
T_{81}	2.36	9	2.56	9	2.46	9	2.36	9	2.26	9	2.36	9
Chi-square(KW test)	20.31**		20.23**		21.38**		25.24**		21.33**		23.48**	

Table 15.1. Selected treatments with highest acceptability for osmo-air dehydrated ring sliced nendran banana

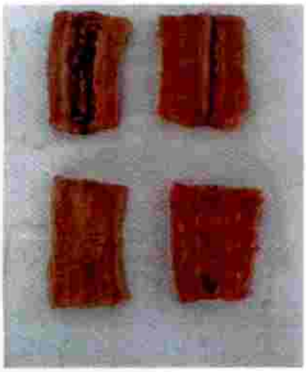
	Sensory parameters											
	Appearance		Taste		Colour		Flavour		Texture		Overall acceptability	
Treatments	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T_{55}	8.4	1	8.86	1	8.4	1	8.4	1	8.66	1	8.4	1
T_{56}	8.26	3	8.36	3	8.26	3	8.3	2	8.46	3	8.26	3
T_{57}	7.26	8	7.26	8	7.26	8	6.43	8	7.26	8	7.26	8
T_{64}	7.5	5	7.3	5	7.5	5	7.33	5	7.5	5	7.5	5
T_{65}	8.33	2	8.66	2	8.33	2	7.96	3	8.33	2	8.33	2
T_{66}	7.2	9	7.2	9	7.06	9	6.36	9	7.2	9	7.2	9
T_{71}	7.4	7	7.4	7	7.4	7	6.73	7	7.56	7	7.4	7
T_{76}	7.63	4	7.73	4	7.63	4	7.46	4	7.73	4	7.63	4
T_{78}	7.43	6	7.3	6	7.43	6	7.33	6	7.3	6	7.43	6
Chi-square (KW test)	23.64**		23.45**		22.34**		25.66**		24.31**		21.64**	

Table 16. Evaluation of sensory parameters for selected treatments with highest acceptability

	Sensory Parameters											
	Appearence		Taste		colour		Flavour		Texture		Over all acceptability	
Treatments	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank	Mean Score	Rank
T1	7.66	6	7.53	6	7.3	6	7.76	6	7.66	6	7.66	6
T2	4.26	12	4.26	12	4	12	4.26	12	4.26	12	4.26	12
T10	6.26	8	6.46	8	6.33	8	6.26	8	6.26	8	6.26	8
T19	4.96	10	5.23	10	5.16	10	4.96	10	4.96	10	4.96	10
T28	8.03	3	8.03	3	7.86	3	8.03	3	8.2	3	8.03	3
T29	7.93	4	8	4	7.6	4	7.96	4	8	4	7.93	4
T39	5.03	9	5.53	9	5.13	9	5.16	9	5.03	9	5.03	9
T46	4.43	11	4.43	11	4.3	11	4.43	11	4.43	11	4.43	11
T55	8.8	1	8.43	1	8.3	1	8.6	1	8.66	1	8.8	1
T64	8.56	2	8.23	2	8.16	2	8.36	2	8.5	2	8.56	2
T73	7.9	5	7.73	5	7.53	5	8	5	7.8	5	7.9	5
T76	6.7	7	6.93	7	6.8	7	6.86	7	6.7	7	6.7	7
Chi-square (KW test)	21.38**		22.36**		23.66**		21.36**		23.64**		24.56**	

Table 17. Selected treatments with highest acceptability for osmo-air dehydrated nendran banana

Rank	Treatments
1	T55: ring, 5 mm, 50^0 B, 40 minutes
2	T64: ring, 10 mm, 50^0 B, 40 minutes
3	T28: round, 5 mm, 50^0 B, 40 minutes
4	T29: round, 5 mm, 50^0 B, 60 minutes
5	T73: ring, 15 mm,50^0 B,40 minutes
6	T1: long, 5 mm, 50 ^{0}B, 40 minutes
7	T76: ring, 15 mm, 60 ^{0}B, 40 minutes
8	T10: long, 10 mm, 50^0 B, 40 minutes
9	T39: round, 10 mm, 50^0 B, 80 minutes
10	T19: long, 15 mm, 50^0 B, 40 minutes



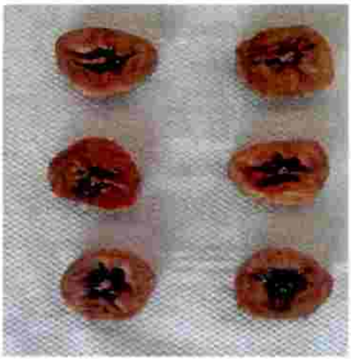
(A) 5 mm

(B) 10 mm

(C) 15 mm

Plate 6. Osmo air dried longitudinal nendran slices

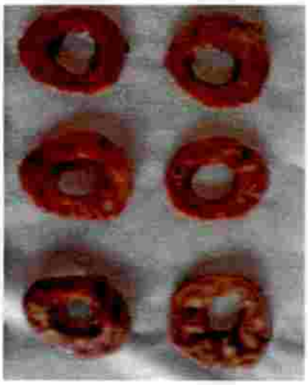
(A) 5 mm



(B) 10 mm

(C) 15 mm

Plate 7. Osmo air dried round nendran slices



(A) 5 mm

(B) 10 mm

(C) 15 mm

Plate 8. Osmo air dried nendran rings

organoleptic qualities and acceptability (Table15). Evaluation of organoleptic qualities for osmo-air dehydrated ring slices of 5mm thickness ($T_{55}$to T_{63}) showed highest mean score for appearance, taste, colour, flavour, texture and overall acceptability for the treatments T_{55} (8.36) followed by T_{58} (8.03) and T_{56} (7.96). Among the treatments of 10 mm thickness slices (T_{65} to T_{72}), the highest mean score was for T_{67} (8.33) followed by T_{64} (7.86) and T_{70} (7.2). Highest acceptability mean score for the treatments with 15 mm thickness ($T_{73}$to T_{81}) was recorded for T_{73} (8.13) followed by T_{76} (7.8) and T_{79} (7.43). Considering the highest scored 3 treatments from each group of thickness (5mm, 10mm, 15 mm) 9 top ranked treatments of ring nendran slices were selected for further sensory analysis are given in Table 15.1. Organoleptic evaluation of these treatments recorded significant difference in acceptability and the treatment T_{55} recorded the highest overall acceptability mean score (ring,5 mm,50 ^{0}B,40 minutes) followed by T_{65} (ring,10 mm,50 ^{0}B,60 minutes) with mean score of T_{65} (8.33) and T_{55} (8.4).

Twelve treatments, 4 each selected from longitudinal, round and ring were pooled and sensory studies were conducted (Table 16). The Kruskall - Wallis chisquare test confirmed the difference among the treatments and ten best treatments were selected based on the score and depicted in Table 17. The results showed that highest ranks were scored by the ring shaped slice, T_{55} with overall aceepatability score of 8.8 and T_{64} with mean score 8.56 followed by round T_{28} T_{29}. Among the thickness, 5mm thickness (T_{55}, T_{28},T_{29}) was preferred followed by 10 mm and osmotic treatment of 50 ^{0}B was found highest acceptability (plate 8).

4.4. STORAGE STUDIES ON OSMO-AIR DEHYDRATED NENDRAN BANANA

Storage stability studies of selected ten best treatments of osmo-air dehydrated nendran banana was done and effect of storage on moisture, reducing sugar, total sugar, acidity, vitamin C, rehydration ratio, browning index and textural qualities are described as below.

4.4.1. Physical Parameters of Stored Nendran Banana Slices

Physical parameters analysed after six months of storage of selected treatments of nendran banana is depicted in Table 23,24,25.

4.4.1.a. *Rehydration Ratio*

Rehydration ratio showed decreasing trend irrespective of the treatments. It decreased from 1.82 at the time of storage to 1.35 % after six months of storage. The interaction effect also showed decreasing trend from 2.80 to 0.96 and it showed that there was a significant difference between the treatments. The lowest rehydration ratio was observed for long 15 mm 50^{o} B 40 minutes (1.15) and highest was observed for round 5 mm 50^{o} B 40 minutes (2.36)

4.4.1.b. *Browning Index*

Browning index showed increasing trend irrespective of the treatments. It increased from 148.29 at the time of storage to 165.60 after six months of storage. The interaction effect also showed increasing trend from 180.56 to 198.50 and it showed that there was a significant difference between the treatments. The highest browning index was observed for long 10 mm thickness with a concentration of 50 ^{o}B and 40 minutes time (187.52) and lowest was observed for round 5 mm 50^{o} B 40 minutes (129.70)

4.4.1.c. *Textural Qualities*

During storage, textural qualities like cutting force and cutting energy showed increasing trend irrespective of the treatments. cutting force increased from 34.73 N to 41.76 N and cutting energy increased from 31.80 Ns to 39.13 Ns from zero months of storage to six months of storage. The interaction effect also showed increasing trend from 13.92 N to 63.66 N in case of cutting force and 19.47 Ns to 75.27 Ns in case of cutting energy and that there was a significant difference between the treatments.

4.4.2. Biochemical Parameters of Stored Nendran Banana Slices

Biochemical parameters analysed after six months of storage of selected treatments of nendran banana is depicted in Table 18,19,20,21,22.

4.4.2.a. ***Moisture***

During storage, moisture content showed increasing trend irrespective of the treatments. Moisture content increased from 17.51% at the time of storage to 24.61% after six months of storage.

4.4.2.b. ***Acidity***

Acidity showed decreasing trend irrespective of the treatments. Acidity decreased from 1.71% at the time of storage to 1.12% after six months of storage. The interaction effect also showed decreasing trend from 1.58% to 1.00% and it showed that there was a significant difference between the treatments. The lowest acidity was observed for ring 5 mm 50^{o} B 40 minutes (1.32%) and highest was observed for long 5 mm 50^{o} B 40 minutes (1.58%) after six months of storage

4.4.2.d. ***Reducing Sugar***

Reducing sugar was increasing during storage irrespective of the treatments. It increased from 44.95% at the time of storage to 51.19 % after six months of storage. The interaction effect also showed increasing trend from 44.11% to 51.77% and it showed that there was a significant difference between the treatments. The highest reducing sugar was observed for ring 10 mm 50^{o} B 40 minutes (48.51%) and lowest was observed for ring 15 mm 60 ^{o}B 40 minutes (47.40%)

4.4.2.e. ***Total Sugar***

Total sugar showed decreasing trend irrespective of the treatments. It was decreased from 55.91 % at the time of storage to 50.65 % after six months of storage. The interaction effect also showed decreasing trend from 53.40% to 49.20% and it showed that there was a significant difference between the

Table 18. Change in moisture content (%) of osmo-air dehydrated nendran banana during storage

Months after storage								
Treatments	0	1	2	3	4	5	6	Mean
Ring 5 mm 50^0 B 40 m	17.52	18.47	19.59	20.58	21.55	22.54	22.58	17.52a
Ring 10 mm 50^0 B 40 m	17.63	18.56	18.59	19.62	20.43	21.39	22.43	17.63a
Round 5 mm 50^0 B 40 m	17.68	18.50	19.51	20.44	21.56	22.54	23.44	17.68a
Round 5 mm 50^0 B 60 m	17.67	18.41	19.34	20.42	21.51	22.62	23.72	17.67a
Ring 15 mm 50^0 B 40 m	17.46	18.55	19.42	20.43	21.62	22.65	23.44	17.46a
Long 5 mm 50^0 B 40 m	17.67	18.58	19.44	20.57	21.50	22.35	23.60	17.67a
Ring 15 mm 60^0 B 40 m	17.36	18.69	19.83	20.50	22.42	23.64	24.81	17.36a
Long 10 mm 50^0 B 40 m	17.35	18.62	19.52	20.42	21.52	22.71	23.57	17.35a
Round 10 mm 50^0 B 80 m	17.40	18.50	19.54	20.62	21.61	22.70	23.51	17.40a
Long 15 mm 50^0 B 40 m	17.39	18.65	19.65	20.72	21.55	22.71	23.71	17.39a
Mean	17.51e	18.55de	19.44dec	20.43dc	21.47cb	23.36ab	24.61a	17.51e
CD (5%)		Between treatments (T)		Between months (M)		Interaction (T X M)		
		2.664		2.229		7.049		

Table 19. Change in acidity (%) of osmo-air dehydrated nendran banana during storage

Months after storage								
Treatments	0	1	2	3	4	5	6	Mean
Ring 5 mm 50^0 B 40 m	1.58	1.57	1.48	1.30	1.20	1.10	1.00	1.32 a
Ring 10 mm 50^0 B 40 m	1.62	1.61	1 52	1.46	1.34	.24	1.13	1 41 b
Round 5 mm 50^0 B 40 m	1.73	1.72	1.69	1.58	1.46	1.30	1.13	1.51 c
Round 5 mm 50^0 B 60 m	1.75	1.73	1.63	1.53	1.42	1.33	1.23	1.52 cd
Ring 15 mm 50^0 B 40 m	1.71	1.69	1.62	1.46	1.36	1.16	1.06	1.44 be
Long 5 mm 50^0 B 40 m	1. 7	1.76	1.71	1 61	1.55	1. 8	1.26	1.58 df
Ring 15 mm 60^0 B 40 m	1.65	1.63	1.53	1.42	1.36	1.20	1.10	1.41 e
Long 10 mm 50^0 B 40 m	1.78	1.77	1.55	1.46	1.30	1.20	1.06	1.44 cefg
Round 10 mm 50^0 B 80 m	1.72	1.70	1.61	1.51	1.36	1.26	1.13	1.47 degh
Long 15 mm 50^0 B 40 m	1 82	1.78	1. 0	1.47	1.40	1.23	1.10	1.47 efgh
Mean	1.71 a	1.69 a	1.58 b	1.48c	1.37 d	1.24e	1.12 f	
CD (5%)		Between treatments (T)		Between month (M)		Interaction (T X M)		
		0.06		0.05		0.16		

Table 20. Change in reducing sugars of osmo-air dehydrated nendran banana during storage

Months after storage								
Treatments	0	1	2	3	4	5	6	Mean
Ring 5 mm 50^0 B 40 m	44.58	46.45	47.36	48.28	49.24	50.28	51.42	48.23 cb
Ring 10 mm 50^0 B 40 m	45.23	46.28	47.31	48.66	49.74	50.57	51.77	48.51 a
Round 5 mm 50^0 B 40 m	44.19	45.32	47.37	48.17	49.60	50.28	51.31	48.03 c
Round 5 mm 50^0 B 60 m	45.23	46.57	47.23	48.28	49.30	50.47	51.60	48.39 ab
Ring 15 mm 50^0 B 40 m	45.30	46.56	47.30	48.27	49.45	50.43	51.52	48.40 ab
Long 5 mm 50^0 B 40 m	44.42	45.46	46.70	47.54	48.37	49.50	50.28	47.47 e
Ring 15 mm 60^0 B 40 m	44.11	45.29	46.50	47.27	48.61	49.62	50.38	47.40 e
Long 10 mm 50^0 B 40 m	45.50	46.18	47.39	48.52	49.58	50.72	51.70	48.51 a
Round 10 mm 50^0 B 80 m	45.43	46.69	46.44	47.21	48.48	49.74	50.53	47.79 d
Long 15 mm 50^0 B 40 m	45.56	46.77	47.30	48.39	49.38	50.48	51.38	48.46 a
Mean	44.95 g	46.16 f	47.09 e	48.06 d	49.18 c	50.21 b	51.19 a	
CD (5%)		Between treatments (T)		Between months (M)		Interaction (T X M)		
		0.331		0.227		0.659		

Table 21. Change in total sugars (%) of osmo-air dehydrated nendran banana during storage

Treatments	Months after storage 0	1	2	3	4	5	6	Mean
Ring 5 mm 50^0 B 40 m	53.40	52.39	51.72	50.67	49.50	49.30	49.20	50.88 d
Ring 10 mm 50^0 B 40 m	54.23	53.19	52.41	51.77	51.07	50.83	49.39	51.84 c
Round 5 mm 50^0 B 40 m	56.25	55.33	54.52	53.46	52.60	51.55	49.95	53.41 b
Round 5 mm 50^0 B 60 m	56.41	55.84	54.51	53.37	52.36	51.25	50.10	53.40 b
Ring 15 mm 50^0 B 40 m	56.27	56.26	55.19	54.40	53.52	51.88	51.45	54.14 a
Long 5 mm 50^0 B 40 m	56.62	55.48	54.67	54.12	53.67	52.21	51.65	54.06 a
Ring 15 mm 60 ^{0}B 40 m	56.20	55.31	54.60	53.97	53.24	52.59	50.96	53.84 ab
Long 10 mm 50^0 B 40 m	56.67	55.43	54.42	53.55	52.63	51.83	50.67	53.60 b
Round 10 mm 50^0 B 80 m	56.30	55.84	55.27	54.18	53.65	52.68	51.19	54.16 a
Long 15 mm 50^0 B 40 m	56.75	55.77	54.40	53.64	52.51	51.99	51.67	53.82 ab
Mean	55.91 a	55.10 b	54.17 c	53.31 d	52.45 e	51.60 f	50.65 g	
CD (5%)		Between treatments (T)		Between months (M)		Interaction (T X M)		
		0.672		0.56		1.77		

Table 22. Change in Vitamin C (mg/100g) of osmo-air dehydrated nendran banana during storage

Treatments	Months after storage 0	1	2	3	4	5	6	Mean
Ring 5 mm 50^0 B 40 m	25.03	23.77	22.39	21.31	20.55	19.50	18.53	21.58 g
Ring 10 mm 50^0 B 40 m	28.64	27.83	26.26	25.63	24.60	23.48	22.42	25.55 c
Round 5 mm 50^0 B 40 m	27.61	27.11	26.24	25.64	24.37	23.78	22.40	25.31 d
Round 5 mm 50^0 B 60 m	26.13	25.68	24.40	23.49	22.50	21.42	20.63	23.46 f
Ring 15 mm 50^0 B 40 m	31.05	30.10	29.09	28.52	27.27	26.55	25.46	28.29 a
Long 5 mm 50^0 B 40 m	25.33	23.82	22.86	21.32	20.26	19.47	18.51	21.57 g
Ring 15 mm 60 ^{0}B 40 m	29.36	28.11	27.38	26.32	25.35	24.28	23.50	26.31 b
Long 10 mm 50^0 B 40 m	26.89	25.88	24.62	23.40	22.33	21.38	20.27	23.54 ef
Round 10 mm 50^0 B 80 m	26.98	26.25	24.43	23.74	22.67	21.54	20.40	23.71 e
Long 15 mm 50^0 B 40 m	31.51	30.09	29.34	28.30	27.29	26.36	25.24	28.30 a
Mean	27.85a	26.86b	25.63c	24.77d	23.72e	22.78f	21.73g	
CD (5%)		Between treatments (T)		Between months (M)		Interaction (T X M)		
		1.182		0.989		3.12		

Table 23. Change in rehydration ratio of osmo-air dehydrated nendran banana during storage

Treatments	Months after storage 0	1	2	3	4	5	6	Mean
Ring 5 mm 50^0 B 40 m	2.80	2.63	2.46	2.36	2.36	2.26	2.16	2.43a
Ring 10 mm 50^0 B 40 m	2.63	2.55	2.44	2.32	2.20	2.10	1.90	2.30b
Round 5 mm 50^0 B 40 m	2.51	2.37	2.48	2.44	2.35	2.24	2.15	2.36ab
Round 5 mm 50^0 B 60 m	1.72	1.65	1.68	1.63	1.50	1.49	1.38	1.58c
Ring 15 mm 50^0 B 40 m	1.50	1.35	1.34	1.26	1.18	1.09	0.96	1.24def
Long 5 mm 50^0 B 40 m	1.46	1.46	1.40	1.33	1.27	1.15	1.00	1.29d
Ring 15 mm 60^0 B 40 m	1.46	1.38	1.36	1.31	1.21	1.10	1.03	1.27de
Long 10 mm 50^0 B 40 m	1.46	1.36	1.34	1.28	1.21	1.05	0.96	1.24def
Round 10 mm 50^0 B 80 m	1.34	1.30	1.29	1.20	1.14	0.99	0.96	1.17f
Long 15 mm 50^0 B 40 m	1.30	1.24	1.22	1.17	1.13	1.00	1.00	1.15f
Ring 5 mm 50^0 B 40 m	1.82a	1.73b	1.70b	1.63c	1.55d	1.45e	1.35f	
CD (5%)		Between treatments (T)		Between months (M)		Interaction (T X M)		
		0.249		0.208		0.659		

Table 24. Change in Browning Index of osmo-air dehydrated nendran banana during storage

	Months after storage							
Treatments	0	1	2	3	4	5	6	Mean
Ring 5 mm 50^0 B 40 m	145.45	146.42	148.40	154.41	156.28	159.68	163.02	153.38c
Ring 10 mm 50^0 B 40 m	125.57	126.42	141.93	134.45	139.37	143.96	145.54	136.75d
Round 5 mm 50^0 B 40 m	121.27	122.30	124.33	129.39	133.66	137.32	139.61	129.70d
Round 5 mm 50^0 B 60 m	132.31	133.34	135.56	138.31	145.24	149.64	198.90	133.32d
Ring 15 mm 50^0 B 40 m	127.75	179.64	180.52	186.35	188.28	193.09	198.42	179.15a
Long 5 mm 50^0 B 40 m	153.49	154.50	156.44	159.33	163.33	168.09	168.96	160.5abc
Ring 15 mm 60^0 B 40 m	152.62	153.54	155.39	160.46	165.50	167.59	169.94	160.72bc
Long 10 mm 50^0 B 40 m	180.56	181.56	183.35	186.30	189.49	195.07	196.31	187.52a
Round 10 mm 50^0 B 80 m	130.62	129.41	131.58	136.40	138.51	142.99	150.46	137.14d
Long 15 mm 50^0 B 40 m	161.39	160.40	158.44	162.38	167.29	169.37	174.16	164.77b
Mean	148.29bc	148.84bc	146.32c	154.06b	154.78b	162.24a	165.60a	
CD (5%)		Between treatments (T)		Between months (M)		Interaction (T X M)		
		14.19		11.87		37.54		

Table 25. Change in texture of osmo-air dehydrated nendran banana during storage

	Months after storage							
	Cutting force				Cutting energy			
Treatments	1	3	6	Mean	1	3	6	Mean
Ring 5 mm 50^0 B 40 m	31.30	34.50	36.83	34.21 e	35.73	40.51	42.66	39.63 b
Ring 10 mm 50^0 B 40 m	13.92	17.45	19.10	16.82 g	20.74	27.50	30.35	26.20 g
Round 5 mm 50^0 B 40 m	19.44	24.17	27.11	23.57 f	24.34	28.86	30.97	28.05 f
Round 5 mm 50^0 B 60 m	43.94	48.15	48.73	46.94 bc	67.79	70.97	75.27	71.34 a
Ring 15 mm 50^0 B 40 m	15.97	25.84	29.20	23.67 f	27.44	29.79	34.89	30.71 de
Long 5 mm 50^0 B 40 m	54.60	59.46	63.66	59.24 a	36.59	40.33	41.70	39.54 b
Ring 15 mm 60^0 B 40 m	44.02	48.04	50.28	47.45 bc	25.99	30.44	33.34	29.92 e
Long 10 mm 50^0 B 40 m	43.23	47.07	46.76	46.02 c	27.17	31.19	34.60	30.98 d
Round 10 mm 50^0 B 80 m	46.40	50.33	53.97	50.23 b	32.79	38.59	40.39	37.25 c
Long 15 mm 50^0 B 40 m	34.47	39.02	44.33	39.27 d	19.47	22.42	27.19	23.03 h
Mean	34.73 c	39.74 b	41.76 a		31.80 c	36.06 b	39.13 a	
CD (5%)								
Between treatments (T)		11.685			13.66			
Between months (M)		6.400			7.485			
Interaction (T X M)		20.23			23.66			

treatments. The lowest total sugar was observed for ring 5 mm 50^{o} B 40 minutes (50.88%) and highest was observed for long 5 mm 50^{o} B 40 minutes (54.16%)

4.4.2.f. *Vitamin C*

Vitamin C showed decreasing trend irrespective of the treatments. It decreased from 27.85 mg/100g at the time of storage to 27.73 mg/100g after six months of storage. The interaction effect also showed decreasing trend from 25.03 mg/100 g to 18.51 mg/100g and it showed that there was a significant difference between the treatments. The lowest vitamin C was observed for ring 5 mm 50^{o} B 40 minutes (21.58 mg/100g) and highest was observed for long 15 mm 50^{o} B 40 minutes (28.30 mg/100g)

4.4.3. Sensory Evaluation of Stored Nendran Banana Slices

Sensory evaluation showed significant difference in storage. Sensory qualities of the product decreased slightly towards the end of the storage. The colour of the product is the key to the success of a processed product in the market. T_{55} (ring, 5mm, 50 ^{o}B, 40 minutes) recorded highest score of 9.00 to 8.56 after six months of storage. Texture score of dehydrated banana slices had decreased with the passage of storage period. The consumers' acceptance of food product depends on many factors among which taste is a major parameter. A large number of research workers and food processors have made processed products from banana fruit which are well accepted by the people which in turn with the competitive world needs to be enhanced and that could be achieved by the mean of blending and thereby improving taste leading to higher consumers' acceptance. In case of appearance, T_{55} (ring, 5mm, 50 ^{o}B, 40 minutes) observed highest score of 8.90 to 8.26 after six months of storage. While for the taste, T_{55} (ring, 5mm, 50 ^{o}B, 40 minutes) observed the highest score of 9.00 to 8.53 after six months of storage. Flavour is the major quality parameter of food stuff. Flavour score of dehydrated banana slices had decreased with advancement of storage. For flavour, T_{55} (ring, 5mm, 50 ^{o}B, 40 minutes) recorded the highest score of 8.83 to 8.30 after six months of storage. The texture of the solid food stuff mainly depends upon on its chewing quality which is mainly determined by mouth feel. Mouth feel is considered without rupturing and not too much hard or soft. T_{55} (ring, 5mm, 50 °B, 40 minutes) recorded the highest score of 9.00 to 8.36 after six months of storage Looking to the overall acceptability of dehydrated banana slices considering appearance, colour, flavour, taste and texture were found acceptable with better shelf life. Overall acceptability score had decreased during storage in all the treatments which may be attributed by the change in chemical composition of the product and loss of colour and flavour during storage. T_{55} (ring, 5mm, 50 °B, 40 minutes) the highest score of 8.93 to 8.53 after six months of storage.

4.4.4. Microbial Evaluation of Stored Nendran Banana Slices

The osmo-dried banana slices were found microbiologically safe for 6 months storage at ambient conditions. Microbial analysis of osmodehydrated nendran banana slices revealed that no cfu was detected during the storage of 6 months at room temperature.

Table 26. Effect of storage on sensory parameters of osmo-air dehydrated nendran banana slices

Treatments	M_0 Mean Score	Rank	M_1 Mean Score	Rank	M_2 Mean Score	Rank	M_3 Mean Score	Rank	M_4 Mean Score	Rank	M_5 Mean Score	Rank	M_6 Mean Score	Rank
Appearance														
T55: ring, 5 mm, 50° B, 40 minutes	8.90	1	8.73	1	8.70	1	8.66	1	8.53	1	8.53	1	8.26	1
T64: ring, 10 mm, 50° B, 40 minutes	8.46	2	8.46	2	8.43	2	8.36	2	8.26	2	8.26	2	8.13	2
T28: round, 5 mm, 50° B, 40 minutes	8.40	3	8.30	3	8.2	3	8.03	3	8.03	3	7.86	3	7.70	3
T29: round, 5 mm, 50° B, 60 minutes	8	4	8.00	4	7.96	4	7.9	4	7.83	4	7.63	4	7.50	4
T73: ring, 15 mm,50° B,40 minutes	7.83	5	7.83	5	7.60	5	7.53	5	7.33	5	7.3	5	7.16	5
T1: long, 5 mm, 50 °B, 40 minutes	7.73	6	7.73	6	7.46	6	7.3	6	7.26	6	7.06	6	6.93	6
T76: ring, 15 mm, 60 °B, 40 minutes	7.23	7	7.1	7	7.00	7	6.73	7	6.66	7	6.66	7	6.66	7
T10: long, 10 mm, 50° B, 40 minutes	6.86	8	6.76	8	6.76	8	6.53	8	6.26	8	6.26	8	6.26	8
T39: round, 10 mm, 50° B, 80 minutes	6.03	9	5.93	9	5.80	9	5.66	9	5.23	9	5.03	9	5.03	9
T19: long, 15 mm, 50° B, 40 minutes	5.43	10	5.33	10	5.2	10	4.9	10	4.90	10	5.33	10	5.13	10
Chi-square (KW test)	21.23**		20.32**		22.36**		22.39**		24.69**		26.39*		19.36**	
Taste														
T55: ring, 5 mm, 50° B, 40 minutes	9	1	8.86	1	8.86	1	8.73	1	8.7	1	8.6	1	8.53	1
T64: ring, 10 mm, 50° B, 40 minutes	8.66	2	8.5	2	8.46	2	8.46	2	8.43	2	8.23	2	8.13	2
T28: round, 5 mm, 50° B, 40 minutes	8.4	3	8.33	3	8.2	3	8.2	3	8.03	3	7.83	3	7.43	3
T29: round, 5 mm, 50° B, 60 minutes	8	4	8	4	7.9	4	7.83	4	7.8	4	7.76	4	7.06	4
T73: ring, 15 mm,50° B,40 minutes	7.83	5	7.76	5	7.66	5	7.63	5	7.6	5	7.46	5	7.43	5
T1: long, 5 mm, 50 °B, 40 minutes	7.73	6	7.56	6	7.53	6	7.53	6	7.5	6	7.5	6	7.26	6
T76: ring, 15 mm, 60 °B, 40 minutes	6.66	7	6.53	7	6.53	7	6.46	7	6.46	7	6.36	7	6.13	7
T10: long, 10 mm, 50° B, 40 minutes	6.86	8	6.76	8	6.76	8	6.53	8	6.26	8	6.26	8	6.26	8
T39: round, 10 mm, 50° B, 80 minutes	5.86	9	5.86	9	5.86	9	5.76	9	5.53	9	5.2	9	5.03	9
T19: long, 15 mm, 50° B, 40 minutes	5.6	10	5.23	10	5.2	10	5.1	10	5.1	10	5.0	10	4.9	10
Chi-square (KW test)	22.36**		23.66**		19.63**		18.47**		19.63**		20.47**		21.36**	
Colour														
T55: ring, 5 mm, 50° B, 40 minutes	9.00	1	8.9	1	8.86	1	8.76	1	8.66	1	8.60	1	8.56	1
T64: ring, 10 mm, 50° B, 40 minutes	8.7	2	8.56	2	8.53	2	8.46	2	8.43	2	8.40	2	8.36	2
T28: round, 5 mm, 50° B, 40 minutes	8.63	3	8.5	3	8.2	3	8.01	3	8.01	3	8.03	3	7.9	3
T29: round, 5 mm, 50° B, 60 minutes	8.53	4	8.93	4	7.93	4	7.86	4	7.86	4	7.76	4	7.73	4
T73: ring, 15 mm,50° B,40 minutes	7.96	5	7.73	5	7.7	5	7.70	5	7.6	5	7.56	5	7.56	5
T1: long, 5 mm, 50° B, 40 minutes	8.03	6	7.63	6	7.53	6	7.43	6	7.23	6	7.2	6	7.16	6
T76: ring, 15 mm, 60 °B, 40 minutes	6.9	7	6.83	7	6.76	7	6.70	7	6.5	7	6.53	7	6.50	7
T10: long, 10 mm, 50° B, 40 minutes	6.73	8	6.63	8	6.53	8	6.5	8	6.40	8	6.33	8	6.20	8
T39: round, 10 mm, 50° B, 80 minutes	5.96	9	5.96	9	5.8	9	5.76	9	5.7	9	5.43	9	5.23	9
T19: long, 15 mm, 50° B, 40 minutes	5.46	10	5.33	10	5.03	10	5.03	10	5.03	10	4.96	10	4.83	10
Chi-square(KW test)	24.36**		21.56**		20.48**		19.63**		18.56**		19.56**		20.36**	

Flavour														
T55: ring, 5 mm, 50⁰ B, 40 minutes	8.83	1	8.8	1	8.80	1	8.56	1	8.53	1	8.33	1	8.3	1
T64: ring, 10 mm, 50⁰ B, 40 minutes	8.5	2	8.46	2	8.43	2	8.36	2	8.26	2	8.2	2	8.0	2
T28: round, 5 mm, 50⁰ B, 40 minutes	8.33	3	8.13	3	8.06	3	8.03	3	8.03	3	7.93	3	7.76	3
T29: round, 5 mm, 50⁰ B, 60 minutes	8.0	4	7.9	4	7.83	4	7.76	4	7.76	4	7.7	4	7.6	4
T73: ring, 15 mm,50⁰ B,40 minutes	7.83	5	7.8	5	7.73	5	7.63	5	7.60	5	7.63	5	7.6	5
T1: long, 5 mm, 50 ⁰B, 40 minutes	7.83	6	7.63	6	7.56	6	7.43	6	7.26	6	7.23	6	7.03	6
T76: ring, 15 mm, 60 ⁰B, 40 minutes	6.76	7	6.6	7	6.6	7	6.6	7	6.56	7	6.53	7	6.43	7
T10: long, 10 mm, 50⁰ B, 40 minutes	6.46	8	6.46	8	6.4	8	6.33	8	6.33	8	6.26	8	6.23	8
T39: round, 10 mm, 50⁰ B, 80 minutes	5.86	9	5.73	9	5.63	9	5.26	9	5.23	9	5.16	9	5.03	9
T19: long, 15 mm, 50⁰ B, 40 minutes	5.60	10	5.36	10	5.26	10	5.06	10	5.03	10	4.93	10	4.9	10
Chi-square(KW test)	**20.12****		**22.4****		**23.64****		**25.64****		**24.31****		**20.77****		**22.64****	
Texture														
T55: ring, 5 mm, 50⁰ B, 40 minutes	9.00	1	8.16	1	8.56	1	8.53	1	8.53	1	8.46	1	8.36	1
T64: ring, 10 mm, 50⁰ B, 40 minutes	8.66	2	8.46	2	8.23	2	8.1	2	8.00	2	7.9	2	7.9	2
T28: round, 5 mm, 50⁰ B, 40 minutes	8.03	3	7.96	3	7.96	3	7.93	3	7.86	3	7.76	3	7.56	3
T29: round, 5 mm, 50⁰ B, 60 minutes	8.00	4	7.9	4	7.83	4	7.66	4	7.56	4	7.5	4	7.43	4
T73: ring, 15 mm,50⁰ B,40 minutes	7.83	5	7.83	5	7.43	5	7.4	5	7.26	5	7.23	5	7.1	5
T1: long, 5 mm, 50⁰ B, 40 minutes	7.73	6	7.73	6	7.5	6	7.36	6	7.06	6	7.00	6	6.96	6
T76: ring, 15 mm, 60 ⁰B, 40 minutes	6.6	7	6.6	7	6.5	7	6.4	7	6.36	7	6.23	7	6.2	7
T10: long, 10 mm, 50⁰ B, 40 minutes	6.36	8	6.26	8	6.26	8	6.26	8	6.16	8	6.13	8	6.03	8
T39: round, 10 mm, 50⁰ B, 80 minutes	5.46	9	5.36	9	5.26	9	5.26	9	5.26	9	5.033	9	5.03	9
T19: long, 15 mm, 50⁰ B, 40 minutes	5.60	10	5.36	10	5.26	10	5.06	10	5.03	10	4.93	10	4.9	10
Chi-square(KW test)	**21.32****		**20.18****		**22.96****		**21.64****		**19.63****		**18.45****		**20.33****	
Overall acceptability														
T55: ring, 5 mm, 50⁰ B, 40 minutes	8.93	1	8.93	1	8.86	1	8.73	1	8.6	1	8.60	1	8.53	1
T64: ring, 10 mm, 50⁰ B, 40 minutes	8.70	2	8.46	2	8.46	2	8.43	2	8.4	2	8.40	2	8.36	2
T28: round, 5 mm, 50⁰ B, 40 minutes	8.63	3	8.33	3	8.3	3	8.20	3	8.13	3	8.20	3	8.03	3
T29: round, 5 mm, 50⁰ B, 60 minutes	8.30	4	8.16	4	8.06	4	8.00	4	8.00	4	8.00	4	7.90	4
T73: ring, 15 mm,50⁰ B,40 minutes	7.96	5	7.93	5	7.86	5	7.83	5	7.83	5	7.83	5	7.7	5
T1: long, 5 mm, 50⁰ B, 40 minutes	8.03	6	7.63	6	7.53	6	7.43	6	7.23	6	7.2	6	7.16	6
T76: ring, 15 mm, 60 ⁰B, 40 minutes	6.83	7	6.70	7	6.6	7	6.5	7	6.2	7	6.20	7	6.1	7
T10: long, 10 mm, 50⁰ B, 40 minutes	6.73	8	6.63	8	6.53	8	6.5	8	6.40	8	6.33	8	6.20	8
T39: round, 10 mm, 50⁰ B, 80 minutes	5.5	9	5.43	9	5.40	9	5.30	9	5.23	9	5.23	9	5.03	9
T19: long, 15 mm, 50⁰ B, 40 minutes	5.26	10	5.23	10	5.13	10	5.13	10	5.13	10	5.13	10	4.90	10
Chi-square(KW test)	**20.46****		**21.45****		**22.36****		**26.37****		**24.12****		**23.16****		**22.17****	

Discussion

5. DISCUSSION

The results obtained from the investigation on 'Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)' are discussed in this chapter.

5.1. OSMO-AIR DEHYDRATION OF NENDRAN BANANA

5.1.1. Mass Transfer Characters of Osmosed Nendran Banana

Mass transfer characters *viz.* solid gain, water loss, weight reduction and water loss to solid gain were optimized for different shapes and thickness of nendran banana. Second order response surface models were developed by RSM to show the relationship between the variables such as concentration of osmotic solution, slice thickness, and immersion time for longitudinal, round and ring slices of nendran banana.

Solid gain is an index of solute diffusion in to the banana slices and it increased with the increase in osmotic solution concentration, immersion time and thickness in all three shapes (longitudinal, round, ring) of nendran banana slices. The interaction effects of thickness and concentration in regression models for all shapes were significant. The contour plots of sold gain for all 3 shapes are given in Fig.1. Longitudinal slices with the thickness of 5.1mm recorded minimum solid gain of 4.63 % when immersed in osmotic concentration of 58.30 ^{0}B for 57.4 minutes. Minimum solid gain of 2.10 % for round sliced nendran banana was obtained for thickness 7.142 mm, concentration 55.689 ^{0}B with an immersion time of 46.03 minutes and for ring shaped slices it was 4.94 % for thickness 7.95 mm, concentration 51.7 ^{0}B with 51.8 minutes immersion time. The results are in conformity with Kumar and Devi (2011) for OD of pineapple which reported that higher concentration increased the solid gain and maximum SG of 14.9% was recorded after 6 h of immersion in 70°B at

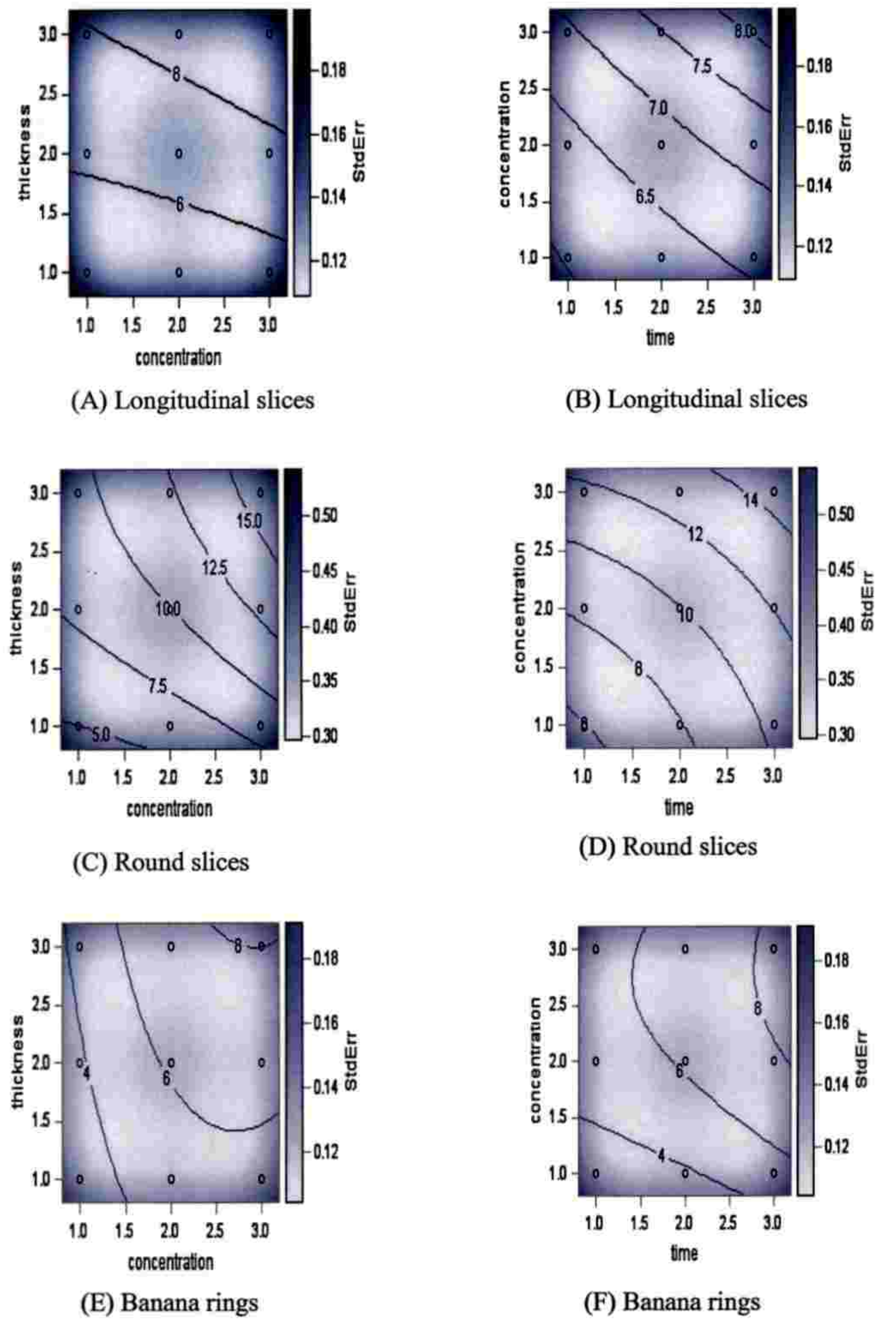


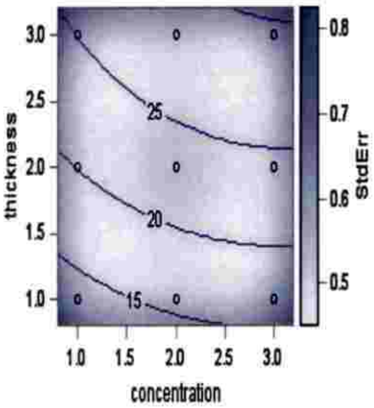
Fig. 1. Change in solid gain (%) of osmosed nendran banana

55°C while the minimum (8.8%) solid gain was recorded with minimum level of all process variables.

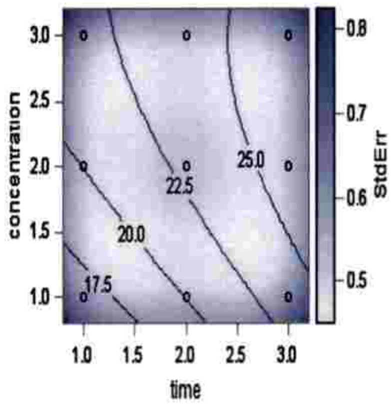
Maximum water loss of 29.38% was observed for longitudinal slices with thickness 14.09 mm, concentration 62.38° B and immersion time 70.42 minutes. Linear effect of thickness and concentration of longitudinal slices showed positive and interaction effects of concentration and thickness exhibited negative effect. For round slices, maximum WL of 18.03% with thickness 12.49 mm, concentration 68.05° B and immersion time 66.40 minutes and it was 15.58% for ring shaped slices with thickness 12.95 mm, concentration 64.63° B and immersion time 73.08 minutes and WL increased with concentration. Linear, quadratic and interaction effect models of thickness and concentration were found significant with $R^2 > 90\%$ for different shapes. The contour plots for WL for different shapes are depicted in Fig.2. Water loss increased with increase in surface area and thickness of fruit pieces and longitudinal slices reported maximum water loss. Rahman (1992) observed that it increased with the increase in syrup concentration and thickness of minimum geometric dimension. Phisut *et al*. (2012) also reported that WL and SG increased with solute concentrations. Panagiotou *et al.* (1998) observed that the size of fruit samples had a negative effect on water loss during osmotic treatment.

Maximum WR of 20.73% was recorded with thickness 13.83 mm, concentration 61.56 °B and 72.42 minutes immersion time for longitudinal slices and 14.35 % for round sliced for thickness 12.90 mm, concentration 67.25 °B with an immersion time of 67.37 minutes and for ring shaped slices it was 8.47% for thickness 12.70 mm, concentration 63.92 °B with 74.88 minutes immersion time.

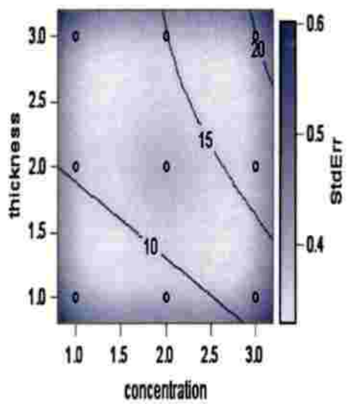
WL/SG is considered as a good indicator for maximisation of WL and minimisation of SG (Ravindra and Chattopadhyay, 2000). In the present study, WL/SG recorded a maximum of 3.68% for longitudinal slices with thickness 9.31mm, concentration 57.78° B and immersion time of 79.30 minutes and



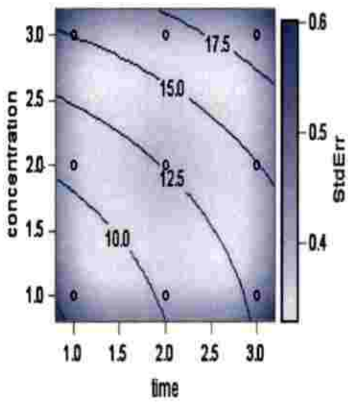
(A) Longitudinal slices



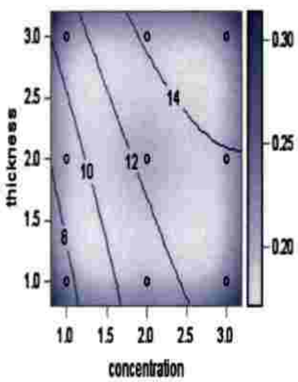
(B) Longitudinal slices



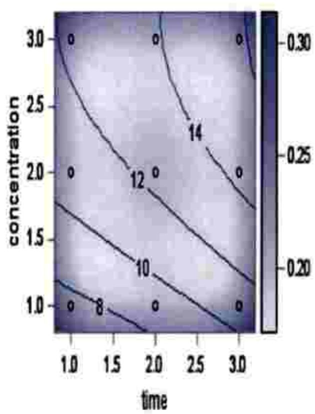
(C) Round slices



(D) Round slices



(E) Banana rings



(F) Banana rings

Fig. 2. Change in water loss (%) of osmosed nendran banana

5.79% for round slices with thickness 14.40 mm, concentration 58.30⁰ B and 68.64 minutes of immersion time and 15.54% for ring shaped slices with thickness of 12.85mm, concentration 64.68⁰ B and immersion time 73.34 minutes.

Linear effect of concentration and interaction effects of concentration and time was found influencing longitudinal slices for WL and WR. Interaction effects of thickness and concentration for SG, WL and WR were found significant for round slices. Model for linear effect of concentration was found significant for ring slices for all mass transfer characters. The higher osmotic concentration may have resulted in higher rate of WL, SG and WR and the rates also increase with immersion time. Various research workers also reported similar trend in mass transfer characters.

Several researchers reported that the kinetics of OD is affected by the shape and size of the samples due to different specific surface area or surface to thickness ratio (Islam and Flink, 1982; Lerici *et al.*, 1985; Sankat *et al.*, 1996; Rastogi *et al.*, 2002). It had been reported that increasing the sugar syrup concentration favours mass transfer characters in osmosed banana (Pointing *et al.*, 1966; Hawkes and Flink, 1978; Torreggiani, 1993; Thippanna, 2005; Mercali *et al.*, 2010) and pineapple (Beristain *et al.*, 1990; Singh, 2008; Sridevi and Genitha, 2012; Fasogban *et al.*, 2013). Increase in osmotic duration resulted in increase in SG of WL, WR and WL/SG of mango and pineapple slices (Pokharkar and Prasad, 1998; Tiwari and Jalali, 2004a and 2004b), banana (Saputra, 2001; Jalalli *et al.*, 2008; Renu, 2012) sapota (Patil *et al.*, 2013; Gupta *et al.*, 2014), and in orange (Pandharipande and Gaikar, 2015). It had also been reported by Rastogi and Raghavarao (1997), Kumar and Devi (2011), Dhingra *et al.* (2013), Khanom (2014) that mass transfer characters also depend on shapes and thickness of fruit slices.

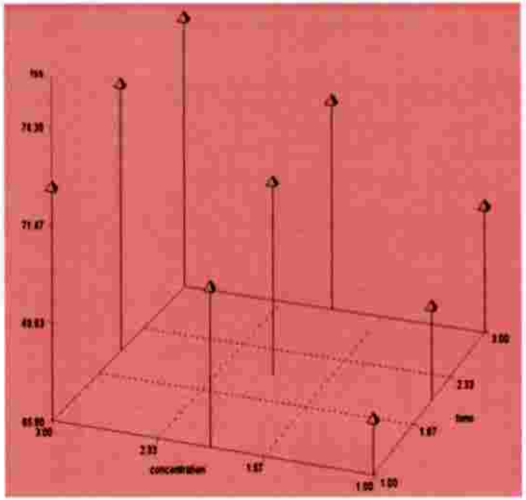
Dhingra *et al.* (2003) studied RSM in pineapple slices with different slice thickness at various osmotic concentrations and reported that kinetics strongly depended on sucrose concentration and slice thickness and WL and SG were more intensive at higher concentrations and lower slice thickness. Sutar and Sutar (2013) also reported that the tissues at different locations in the same fruit respond differently to OD.

Rahman and Lamb (1990) reported that the slice thickness had very least effect on process parameters and osmosis effect increased linearly with the increase of sugar concentration up to 60-63 %. Further increase of sugar concentration reduced the water loss that lead to sugar gain by the fruits which was not desirable The size of fruit samples had a negative effect on water loss and solute gain (Agnelli *et al.*, 2005), where the water loss and solute gain were more in apple cubes of 15 mm as compared to 20 mm during osmotic dehydration. The distance to be travelled by water to reach the fruit surface was smaller causing higher water loss in thinner slices and higher solute gain occurred due to increased flow of sucrose solution to the fruit slice Dhingra *et al.* (2013).

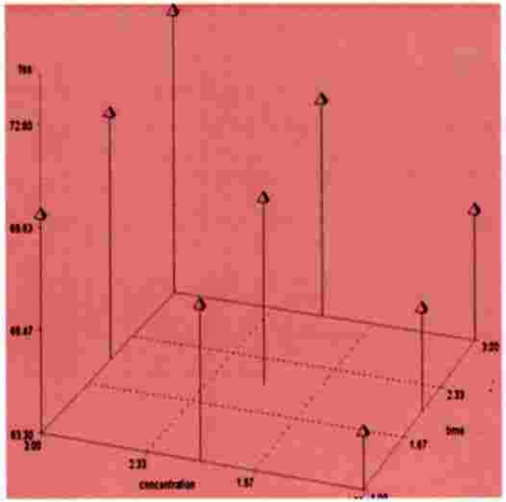
5.1.2. Biochemical Parameters of Osmosed Nendran Banana Slices

Biochemical parameters *viz.* TSS, titratable acidity, reducing sugar, total sugar and vitamin C were optimized for different shapes and thickness of nendran banana.

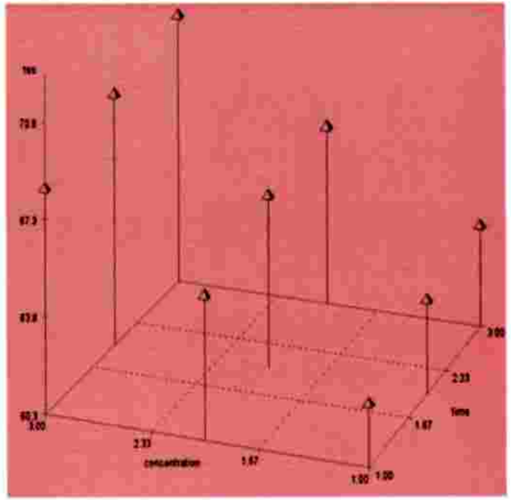
Maximum TSS of 73.10 ^{0}B was recorded with thickness 12.59 mm, concentration 67.93 ^{0}B and 66.34 minutes immersion time for longitudinal slices and 71.10 ^{0}B for round sliced for thickness 12 mm, concentration 67.59 ^{0}B with an immersion time of 70.20 minutes and for ring shaped slices it was 69.01 ^{0}B for thickness 11.45 mm, concentration 69.14 ^{0}B with 65.48 minutes immersion time. Change in TSS in all three shapes is depicted in Fig. 3. Osmosis decreased moisture content of fruit slices and also facilitated the absorption of sugar by the slices which ultimately increased the TSS content of osmosed fruit slices. These findings are in conformity with the result obtained



(A) Longitudinal slices

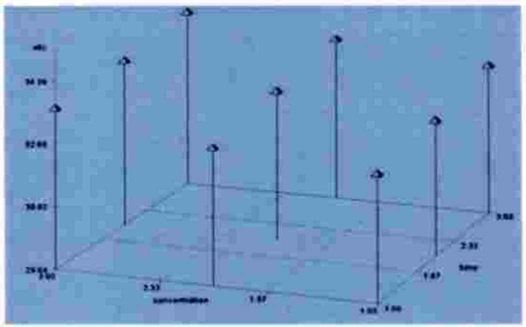


(B) Round slices

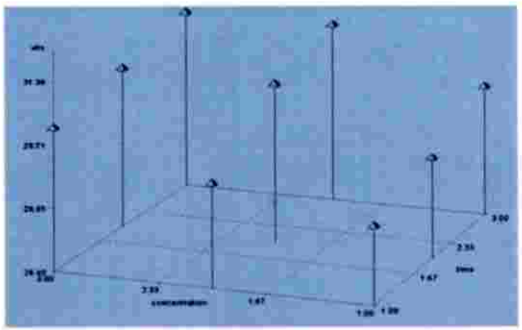


(C) Ring slices

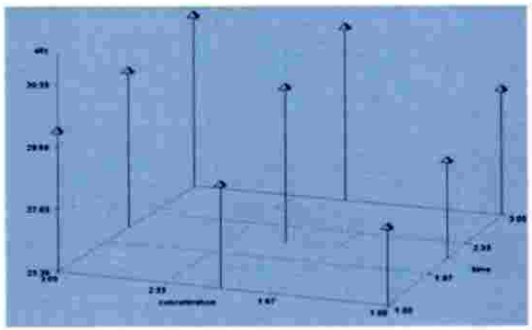
Fig. 3. Change in TSS (^0B) of osmosed nendran banana



(A) Longitudinal slices



(B) Round slices



(C) Ring slices

Fig. 4. Change in vitamin C (mg/100g) of osmosed nendran banana

in osmotic dehydration of pineapple slices by Rashmi (2002) and in aonla by Geetha *et al.* (2006) and pineapple by Dionello *et al.* (2009).

Minimum acidity of 2.56% was recorded with thickness 12.43 mm, concentration 66.61^{0}B and 71.4 minutes immersion time for longitudinal slices and 2.57 % for round sliced for thickness 12.25 mm, concentration 66.9 ^{0}B with an immersion time of 71.08 minutes and for ring shaped slices it was 2.34 % for thickness 14.05 mm, concentration 65.2 ^{0}B with 64.92 minutes immersion time. Osmosis also resulted in reduction of titratable acidity. Acidity decreased with increase in osmotic concentration. Reduction might be due to leaching of acid from fruits to hypertonic solution through a semi permeable membrane (Sagar and Kumar, 2009). Increase in osmotic concentration showed decreasing trend of acidity in osmosed banana. These results were supported by Sharma and Kaushal (1999), Sharma *et al.* (2004), Devic *et al.* (2010), Vijayakumari *et al.* (2007) and Phisut *et al.* (2012).

Maximum reducing sugar of 43.43% was recorded with thickness 10.86 mm, concentration 68.15 ^{0}B and 71.08 minutes immersion time for longitudinal slices and 40.30 % for round sliced for thickness 12.4 mm, concentration 67.3 ^{0}B with an immersion time of 69.42 minutes and for ring shaped slices it was 38.95 % for thickness 11.27 mm, concentration 68.33 ^{0}B with 69.8 minutes immersion time. Maximum total sugar of 56.33% was recorded with thickness 10.86 mm, concentration 68.81 ^{0}B and 68.76 minutes immersion time for longitudinal slices and 52.97 % for round sliced for thickness 11.13 mm, concentration 69.05 ^{0}B with an immersion time of 67.16 minutes and for ring shaped slices it was 47.82 % for thickness 13.25 mm, concentration 65.6 ^{0}B with 70.20 minutes immersion time.

Reducing and total sugar increased with increase in concentration and immersion time in all slices because of the increased sugar uptake and moisture removal. Uptake of solutes and a resultant increase in sugar content in fruit slices is characteristic phenomenon of the osmosis process as reported by

Raoult-wack *et al.* (1991), Torreggiani, (1993), Chavan *et al.*, (2010), Amin and Hossain (2012) and Patil *et al.* (2013).

Maximum vitamin C of 38.98 mg/100g was recorded with thickness 11.03 mm, concentration 51.04 ^{0}B and 52.10 minutes immersion time for longitudinal slices and 36.23 mg/100g for round sliced for thickness 11.95 mm, concentration 53.1 ^{0}B with an immersion time of 47.86 minutes and for ring shaped slices it was 35.28 mg/100g for thickness 11.35 mm, concentration 53.6 ^{0}B with 45.6minutes immersion time (Fig 4). Vitamin C showed decreasing trend with increase in immersion time during osmosis. This may be due to the transfer of ascorbic acid from fruit to the solution with more time of immersion. However osmotic concentration ranging from 50 to 60^{0}B was optimised for minimum loss of vitamin C in all shapes. Osmotic treatment helped in reducing the degradation of ascorbic acid. Sagar and Kumar (2009) reported that the higher concentration of sugar syrup provided more protection to degradation of ascorbic acid. 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 as reported by Vial *et al.* (1991), Pizzocaro *et al.* (1993), Azoubel (2000), Park *et al.* (2002), Chiralt and Talens (2005), Mandala *et al.* (2005), Rasheed (2005), Singh *et al.* (2007), Elbeltagy *et al.* (2008), Santos and Silva (2008), Shi and Xue (2009) and Nadia *et al.* (2013).

5.1.3. Physical Parameters of Osmo-air Dehydrated Nendran Banana Slices

Physical characters *viz.* water loss, weight reduction, yield, drying rate, rehydration ratio, shrinkage, browning index, texture were optimized for osmo-air dehydrated nendran banana of different shapes and thickness of nendran banana.

Maximum water loss of 51.08 % was recorded with thickness 5.13 mm, concentration 58.83 ^{0}B and 55.96 minutes immersion time for longitudinal slices and 57.46 % for round sliced for thickness 5.19 mm, concentration 57.93 ^{0}B with an immersion time of 56.26 minutes and for ring shaped slices it was 58.84 % for thickness 10.31 mm, concentration 57.56 ^{0}B with 40.64 minutes immersion time. Water loss was influenced by the size and shape of fruit pieces. It was also influenced by the osmotic concentration. In the present study, highest water loss was seen in osmotic concentration in the range of 55-60 ^{0}B. The results were supported by Noguera *et al.* (2010) in case of strawberry halves treated in the 50% sucrose solution recorded high water loss than at 25%. A decrease in per cent water loss was observed with increase in osmotic concentration and immersion time. The result is supported by the findings of Fernandes *et al.* (2008) and Noguera *et al.* (2010) who reported that decrease in effective water diffusivity during drying might be due to extra resistance by higher sugar concentration creating or less potential for water to diffuse out.

Maximum weight reduction of 30.82% was observed for longitudinal slices with thickness 5.14 mm, concentration 62.32^o B, immersion time 59.03 minutes, 41.50% for round slices with thickness 5.04mm, concentration 60.31^o B and immersion time 62.46 minutes and 48.98% for ring shaped slices with thickness 13.82 mm, concentration 63.08^o B and immersion time 71.03 minutes. Highest weight reduction was observed in ring slices which might be due to the highest percentage of water loss. Weight reduction and water loss were positively affected by concentration and supported by the findings of Noguera *et al.* (2010) in strawberries, Kumar and Devi (2011) in pineapple, and Rizzoloa *et al.* (2015) in mango.

Maximum yield of 82.63 % for longitudinal sliced nendran banana was obtained for thickness 14.69 mm, concentration 59.27 ^{0}B with an immersion time 66.74 minutes, and 71.52 % for round sliced nendran banana (thickness 14.34 mm, concentration 64.62 ^{0}B, immersion time 56.52 minutes) and for ring shaped slices maximum yield observed was 57.21 % for thickness 5.68 mm, concentration 57.82 ^{0}B with 50.86 minutes immersion time. Increase in drier yield and process yield had been reported for osmo dehydrated products due to solid gain and volume reduction (Torreggiani, 1993). Increase in recovery of dried products by osmotic treatments was reported in other fruits like ber (Devaraju, 2001), sapota (Lakkond, 2002) and guava (Pedapathi and Tiwari, 2014).

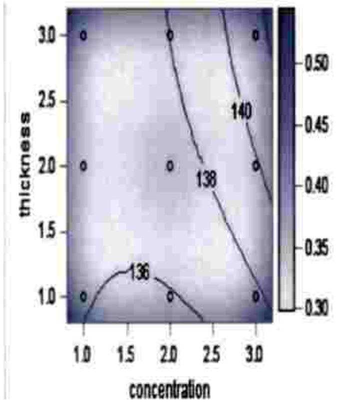
Maximum drying rate of 2.07 % was obtained for slices with thickness 5.01 mm, concentration 59.83 ^{0}B and immersion time 61.56 minutes for longitudinal, 0.675 % was obtained for slices with thickness 5.075 mm, concentration 60.92 ^{0}B and immersion time 56.94 minutes for round, 0.805 % was obtained for slices with thickness 5.05 mm, concentration 61.36 ^{0}B and immersion time 59.28 minutes for ring slices. Increased drying rate during dehydration process is due to increase in moisture content. Increase in osmotic solution concentration resulted in corresponding increase in water loss to equilibrium level and drying rate decreased. Shape and thickness also affected the drying rate and is clear from the results of water loss of osmosed nendran banana. The result is in conformity with the reports of Ling *et al.* (1982), Dandamrongrak *et al.* (2003), Mahendran and Prasannath (2004), Abano *et al.* (2011) and Thuwapanichayanan *et al.* (2011) and Pekke *et al.* (2013) in banana.

Maximum rehydration ratio was 2.58 for longitudinal slices (6.97 mm thickness, concentration 54.27 ^{0}B and immersion time 48.92 minutes), 1.58 for round slices (thickness of 6.53 mm, concentration 55.23 ^{0}B with immersion time 49.14 minutes), and 1.37 for ring slices (thickness 7.066 mm, concentration 55.93 ^{0}B and immersion time 45.98 minutes). Osmotic solution concentration showed significance for rehydration ratio in all three shapes. Porosity of the raw material has a significant effect on shrinkage phenomena and mass transfer rates as well as rehydration ratio (Mavroudis *et al.*, 1998). The shape and size of product affect the surface area to volume ratio of the product with the solution was reported by Contreras and Smyrl (1998). Since solute impregnation is a surface controlled phenomenon, high specific surface values favour solute uptake (Lerici *et al.*, 1985 and Torreggiani, 1993). In terms of final product characteristics, sugar uptake affects both rehydration and flavour retention due to lower rehydration of sugar in the fruit, compared with fruit tissue itself (Chaudhari *et al.*, 1993; Ghosh *et al.*, 2004). Abano and Amoah (2011) reported that no much difference in rehydration capacity of osmotically dried banana with slice thickness.

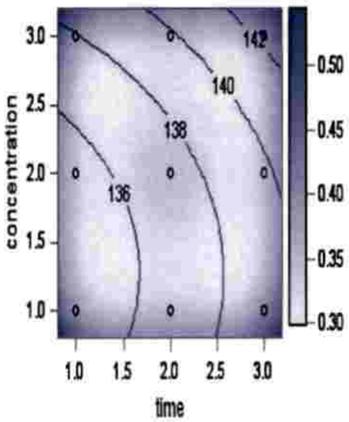
Maximum shrinkage of 70.37 % was obtained for longitudinal slices with thickness 12.45 mm, concentration 58 ^{0}B and immersion time 43.06 minutes, and was 48.40 % was for round slices with thickness 5.73 mm, concentration 65.23 ^{0}B and immersion time 59.6 minutes, 74.09 % for ring slices with thickness 10.65 mm, concentration 50.14 ^{0}B and immersion time 57.78 minutes. Drying of a product usually results in smaller size than its original wet form. The shrinkage of volume is dependent on the density affected by the diffusion coefficient of the material, which is one of the main parameters governing the drying process (Queiroz and Nebra, 1996; Lima *et al.*, 2002). A decrease in shrinkage was found with increase in concentration and the result is in agreement with Tiroutchelvame *et al.* (2015) in aonla.

Longitudinal slices recorded minimum browning index of 134.67 (thickness 6.95 mm, concentration 57.7 ^{0}B and 44.68 minutes immersion time), 134.58 for round slices (thickness 7.69 mm, concentration 53.0 ^{0}B and immersion time 49.08 minutes) and 127.74 % for ring slices (thickness 6.76 mm, concentration 56.02 ^{0}B and immersion time 46.98 minutes). Browning index showed increasing trend with increase in osmostic solution concentration (Fig. 5). It may be due to an increase of soluble solids content of the fruit. Higher sugar concentration may have resulted in the browning. Alline *et al.* (2003) in papaya also reported that colour development of osmotic dehydrated fruits increased with concentration. Increased browning index may be due to Millard reactions by Phisut *et al.* (2012).

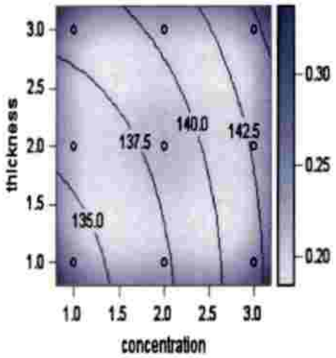
Maximum cutting force of 38.67 N was obtained for slices with thickness 14.71 mm, concentration 63.08 ^{0}B and immersion time 62.82 minutes for



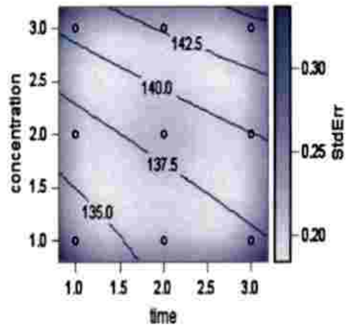
(A) Longitudinal slices



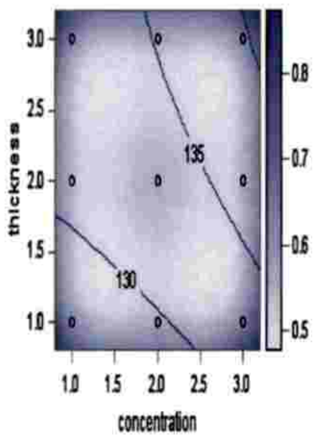
(B) Longitudinal slices



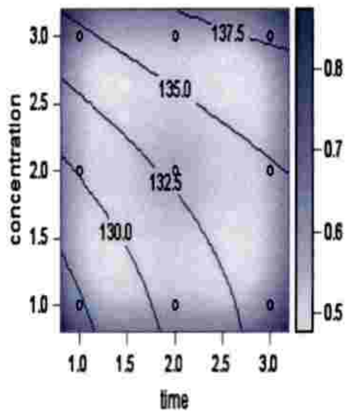
(C) Round slices



(D) Round slices



(E) Banana rings



(F) Banana rings

Fig. 5. Change in browning index of osmo-air dehydrated nendran banana

longitudinal slices, 51.69 N was obtained for slices with thickness of 14.89 mm, concentration 61.97 ^{0}B and immersion time 60.99 minutes for round slices, 54.95 N was obtained for slices with thickness 14.55 mm, concentration 63.02 ^{0}B and immersion time 65.55 minutes for ring slices. Maximum cutting energy of 38.54 NS was obtained for slices with thickness 14.76 mm, concentration 62.90 ^{0}B and immersion time 61.88 minutes for longitudinal slices, 66.87 NS was obtained for slices with thickness of 14.77 mm, concentration 62.47 ^{0}B and immersion time 63.25minutes for round slices, 42.68 NS was obtained for slices with thickness 14.866 mm, concentration 62.187 ^{0}B and immersion time 61.384 minutes for ring slices. Texture is expressed in terms of cutting force and cutting energy and both showed increasing trend with increase in thickness and concentration. Osmotic dehydration increases the sugar to acid ratio and improves the texture and stability of pigments during dehydration (Rastogi *et al.*, 2002). Prinzivalli *et al.* (2006) reported that for osmotically dehydrated strawberries texture was modified due to pectin dissolution and breakdown of cells after 30 minutes of pretreatment. Germer *et al.* (2010) reported that multi regression analysis of cutting force revealed that there was no influence of concentration on cutting force. Increase in textural quality with concentration was reported due to solid diffusion into the fruit (Moyano *et al.* 2010).

5.1.4. Biochemical Parameters of Osmo-air Dehydrated Nendran Banana Slices

Minimum acidity of 1.50 % was obtained for slices with thickness 12.09 mm, concentration 68.70 ^{0}B and immersion time 64.94 minutes for longitudinal slices, 1.57 % was obtained for round slices with thickness of 13.13 mm, concentration 65.23 ^{0}B and immersion time 71.54 minutes and, 1.50 % was obtained for ring slices with thickness 12.21 mm, concentration 68.44 ^{0}B and immersion time 66.02 minutes for ring slices. Air drying decreased the acidity of osomosed nendran banana and the result is supported by the findings of Piga *et al.* (2004) in drying of figs, Devic *et al.* (2010) in cantaloupe, Sakhale and Pawar (2011) in mango.

Maximum reducing sugar of 46.91 % was obtained for longitudinal slices with thickness 13.33 mm, concentration 63.29 ^{0}B and immersion time 73.38 minutes, 46.17 % for round slices with thickness of 13.89 mm, concentration 65.82 ^{0}B and immersion time 64.6 minutes. 45.88 % for ring slices with thickness 11.11 mm, concentration 67.14 ^{0}B and immersion time 69.06 minutes for ring slices. Maximum total sugar of 52.76 % was obtained for longitudinal slices with thickness 7.44 mm, concentration 67.41 ^{0}B and immersion time 67.94 minutes longitudinal slices, 54.92 % was obtained for round slices with thickness of 12.14 mm, concentration 68.65 ^{0}B and immersion time 65.16 minutes, 52.59 % for ring slices with thickness 11.59 mm, concentration 68.86 ^{0}B and immersion time 66.72 minutes. Total sugar and reducing sugar content was found higher in dried slices which may be due to the loss of moisture. The results are in conformity with earlier findings with Mehta and Tomar (1980) papaya, Madmba and Lopez (2002) in mango, (Elbeltagy *et al.*, 2008) strawberries, (Shedame *et al.*, 2008) grapes, (Assous *et al.*, 2012) guava.

Maximum vitamin C of 33.87 mg/100g was obtained for longitudinal slices with thickness 12.6 mm, concentration 67.07 ^{0}B and immersion time 69.44 minutes for longitudinal slices, 30.53 mg/100g was obtained for round slices (thickness of 13.1 mm, concentration 65.96 ^{0}B and immersion time 70.18 minutes) 29.62 % for ring slices (thickness 13.61 mm, concentration 64.64 ^{0}B and immersion time 70.22 minutes). Regression analysis showed that thickness had significant influence on vitamin C during air drying and vitamin C retention increased with increase in thickness and concentration. The vitamin C can be easily degraded, depending on many variables such as pH, temperature, light, and presence of enzymes and oxygen (Santos and Silva, 2008), Azoubel *et al.* (2000), Phisut *et al.* (2012).

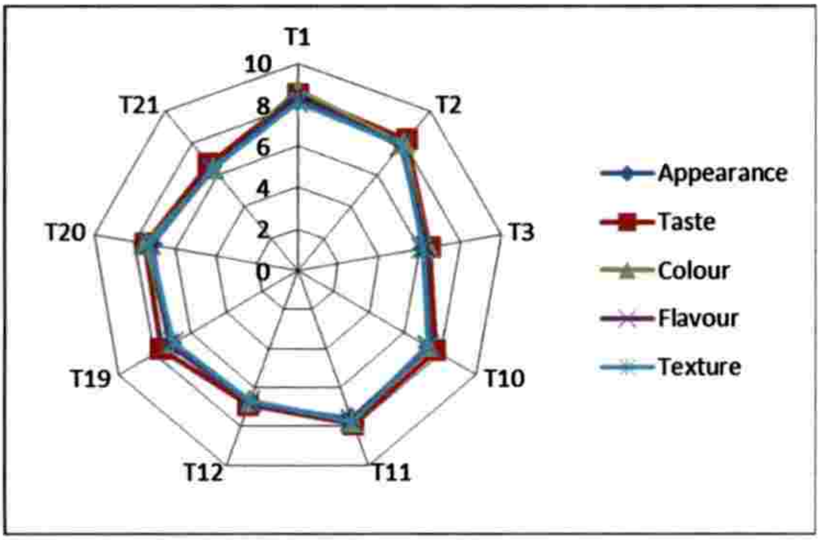


Fig.6. Sensory analysis of selected osmo-air dehydrated longitudinal nendran banana slices

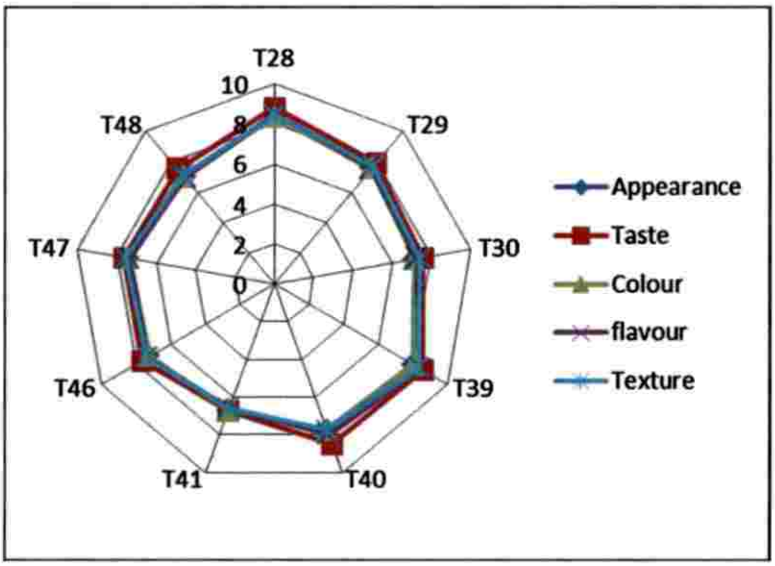


Fig.7. Sensory analysis of selected osmo-air dehydrated round sliced nendran banana

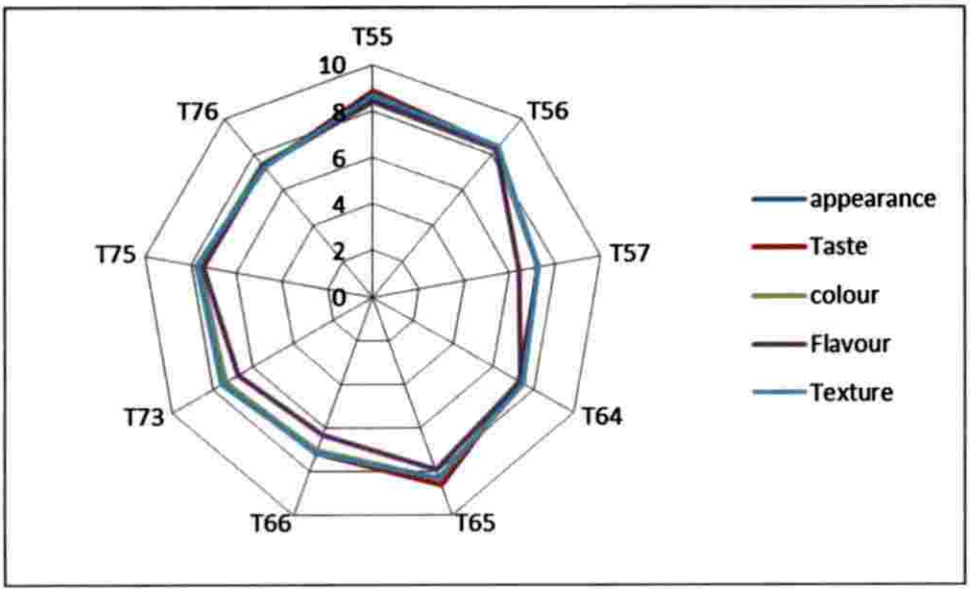


Fig.8. Sensory analysis of selected osmo-air dehydrated ring sliced nendran banana

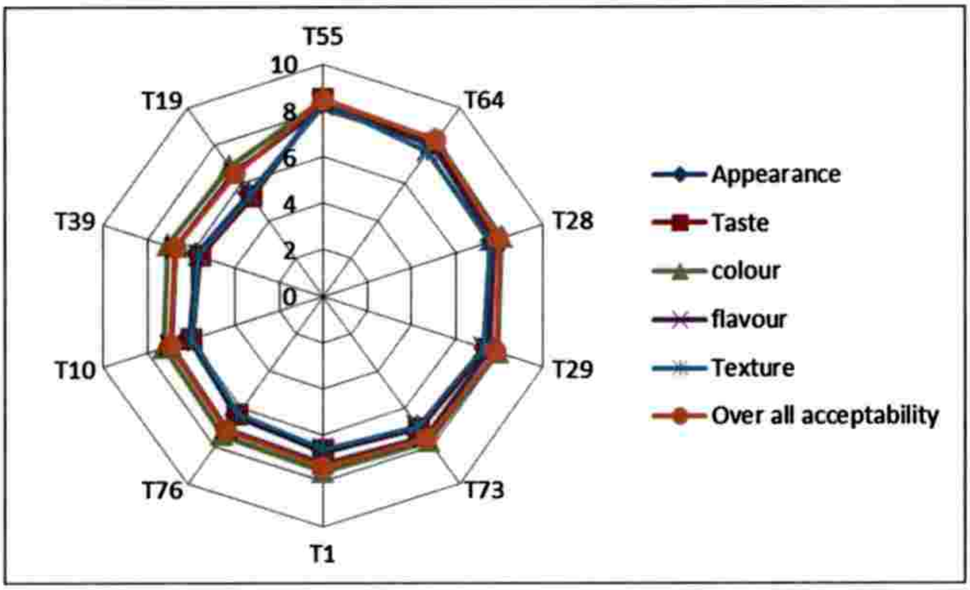


Fig.9. Sensory evaluation of selected best ten treatments

5.1.5. Sensory Parameters for Osmo-air Dehydrated Fruits

Evaluation of organoleptic qualities for osmo-air dehydrated longitudinal, round and ring slices were conducted separately and 12 treatments from all three shapes (four from each shape) were pooled. The sensory analysis of the selected treatments were conducted and chi- square test confirmed significant difference among the treatments. From the twelve treatments, best 10 were selected for storage studies. The ring shaped (T_{55}, T_{64}) osmodehydrated nendran was preferred followed by round (T_{28}, T_{29}) and in thickness; 5mm got highest acceptability followed by 10 mm. The dehydrated ring slices of 5mm thickness with 50 ^{o}B concentration for 40 minutes got the highest acceptability followed by round and longitudinal slices (Fig. 6, 7, 8, 9.). The maximum acceptance was noticed for osmotically dehydrated product under process condition of low osmotic concentration and less time. This result is supported by Gurumeenakshi *et al.* (2005) in osmo-air dehydrated papaya, Kumar and Sagar (2009) in pineapple, Shafiq *et al.* (2010) in aonla. Cortellino *et al.* (2011) reported that 6 mm sliced pineapple rings recorded highest sensory acceptability. Anand and Genitha (2011) in banana reported that among different shapes, round was found highest acceptability than longitudinal and cubes at osmotic concentration of 50 ^{o}B.

5.2. STORAGE STUDIES ON OSMO-AIR DEHYDRATED NENDRAN BANANA

5.2.1. Physical Parameters of Stored Nendran Banana Slices

Significant differences were recorded for rehydration ratio of osmotically dehydrated banana slices during storage and exhibited a decreasing trend. The reason for decreased rehydration ratio may be due to increased moisture content (absorbed from environment) during storage. It also came into agreement with Prakah (2004) in carrot, Singh and Sharma (2015) in pineapple.

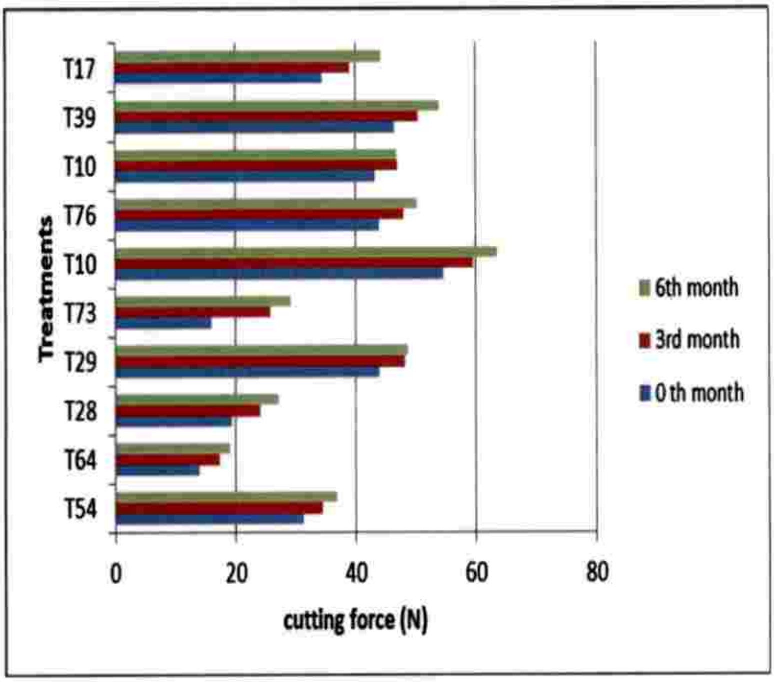


Fig. 10. Change in cutting force of osmo-air dehydrated nendran banana during storage

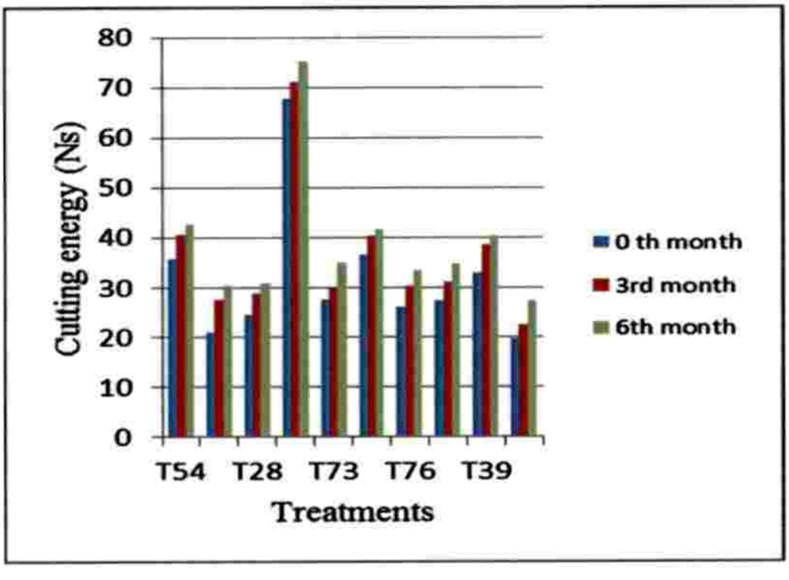


Fig. 11. Change in cutting energy of osmo-air dehydrated nendran banana

Browning is an important problem and is considered to be one of the main causes of quality loss during handling, processing and storage. Browning index showed increasing trend irrespective of the treatments. It increased from 148.29 at the time of storage to 165.60 after six months of storage. The mechanism of browning of banana slices can be due to millard reaction. These results were also supported by Waliszewski *et al.* (2000) and Pekke *et al.* (2013) in banana, Phisut *et al.* (2012) in cantaloupe melons, Grabowski *et al.* (2015) in cranberries, Singh and Sharma (2015) in pineapple.

During storage, textural qualities like cutting force and cutting energy showed increasing trend irrespective of the treatments. Cutting force increased from 34.73 N to 41.76 N and cutting energy increased from 31.80 Ns to 39.13 Ns at the time of six months of storage. It may be due to the increase in moisture content of slices with storage (Fig 10 and 11). Texture is the quality deciding factor and it depends on concentration, thickness and time. similar results were reported by Illeperuma and Jayanthuge (2001) in kolikuttu banana, Farnis *et al.* (2008) and Rizzolo *et al.* (2015) in apple.

5.2.2. Biochemical Parameters of Stored Nendran Banana Slices

During storage significant change in moisture content of osmo-air dried banana slices was recorded due to different osmotic treatments as well as interactions between treatments. It showed increasing trend during storage irrespective of the treatments. Moisture content increased from 17.51% at the time of storage to 24.61% after six months of storage (Fig 12). It may be due to absorption of moisture from air. The results were also in conformity with Chauhan *et al.* (1995) in mango slices, Prakash (2004) in carrot, Singh and sharma (2015) in pineapple.

Acidity showed decreasing trend irrespective of the treatments. Acidity decreased from 1.71% at the time of storage to 1.12% after six months of storage. The interaction effect also showed decreasing trend from 1.58% to 1.00% and it showed that there was a significant difference between the

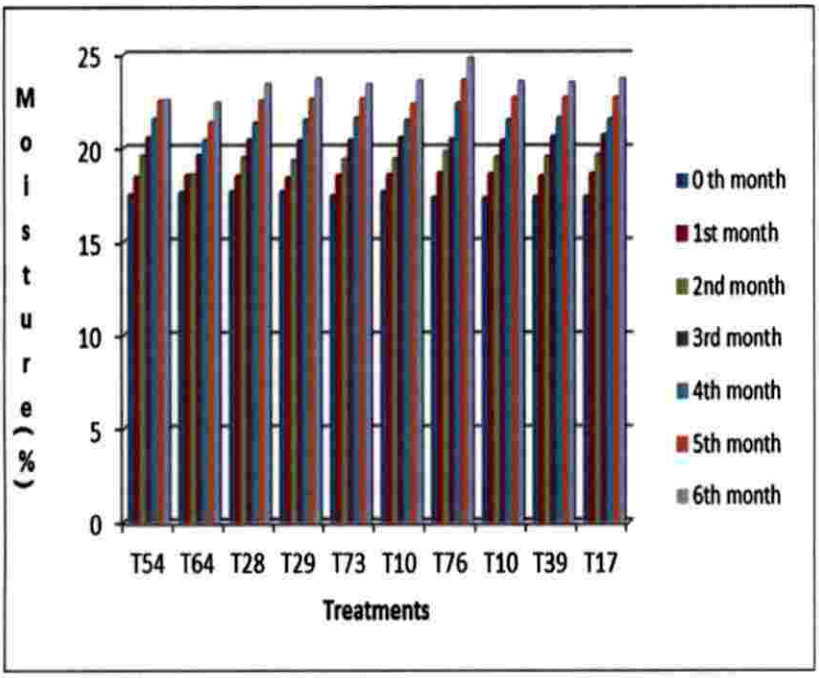


Fig. 12. Change in moisture content (%) of osmo-air dehydrated nendran banana during storage

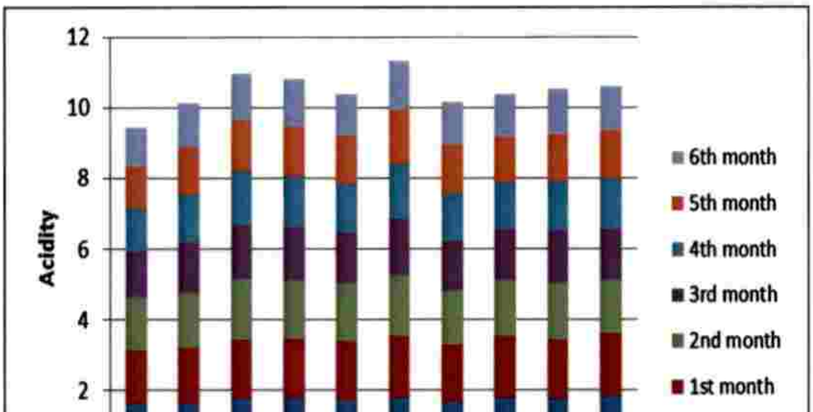


Fig. 13. Change in acidity (%) of osmo-air dehydrated nendran banana during storage

treatments. The lowest acidity was observed for ring 5 mm 50° B 40 minutes (1.32%) and highest was observed for long 5 mm 50° B 40 minutes (1.58%) after six months of storage (Fig 13). It may be due to hydrolysis of polysaccharides and non reducing sugar through utilization of acids for converting them to hexose. These results were supported by Sagar and Khurdiya (1999) and Sagar and Kumar (2009) in mango.

Reducing sugar increased from 44.95% at the time of storage to 51.19 % after six months of storage. The interaction effect between treatment and storage period also showed increasing trend from 44.11% to 51.77%. This might be due to hydrolysis of total sugar into reducing sugar. Similar results were reported by Chauhan *et al.* (1995) in mango, Sharma and Kaushal (1998) in plum and Palve and Singh (2007) in figs, Sagar and Kumar (2009) in mango. Total sugar showed decreasing trend irrespective of the treatments. It was decreased from 55.91 % at the time of storage to 50.65 % after six months of storage. It may be due to gradual breakdown of carbohydrates. The results are in conformity with the findings of Mehta and Tomar (1980) in guava, Aruna *et al.* (1999) in apple, Vennilla *et al.* (2004) and, Sivakumara *et al.* (2005) in guava, Arbat (2009) in sapota.

Vitamin C showed decreased trend irrespective of the treatments. It decreased from 27.85 mg/100g at the time of storage to 27.73 mg/100g after six months of storage. The ascorbic acid content decreased gradually during storage in all the samples and it may be due to loss of ascorbic acid and increase in moisture level, exposure to light, may also influenced Similar types of observations were recorded by Aruna *et al.* (1999) in apple and Hemakar *et al.* (2000) in mango and guava, due to oxidation of ascorbic acid to dehydro-ascorbic acid during storage Chavan *et al.* (2010).

5.2.3. Sensory Evaluation of Stored Nendran Banana Slices

Sensory analysis of stored samples conducted at an monthly intervals revealed that mean score pertaining to appearance, colour, flavour, texture, taste and overall acceptability of dehydrated banana slices showed slight reduction towards the end of six month storage.

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. Reduced mean score during storage for colour, flavour, taste and over all acceptability was supported by Aruna *et al.* (1999) in apple, Awasthi *et al.* (1984) in banana and Narayana *et al.* (2003) in banana fig, Ahmed *et al.* (2004) and Vennilla *et al.* (2004) in papaya.

Flavour is the major quality parameter of food stuff. Flavour score of dehydrated banana slices had decreased with advancement of storage. This might be due to the browning reaction increase in moisture level as evidenced by decrease in colour score. Similar results were reported by Aruna *et al.* (1999), Awasthi (1984) in banana and Narayana *et al.* (2003) and Vennilla *et al.* (2004) in papaya.

Texture of solid food stuff mainly depends upon on its chewing quality which is mainly determined by mouth feel. Mouth feel is considered good when it is not too much hard or soft. Texture score of dehydrated banana slices had decreased with the advance of storage period, which may be due to more moisture. The result is supported by Aruna *et al.* (1999), Awasthi *et al.* (1984) and Narayana *et al.* (2003) and Ahmad *et al.* (2004).

The consumers' acceptance of food product depends on many factors among which taste is a major parameter. A large number of research workers and food processors have made processed products from banana fruit which are well accepted by the people. Taste score had decreased with advancement of storage period because during storage, moisture increase and there by dilution of sugar and change in acidity in product. Similar results were supported by Aruna *et al.* (1999), Awasthi *et al.* (1984), Narayana *et al.* (2003), Ahmed *et al.* (2004) and Vennilla *et al.* (2004).

Overall acceptability of dehydrated banana slices considering colour, flavour, taste and texture were found acceptable with better shelf life. Overall acceptability score had decreased during storage in all the treatments which may be attributed by the change in chemical composition of the product and loss of colour and flavour during storage. These similar results were reported by Awasthi *et al.* (1984), Aruna *et al.* (1999), Narayana *et al.* (2003), Ahmed *et al.* (2004) and Vennilla *et al.* (2004) and Singh *et al.* (2006) in aonla.

In respect of organoleptic evaluation of dehydrated banana slices, it can be elucidated that ring and round slices had higher overall acceptability with the maximum shelf life and better quality rather than longitudinal round slices with 15 mm thickness.

5.2.4. Microbial Evaluation of Stored Nendran Banana Slices

Osmo- air dried nendran banana slices on storage for 6 months were found microbiologically safe, which could probably because of addition of KMS, citric acid and high concentration of sugar. Higher TSS and acidity of the product might have also played a role in preservation of the product. It also came in to confirmation with the findings of Illeperuma and Jayanthuge (2001) in kolikuttu banana that found safe up to 8 months of storage, Chavan *et al.* (2010) in banana, Zapata *et al.* (2011) in pineapple, Assous *et al.* (2012) in guava, Karunarathna and Rathnayak (2012) in pineapple.

Summary

6. SUMMARY

The present investigation entitled "Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)" was carried out at Department of Processing Technology, College of Agriculture, Vellayani during the period 2013-2015 with the objective to standardize different process variables like shape of the fruit slice, thickness, osmotic solution concentration and immersion time for osmo-air dehydration of nendran banana and to optimise the conditions suitable for better mass transfer kinetics.

Optimally ripened nendran banana (cv. Kaliethan) sliced into three shapes *viz.* long (5cm), round and ring of thickness 5, 10 and 15 mm each were osmosed in sugar syrup of 50, 60 and 70^0 B concentration with an immersion time of 40, 60 and 80 minutes. Osmosed fruit slices were dried in cabinet drier at 50^0 C till it attained moisture content of 17 ± 1 % and analysed for physical, nutritional and sensory qualities. Observations on mass transfer, physical and nutritional parameters were statistically analysed using Response Surface Methodology (RSM) and response surfaces were fitted using SAS software (ver 9.3). Quadratic regression equation models were developed for all the responses with $R^2 > 90$ %.

Mass transfer characters *viz.* solid gain, water loss, weight reduction and ratio of water loss to solid gain increased with increase in concentration of osmotic solution, thickness of slices and duration of immersion time irrespective of fruit shapes. Solid gain is an index of solute diffusion in to the banana slices and it increased with the increase in osmotic solution concentration, immersion time and thickness in all the three shapes (longitudinal, round, ring) of nendran banana slices. The interaction effects of thickness and concentration in the regression models for all shapes were significant. For longitudinal slices the model fitted for solid gain is $2.29 + 2.08X_1 - 0.42X_2 - 0.07X_3 - 0.18X_{11} + 0.10X_{22} - 0.003X_{33} + 0.16X_1X_2 + 0.12X_1X_3 + 0.13X_2X_3$ where X_1 is thickness, X_2: concentration and X_3: time of immersion and coded as X_1=thickness/5, X_2= (concentration-40)/10, X_3=(Time-20)/20. Minimum solid gain of 4.65 % was recorded for 5.1 mm thick slices osmosed in concentration 58.3 ^{0}B for an immersion time of 57.4 minutes and maximum solid gain of 8.78 % was obtained for slices with thickness 14.25 mm, concentration 64.26 ^{0}B and immersion time 65.6 minutes. The model fitted for solid gain of round and ring slices is $1.83 + 0.54X_1 - 1.38X_2 + 0.50X_3 - 0.18X_{11} + 0.4X_{22} - 0.08X_{33} + 0.18X_1X_2 + 0.0016 X_1X_3 + 0.05X_2X_3$ and $0.89 + 0.33X_1 + 2.077X_2 + 1.10X_3 + 0.29X_{11} - 0.06X_{22} - 0.05X_{33} - 0.36X_1X_2 - 0.16X_1 X_3 - 0.076X_2X_3$ respectively.

Estimated minimum water loss for osmosed longitudinal slices was 15.14 % for thickness 5.54 mm, concentration 56.94 ^{0}B , immersion time 53.26 minutes whereas estimated maximum water loss of 29.38 % was obtained for slices with thickness 14.09 mm, concentration 62.38 ^{0}B and immersion time 70.41 minutes. For round slices maximum water loss was 18.03% with thickness 12.49 mm, concentration 68.05 ^{0}B and immersion time 66.40 minutes and it was 15.58% for ring slices with thickness 12.95 mm, concentration 64.63 ^{0}B and immersion time 73.08 minutes and water loss increased with concentration. Predictive model for water loss of longitudinally sliced nendran banana due to osmotic treatment is $-7.01 + 8.77X_1 + 6.52X_2 + 3.57X_3 - 0.91X_{11} - 0.89X_{22} - 0.036X_{33} + 0.20X_1X_2 + 0.29X_1X_3 - 0.68X_2X_3$ and $-1.44 + 4.91X_1 - 1.48X_2 + 2.12X_3 - 0.86X_{11} + 0.84X_{22} + 0.19X_{33} + 0.94X_1X_2 - 0.085X_1X_3 - 0.30X_2X_3$ for round slices and $-1.26 + 0.59X_1 + 6.55X_2 + 0.82X_3 + 0.22X_{11} - 0.99X_{22} + 0.15X_{33} - 0.10X_1X_2 + 0.13 X_1X_3 + 0.025X_2X_3$ for ring slices of nendran banana.

Ratio of water loss to solid gain is considered as a good indicator for maximisation of water loss and minimisation of solid gain. In the present study, ratio of water loss to solid gain recorded a maximum of 3.68% for longitudinal slices with thickness 9.31mm, concentration 57.78 ^{0}B and immersion time of 79.30 minutes and 5.79% for round slices with thickness 14.40 mm, concentration 58.30 ^{0}B and 68.64 minutes of immersion time and 15.54% for ring shaped slices with thickness of 12.85mm, concentration 64.68 ^{0}B and immersion time 73.34 minutes.

Biochemical parameters *viz*. TSS, titratable acidity, reducing sugar, total sugar and vitamin C were optimized for the three shapes and thickness of nendran banana for different osmotic treatments. An increase in total soluble solids, reducing sugars, total sugars with increase in thickness, concentration and time of immersion and a decreasing trend in acidity and vitamin C in all the three shapes was noticed. Maximum TSS of 73.10% was recorded with thickness 12.59 mm, concentration 67.93 ^{0}B and 66.34 minutes immersion time for longitudinal slices and 71.10 % for round sliced with thickness 12 mm, concentration 67.59 ^{0}B with an immersion time of 70.20 minutes and for ring shaped slices it was 69.01 % for thickness 11.45 mm, concentration 69.14 ^{0}B with 65.48 minutes immersion time. Osmosis decreased moisture content of fruit slices and also facilitated the absorption of sugar by the slices which ultimately increased the TSS content of osmosed fruit slices. Minimum acidity of 2.56% was recorded with thickness 12.43 mm, concentration 66.61^{0}B and 71.4 minutes immersion time for longitudinal slices and 2.57 % for round sliced for thickness 12.25 mm, concentration 66.9 ^{0}B with an immersion time of 71.08 minutes and for ring shaped slices it was 2.34 % for thickness 14.05 mm, concentration 65.2 ^{0}B with 64.92 minutes immersion time. Osmosis also resulted in reduction of titratable acidity. Acidity decreased with increase in osmotic concentration. Maximum reducing sugar of 43.43% was recorded with thickness 10.86 mm, concentration 68.15 ^{0}B and 71.08 minutes immersion time for longitudinal slices and 40.30 % for round sliced for thickness 12.4 mm, concentration 67.3 ^{0}B with an immersion time of 69.42 minutes and for ring shaped slices it was 38.95 % for thickness 11.27 mm, concentration 68.33 ^{0}B with 69.8 minutes immersion time. Maximum total sugar of 56.33% was recorded with thickness 10.86 mm, concentration 68.81 ^{0}B and 68.76 minutes immersion time for longitudinal slices and 52.97 % for round sliced for thickness 11.13 mm, concentration 69.05 ^{0}B with an immersion time of 67.16 minutes and for ring shaped slices it was 47.82 % for thickness 13.25 mm, concentration 65.6 ^{0}B with 70.20 minutes immersion time. The models were fitted for biochemical parameters for all the treatments.

Physical characters *viz.* water loss, weight reduction, yield, drying rate, rehydration ratio, shrinkage, browning index, texture were optimized for osmo-air dehydrated nendran banana of different shapes and thickness of nendran banana. Maximum water loss of 51.08 % was recorded with thickness 5.13 mm, concentration 58.83 ^{0}B and 55.96 minutes immersion time for longitudinal slices and 57.46 % for round sliced for thickness 5.19 mm, concentration 57.93 ^{0}B with an immersion time of 56.26 minutes and for ring shaped slices it was 58.84 % for thickness 10.31 mm, concentration 57.56 ^{0}B with 40.64 minutes immersion time.

During drying, water loss, weight reduction, drying rate and rehydration ratio decreased with increase in thickness and it increased with concentration and time of immersion where as shrinkage, browning index and textural qualities like cutting force and cutting energy increased. Maximum weight reduction of 30.82% was observed for longitudinal slices with thickness 5.14 mm, concentration 62.32^0 B, immersion time 59.03 minutes, 41.50% for round slices with thickness 5.04mm, concentration 60.31^0 B and immersion time 62.46 minutes and 48.98% for ring shaped slices with thickness 13.82 mm, concentration 63.08^0 B and immersion time 71.03 minutes. Highest weight reduction was observed in ring slices which might be due to the highest percentage of water loss. Longitudinal slices recorded minimum browning index of 134.67 (thickness 6.95 mm, concentration 57.7 ^{0}B and 44.68 minutes immersion time), 134.58 for round slices (thickness 7.69 mm, concentration 53.0 ^{0}B and immersion time 49.08 minutes) and 127.74 for ring slices (thickness 6.76 mm, concentration 56.02 ^{0}B and immersion time 46.98 minutes). Browning index showed increasing trend with increase in osmostic solution concentration and higher sugar content might be resulted in the browning. Significant differences were recorded for dried yield and drying rate due to osmotic pre-treatments and interaction.

Minimum acidity of 1.50 % was obtained for slices with thickness 12.09 mm, concentration 68.70 ^{0}B and immersion time 64.94 minutes for longitudinal slices, 1.57 % was obtained for round slices with thickness of 13.13 mm, concentration 65.23 ^{0}B and immersion time 71.54 minutes and, 1.50 % was obtained for ring slices with thickness 12.21 mm, concentration 68.44 ^{0}B and immersion time 66.02 minutes for ring slices. Total sugar and reducing sugar content was found higher in dried slices which may be due to the loss of moisture. Regression analysis showed that thickness had significant influence on vitamin C during air drying and vitamin C retention increased with increase in thickness and concentration.

Evaluation of organoleptic qualities for osmo-air dehydrated longitudinal, round and ring slices were conducted and chi- square test confirmed significant difference among the treatments. The ring shaped osmodehydrated nendran slices were preferred followed by round and in thickness; 5mm got highest acceptability followed by 10 mm. The dehydrated ring slices of 5mm thickness with 50 ^{0}B concentration for 40 minutes got highest acceptability followed by round and longitudinal slices. The maximum acceptance was noticed for osmotically dehydrated product under process condition of low osmotic concentration and less time.

Based on sensory analysis, ten best treatments were selected and stored at room temperature for six months after packaging in 200 gauge polypropylene and analysed at monthly interval for nutritional, physical and sensory qualities. Effect of storage on moisture, reducing sugar, total sugar, acidity, vitamin C, rehydration ratio, browning index and textural qualities were analysed. During storage, increase in moisture content (17.51 to 24.61 %), reducing sugar (44.95 to 51.19 %) and browning index (148.29 to 165.60) were observed where as acidity (1.71 to 1.12 %), total sugars (55.91 to 50.65%), vitamin C (27.85 to 27.73 mg/100 g) and rehydration ratio (1.82 to 1.35) decreased. Textural qualities *viz.* cutting force and cutting energy increased from 34.73 to 41.76 N and 31.80 to 39.13 Ns respectively during storage. Sensory qualities of the product decreased slightly towards the end of storage and no microbial growth was found till the end of storage.

Second order response surface models were developed for mass transfer, drying and nutritional parameters of osmo-air dehydrated nendran banana. Slices of 5 to 10 mm thickness, 50 to 60^0 B concentration and 50 to 60 minutes of immersion time were the optimized parameters for longitudinal and round slices whereas it was 5 to 8 mm, 50 to 55^0 B and 40 to 50 minutes for ring shaped slices. Five and 10 mm thick rings of ripe nendran banana followed by 5 mm round slices osmosed in 50 ^{0}B sugar syrup for 40 minutes were highly acceptable for developing good quality osmo dehydrated products. The products packaged in 200 gauge polypropylene were acceptable and microbiologically safe up to six months when stored at room temperature.

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Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)

KEERTHISHREE M

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Abstract of the

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COLLEGE OF AGRICULTURE

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Abstract

ABSTRACT

The study entitled "Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)" was conducted at Department of Processing Technology, College of Agriculture, Vellayani, during 2013-15 with the objective to standardize different process variables like fruit slice shape and thickness, osmotic solution concentration and immersion time for osmo-air dehydration of Nendran banana and to optimise the conditions suitable for better mass transfer kinetics.

Optimally ripened nendran banana (cv. Kaliethan) sliced into three shapes viz. long (5cm), round and ring of thickness 5, 10 and 15 mm each were osmosed in sugar syrup of 50, 60 and 70^0 B concentration with an immersion time of 40, 60 and 80 minutes. Osmosed fruit slices were dried in cabinet drier at 50^0 C till it attained moisture content of 17 ± 1 % and analysed for physical, nutritional and sensory qualities. Observations on mass transfer, physical and nutritional parameters were statistically analysed using Response Surface Methodology (RSM) and response surfaces were fitted using SAS software (ver 9.3).

Mass transfer characters *viz.,* solid gain, water loss, weight reduction and ratio of water loss to solid gain increased with increase in concentration of osmotic solution, thickness of slices and duration of immersion time irrespective of fruit shapes. Nutritional parameters of osmosed nendran banana exhibited an increase in total soluble solids, reducing sugars, total sugars with increase in thickness, concentration and time of immersion and a decreasing trend in acidity and vitamin C in all the three shapes. During drying water loss, weight reduction, drying rate and rehydration ratio decreased with increase in thickness and it increased with concentration and time of immersion. Shrinkage (%), browning index and textural qualities like cutting force and cutting energy also increased. Quadratic regression equation models were developed for all the responses with $R^2 > 90$ %. Predictive model for water loss of longitudinally sliced nendran banana is $WL= -7.01+8.77X_1+6.52X_2+3.57X_3-0.91X_{11}-0.89X_{22}-0.036X_{33}+0.20X_1X_2+0.29X_1X_3-0.68X_2X_3$ where X_1 is thickness, X_2: concentration and X_3: time of immersion and coded as X_1=thickness/5, X_2= (concentration-40)/10, X_3=(Time-20)/20. Estimated minimum water loss for osmosed longitudinal slices was 15.14 % at thickness 5.54 mm, concentration 56.94 ^{0}B , immersion time 53.26 minutes whereas estimated maximum water loss of 29.38 % was obtained for slices with thickness 14.09 mm, concentration 62.38 ^{0}B and immersion time 70.41 minutes.

Based on sensory analysis, ten best treatments were selected and stored at room temperature for six months after packaging in 200 gauge polypropylene and analysed at monthly interval for nutritional, physical and sensory qualities. During storage, increase in moisture content (17.51 to 24.61 %), reducing sugar (44.95 to 51.19 %) and browning index (148.29 to 165.60) were observed where as acidity (1.71 to 1.12 %), total sugars (55.91 to 50.65%), vitamin C (27.85 to 27.73 mg/100 g) and rehydration ratio (1.82 to 1.35%) decreased. Textural qualities viz. cutting force and cutting energy increased from 34.73 to 41.76 N and 31.80 to 39.13 Ns respectively during storage. Sensory qualities of the product decreased slightly towards the end of storage and no microbial growth was found till the end of storage.

Second order response surface models were developed for mass transfer, drying and nutritional parameters of osmo-air dehydrated nendran banana. Slices of 5 to 10 mm thickness, 50 to 60^0 B concentration and 50 to 60 minutes of immersion time were the optimized parameters for longitudinal and round slices whereas it was 5 to 8 mm, 50 to 55^0 B and 40 to 50 minutes for ring shaped slices. Five and 10 mm thick rings of ripe nendran banana followed by 5 mm round slices osmosed in 50 ^{0}B sugar syrup for 40 minutes were highly acceptable for developing good quality osmo dehydrated products. The products packaged in 200 gauge polypropylene were acceptable and microbiologically safe up to six months when stored at room temperature.

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Appendices

Appendix I

Kerala Agricultural UniversityCollege of Agriculture

Department of Processing Technology

SCORE CARD FOR ORGANOLEPTIC EVALUATION OF OSMO-AIR DEHYDRATED NENDRAN BANANA

Name of student: Keerthishree, M.
Title of thesis: Optimization of process variables for osmo-air dehydrated Nendran banana (*Musa* spp.)

Sample:

Criteria	1	2	3	4	5	6	7	8	9	10
Appearance										
Colour										
Flavour										
Texture										
Taste										
Overall acceptability										

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 :