PROCESS STANDARDISATION AND VARIETAL SCREENING FOR OSMODEHYDRATION IN MANGO

(*Mangifera indica.*L)

By

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(2011-12-108)

THESIS

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DECLARATION

I hereby declare that the thesis entitled **"Process standardisation and varietal screening for osmodehydration in mango (*Mangifera indica.*L)."** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that the thesis entitled "Process standardisation and varietal screening for osmodehydration in mango (*Mangifera indica*.L)." is a bonafide record of research work done independently by Ms. RESHMA RAMAKRISHNAN under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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Introduction

1. INTRODUCTION

Mango (*Mangifera indica* .L), a member of the family Anacardiaceae is the most important fruit crop in tropical and sub-tropical regions of the world. Mango fruit is considered to be one of the premium fruits in the world market because of its excellent taste, flavour, attractive fragrance, beautiful colour, delicious taste and health giving properties (Salunkhe and Desai, 1984). It is a very popular tropical fruit, consumed mainly in fresh form, with great potential for industrialisation. Mango contains 10-20 per cent sugar, vitamins A, B and C, small amount of protein, iron, calcium and phosphorus (Amur, 1986). Mango occupies a prominent place among the fruits grown in India because of its great utility and is acknowledged as the "King of tropical fruits".

Mango is one of the major fruit crops of Asia and India is the major producer of mango in the world. Currently, it occupies 2297 thousand ha which is 36.0 per cent of total area under fruit crops, with a total production of 15188 thousand MT which is 20.3 per cent of total fruit production. Annually, India supplies 50,000 tonnes of mangoes to different parts of the world including Middle East, Europe and United States (Gerbaud, 2008).

Mango fruit is important from the processing point of view and contributes a share of 43 to 44 per cent to the total production of processed fruits and vegetables (Chadha, 1995). There is a great demand in the market for different value added products from ripe as well as raw mangoes. Ripe fruits are utilised for preparing squash, jam, jelly, juice, mango leather, candy, nectar, murabba, preserve, toffee and powder. Raw mango fruits are used for the preparation of pickle, brined slices and chutney powder. Thus for India, mango plays a vital role in foreign exchange earnings as well as in the empowerment of rural communities, engaged in mango cultivation.

Availability of mango fruits is restricted to a very short period. Low cost technologies for producing locally and globally consumable commodities need to be developed to encourage mango processing at home scale, cottage and small scale levels. The major processing techniques employed on industrial scale to preserve mango fruits are canning, dehydration and freezing.

Dehydration is a simple and economic method of preservation best suited for developing countries like India. Although spoilage of food is generally reduced by dehydration, undesirable changes due to several reactions may result in quality changes. The most common quality defects of dehydrated foods are tough texture, slow or incomplete rehydration, shrinkage caused by cell collapse, loss in colour, flavour and nutritional quality.

Osmotic dehydration has gained attention recently due to its potential application in the food processing industry. Osmotic dehydration is widely used for the partial removal of water from plant tissues by immersion in a hypertonic solution. The diffusion of water is accompanied by the simultaneous counter diffusion of solutes from the osmotic solution into the tissue (Lenart and Flink, 1984). It decreases the water activity in high water content foods such as fruits. This allows development of new product; make them storable without refrigeration and with minimum energy input. Osmodehydration is one of the most important complementary treatments and food preservation techniques in the processing of dehydrated foods, since it provides some benefits such as reducing the damage of heat to the flavour and colour, inhibit the enzymatic browning and decrease the energy costs.

Osmodehydration is an effective method for preservation of fruits. It facilitates processing of tropical fruits and vegetables with retention of their initial quality characteristics *viz.* colour, aroma, texture and nutritional composition. It has potential advantages for the processing industry to maintain the food quality and to preserve the wholesomeness of food (Chavan and Amarowicz, 2012).

Mango is the most ideal fruit for osmodehydration due to its excellent taste and nutritive value. The concentration and temperature of osmotic solution, duration of osmotic treatment and fruit to solution ratio are considered as significant factors during osmotic dehydration. The quality of the final product is also influenced by the variety used for osmodehydration.

Hence the study was proposed with the following objectives:

1. To standardise the process variables for osmodehydration in mango
2. To evaluate varietal suitability and storage stability of the product

Review of literature

2. REVIEW OF LITERATURE

Mango is one of the most cultivated tropical fruits in the world. It is known as "King of fruits" owing to its delicious taste and richness in vitamins and minerals. Mango, due to its excellent taste, flavour and nutritive value is a favourite fruit in all parts of the country (Singh, 1990). India is the largest producer of mango fruit accounting for about 65 per cent share in the world production (Kalra *et al.,* 1993).

Fresh mango fruits are considered as the integral part of any dietary system, since they are the rich source of minerals, vitamins and dietary fibre. The fruit is regarded as an excellent source of fibre and vitamins A, C and B complex (Tedjo *et al.*, 2002).

Osmotic dehydration is a food preservation technique that relies on the reduction of water activity and humidity of the product, which has advantages over other dehydration techniques because it preserves the sensory and nutritional characteristics of foods (Ozdemir *et al.*, 2008),

Osmotic dehydration is becoming more popular as a complementary treatment in the processing of dehydrated foods, since it presents some advantages such as minimising heat damage to the colour and flavour, inhibiting enzymatic browning and thus dispensing the addition of sulphite and, mainly, reducing energy costs (Bernardi *et al.*, 2009).

In addition it has proved to be a good method to obtain minimally processed fruits, due to the great sensory similarity between the dehydrated and in natura products (Lerici *et al.*, 1985; Sousa *et al.*, 2003).

This chapter presents the research work done in osmodehydration of fruits.

2.1. Importance of mango for processing

Mango is perishable in nature and due to inadequate storage and transportation facilities, considerable amount of mango fruit goes waste every year. One of the methods to avoid such losses of mango fruits is to process the fresh mangoes into different products. The variety of processed mango products is endless, and variations exist from country to country and region to region. An intensified effort for post harvest preservation of mango fruit is highly essential to ensure fair returns to the growers and to improve their economic conditions (Shaw *et al.*, 1993).

Mango is a fruit which has many varieties and is grown in majority of the states. Pickles, chutneys and many sweet preparations like murabba are made from unripe or semi-ripe mangoes. Ripe mangoes may be frozen as whole or peeled, sliced and packed in sugar. Thin slices of raw mango, seasoned with turmeric, are dried, and sometimes powdered, and used to impart an acid flavour to chutneys, vegetables and soup. (Morton, 1987).

Mango with many versatile properties has naturally found application for processing into various products unparalleled by any other fruit. There is a great demand in the market for the different value added products from mango. Unripe mango is processed into pickles, brine stock, chutneys and used for making chutney powder (Hicks, 1990). Ripe mango could be processed into a variety of products including juice, nectar, concentrate, jam, fruit bar (Schieber *et al.,* 2000; Berardini *et al.*, 2005).

2.2. Preservation of mango by dehydration

The choice of preservation method most often depends on the raw material. Jayaraman and Dasgupta (1992) observed that the increasing rejection of chemicals for food preservation and the demand to provide a comprehensive range of products has generated renewed interest in drying operations.

The removal of water from solid foods is a form of food conservation, inhibiting the growth of microorganisms, besides preventing a large part of biochemical reactions, which occur while the moisture is present (Park *et al.*, 2002).

Mango fruit is highly perishable and must be consumed within a few days after harvesting or it must be dried to a lower moisture content for long-term storage (Akoy *et al.*, 2013).

2.3. Osmodehydration as a technique for processing and preservation of fruits and vegetables

Research on osmotic dehydration of foods was pioneered in 1966 by Ponting and co-workers and many review articles have already been published dealing with various parameters such as mechanism of osmotic dehydration, modelling of water loss and solid gain etc.

The fundamental purpose of food dehydration is to lower the water content in order to minimise rates of chemical reactions and to facilitate distribution and storage. In osmotic dehydration, foods are immersed or soaked in a saline or sugar solution (Ponting, 1973).

Osmotic dehydration is a technique that involves product immersion in a hypertonic aqueous solution leading to loss of water through the cell membranes of the product and subsequent flow along the inter-cellular space before diffusing into the solution (Sereno *et al.*, 2001). It is a novel approach towards preservation and is done by immersing the fruit in an aqueous solution with a greater osmotic pressure. It involves two major processes, one being the outflow of water from the fruit and the other being inflow of solute into the fruit (Khan *et al.*, 2012). Osmotic dehydration is an excellent alternative for conservation of cut products. Its processes involve simultaneous water loss and solute gain (Saxena *et al.*, 2009).

Osmotic concentration is the process of water removal from fruits and vegetables, because the cell membranes are semi-permeable and allow water to pass through them more rapidly than sugar (Chavan and Amarowicz, 2012).

Osmodehydration has potential advantages of less heat damage, good blanching effect, less enzymatic browning, better retention of flavour and energy saving (Chaudhari *et al.* 1993). Various studies have been conducted to evaluate the use of osmotic processes for the development of different kinds of fruit products or food ingredients such as minimally processed or intermediate moisture fruits, or their application as a pretreatment in freezing (Pinnavaia *et al.*, 1988; Giangiacomo *et al.*, 1994) or in air drying (Alvarez *et al.*, 1995; Nieto.,1998; Sormani *et al.*, 1999; Maestrelli *et al.*, 2001).

Osmotic dehydration has some limitation according to Ponting *et al.* (1966). The decrease in acidity may be a disadvantage in certain products which is corrected by adding a fruit acid to the osmotic solution. Normally a residue of the sugar is left on the fruit after drying and although this is usually only a thin film on the surface it may be undesirable. This is reduced by a quick rinse in water after the osmotic dehydration step. Osmotic drying caused a reduction in anthocyanin in cranberries due to leaching in the syrup (Girabowski *et al.*, 2002).

Flink (1979) conducted a study on the influence of osmotic dehydration on drying behaviour and product quality of carrot slices and observed that osmotic dehydration yielded good quality product with better texture and colour stability.

The rate of osmotic dehydration is enhanced by agitation or circulation of the osmotic solution around the sample (Hawkes and Flink ,1978; Contreras and Smyrl, 1981; Lenart and Flink, 1984) . Raoult-Wack *et al.*, (1989) observed that agitation favours water loss, especially at lower temperatures (< 30°C), where viscosity is high during the early stages of osmosis.

Huxsoll (1982) reported that a substantial proportion of energy is saved when foods were osmotically dehydrated before freezing. Refrigeration load during freezing can be reduced when there is a reduction in the moisture content of food by osmotic dehydration. Osmotic dehydration increased nutrient retention during the subsequent drying (Islam and Flink, 1982). Tomar *et al.* (1990) recorded 37.9 per cent and 40 per cent decline in case of pineapple and pear.

Bolin *et al.* (1983) reported that the syrup remaining after osmotic drying can be recycled as table syrup, concentrated beverage, wines and jellies. Biswal *et al.* (1991) stated that osmotic dehydrated fruits and vegetables prior to freezing saves packing and distribution costs. The product quality is comparable with that of conventional products. The process is referred to as "dehydrofreezing".

The process of water removal and increase in osmo-active substances lowers the water activity in the cell (Lewicki and Lenart, 1992). Osmotic dehydration has also been coined as 'Dewatering and Impregnation Soaking (DIS) process' (Raoult-Wack *et al.*, 1991)

Torreggiani (1993) reported that osmotic dehydration can be used as a pretreatment to many processes used for the improvement of nutritional, sensorial and functional properties of food without changing its integrity.

Hough *et al.* (1993) observed mass transfer during osmotic treatment through semi permeable cell membranes present in biological materials which offers dominant resistance to the process. The authors also indicated that mass transfer in osmotic dehydration is combination of simultaneous water loss and solid gain.

Aguilera and Stanley (1999) mentioned that the osmotic step helps the fruit to retain its original shape and has a protective effect during air dehydration.

Osmotic drying has been successfully used to reduce water activity of fruits and vegetables to about 0.9, keeping much of the original quality. Osmotic dehydration is now considered a valuable tool in minimal processing of foods. It can be applied either as an autonomous process or as a processing step in alternative processing schemes leading to a variety of end products (Lazarides *et al.*,1999).

Solar assisted osmotic dehydration (SAOD) leads to considerable amount of moisture removal in the initial stage with the help of an osmotic agent, which shortens the solar drying time (Sudheer and Dash, 1999).

Dehydration ratio of dehydrated potato slices was good in osmotic dehydration followed by brine blanching and KMS (Kad *et al.*, 2001).

Dehydration rate is the highest at the beginning of the process of osmotic dehydration because of the large differences between osmotic pressure in the solution and the plant tissue and the degree of solution mixing (Sachetti et al., 2001; Shi *et al.*, 2002).

According to Chiralt and Fito (2003), in osmotic dehydration, water loss in the cells was promoted due to the differences in water chemical potential established between the external solution and the internal liquid phase of the cells.

Recently osmotic dehydration process received more attention due to the consumer demand for minimally processed products (Antonio *et al.*, 2004). Tiwari and Jalali (2004) reported that osmotic dehydration improved the quality of final product by increasing the sugar to acid ratio.

Osmotic dehydration is a complementary treatment in the processing of dehydrated foods, since it presents some advantages such as minimising heat damage to the colour and the flavour, inhibiting enzymatic browning and reducing energy costs (Alakali *et al.*, 2006; Torres *et al.*, 2007). As a technique for obtaining minimally processed fruits, osmotic dehydration (OD) is adequate, and does posses advantages over other drying techniques, yet it seems that some hydrosoluble components may escape into the osmotic solution (OS) during the process. On the other hand, the reuse of the OS in successive OD operations can be a good way of making the process economical and environmentally friendly (Mena *et al.*, 2007).

Studies on osmotic dehydration, ultrasound and ultrasound assisted osmotic dehydration have shown that different fruits respond differently to the application of these drying pre-treatments (Fernandes *et al.*, 2006; Souza *et al.*, 2007).

Due to the kinetics of the osmotic dehydration operation it may be used to obtain products of reduced but still relatively high moisture content, classified as intermediate moisture products, but microbiologically stable due to reduced water activity (Masmoudi *et al.,* 2007). Osmotic dehydration processes are widely applied to obtain high quality intermediate moisture foods.

A considerable cost reduction occurs in packaging and distribution of osmotically dehydrated product due to the simple nature (reduction in product weight and volume) of osmotically dehydrated products resulting in easier handling and transportation to market (Tortoe, 2010).

Osmotic dehydration is a traditional water removal process that decreases the water activity in high water content foods such as fruits. Placing foods in a hypertonic solution, two major processes take place simultaneously: water flow from the food into the solution and solute transfer from the solution into the food matrix. The natural cell surface acts as a semi-permeable membrane. Since the membrane responsible for osmotic transport is not perfectly selective, other natural solutes present in the cells such as sugars, organic acids, minerals, salts, etc. can also be leached into the osmotic solution (Naknean, 2012).

Osmotic dehydration is used to improve the economics of dehydration processes for extension of the sustainability of fruit and vegetable drying. The aim of osmotic dehydration is partial removal of water to obtain a better quality final product (Singh *et al.*, 2012).

Two osmotic dehydration methods including fast osmotic dehydration (FOD) and slow osmotic dehydration (SOD) are commonly used to produce osmo-dried fruit (Phisut *et al.*, 2013).

2.4. Effect of pre-treatments on osmodehydration

Torreggiani (1998) indicated that as a result of osmotic dehydration with aqueous sucrose solutions, apple pieces lost water and texture and gained sucrose, having poor final texture. Samples treated with $CaCl_2$ had the largest sucrose gains and best final texture.

Blanching treatments are recommendable before minimally processing the strawberry in order to preserve its colour during storage. The traditional blanching treatments using boiling water and steam, induce a faster mass transfer, when they are applied before osmotic dehydration (Alzamora *et al.*, 1997).

Calcium plays a very important role in the maintenance of quality in vegetable foods and it is used as a texturing agent (Lee *et al.*, 2003; Saftner *et al.*, 2003). Torres *et al.* (2006) studied the influence of osmotic treatments using 45 and 65°Brix sucrose containing calcium lactate at different levels on the mechanical properties of mango samples. The mechanical properties measured were affected by treatment conditions. Calcium obviously made samples stiffer, shorter and firmer.

Temperature, sucrose concentration and time of osmotic dehydration had a significant influence on the mechanical properties of osmodehydrated apples which were simultaneously impregnated with calcium. Sample thickness was significant also, but only in osmodehydrated apples without calcium impregnation (Kowalska *et al.*, 2009).

The effect of sugar concentration, syrup temperature and duration of osmosis during the osmotic dehydration process was investigated by Jain *et al.* (2011). The regression equations of second order polynomial were found to predict the behaviour of osmotic dehydration process of papaya cubes. If the papaya cubes were osmodehydrated in sugar syrup having 37°C syrup temperature, 60°Brix syrup concentration for 4.25 hours then 28% of water loss could take place with 4% solid gain which would be the good quality market acceptable product.

An attempt was made by Sakhale and Pawar (2011) to preserve mango slices by treating with 2% calcium chloride solution followed by dipping in sugar syrup of different concentrations (50, 60 and 70°Brix). The treated slices were subjected to drying in different modes of drying (oven, microwave oven and cabinet tray drying) and analyzed for various physico-chemical and organoleptic quality characteristics. The study showed that the osmo-air dried slices of mango produced with partial dehydration facilitated by osmotic agent (sugar syrup of 60 °Brix, a fruit to sugar syrup ratio of 1:4 (w/v) for 18 h at 40°C temperature) followed by mechanical drying showed superiority in sensorial quality attributes over other concentrations of ingredients and the rest of the modes of drying. The good quality osmotically dehydrated mango slices could be preserved with maximum retention of vitamins with better dehydration, rehydration and sensorial quality characteristics.

2.5. Factors influencing osmodehydration process

The chemical composition (protein, carbohydrate, fat and salt), physical structure (porosity, arrangement of cells, fibre orientation and skin) and pre-treatments may affect the kinetics of osmosis of food (Islam and Link, 1982). The geometry of sample pieces affects the behaviour of the osmotic concentration due to the variation of the surface area per unit volume (or mass) and diffusion length of water and solutes involved in mass transport (Lerici *et al.*, 1985).

Several factors affect the osmotic dehydration process, including the type and concentration of the osmotic solution, processing temperature and time, brine to tissue ratio, rate of agitation and raw material characteristics (Cunha *et al.*, 2001). Variables like maturity, variety, pretreatments, temperature, nature and concentration of osmotic agent, agitation, geometry of the material, fruit pieces to osmotic solution ratio, physico-chemical properties, additives, structure and pressure affect the osmotic dehydration process (Chavan and Amarowicz, 2012).

2.5.1. Osmotic agents

Rehydration rate and moisture absorption capacity of the osmodehydrated blue berries were reduced by intake of sugar (Kim and Toledo, 1987). Several solutes, alone or in combinations, have been used in hypertonic solutions for osmotic dehydration (Maguer, 1988). Bawa and Gujral (2000), evaluated the effect of some osmotic solutions (sucrose and honey) on water loss and solid gain of raisins. The rate of moisture loss in the fruit varied with both the osmotic agents as well as their concentration. The sensory scores indicated that honey treated samples gave better flavour while sugar treated ones gave better colour and overall acceptability.

Vial *et al.* (1991) evaluated the use of inverted sugar as osmotic agent in the osmotic dehydration of kiwi. However, due to its lower cost, sucrose is the most widely used sugar in the majority of studies using this technique.

Osmotic dehydration involves the immersion of foods in osmotic solution such as salts, alcohols, starch solutions and concentrated sugars, which to some extent dehydrates the food (Erle and Schubert, 2001). Different types of solutes such as fructose, corn syrup, glucose, sodium chloride and sucrose are used as osmotic agent for OD (Azuara and Beristain, 2002).

By using trehalose in osmotic solution, Aktas *et al.* (2007) observed less shrinkage, better colour properties and better cell reconstruction properties for dried carrot and potato. The osmotic treatment induced an increase of ethyl esters and hexanal, and the amount depended on time of osmosis (Rizzolo *et al.*, 2007).

For fruit and vegetable dehydration, the most commonly used osmotic agents are sucrose and sodium chloride and their combination. Glucose, fructose, maltodextrin and sorbitol also can be used for osmotic dehydration (Ispir and Togrul, 2009).

Use of sugar beet molasses as hypertonic solution improves osmotic dehydration processes (Misljenovic *et al.*, 2010). Loss of fresh fruit flavour commonly found with ordinary air or vacuum drying methods is prevented by the use of sugar or syrup as the osmotic drying agent (Tortoe, 2010).

Several studies were conducted to find out the effect of different osmotic agents on the osmotic dehydration process. The most commonly used osmotic agents were sucrose, glucose for fruits and NaCl for vegetables. Other osmotic agents include calcium chloride, monohydroxy ethanol and polyhydroxy compounds such as lactose, malt dextrin, corn syrup and mixtures of these items (Chavan and Amarowicz, 2012). Apricot cubes osmodehydrated in sucrose showed more pronounced drying rate reduction when compared to non-pretreated ones (Essmat *et al.*, 2012).

2.5.2. Fruit to solution ratio

Ponting *et al.* (1966) and Flink (1979) reported that an increase of osmotic solution to sample mass ratio resulted in an increase in both the solid gain and water loss in osmotic dehydration.

Heating of ripe mango (cv. Dasehari) slices in an equal weight of sugar syrup (70°Brix) containing 0.1 per cent KMS at 90°C for 2 minutes followed by drying in cabinet drier at 60°C gave the best dehydrated product (Sagar and Khurdia, 2000).

With an increase in solution to sample ratio, rate of osmosis increases up to certain level. However, it is essential to use an optimum ratio since larger ratios offer practical difficulties in handling the syrup fruit mixture for processing. A ratio of 1:2 or 1:3 is optimum for practical purpose (Tiwari, 2005).

Noroes *et al.* (2010) reported that 1:2 ratio achieved highest water loss and less solid gain which is desirable due to higher dehydration effect and less sensory changes.

2.5.3. Process temperature

Lenart and Lewicki (1988) observed that energy consumption in osmotic dehydration at 40°C with syrup re-concentration by evaporation was at least two times lower than convection air drying at 70°C. Beristain *et al.* (1990) stated that increase in temperature of osmotic solution resulted in increase in water loss, whereas solid gain was less affected by temperature.

Rahman and Lamb (1990) observed that at high temperature solute does not diffuse as easily as water through the cell membrane and thus the approach to osmotic equilibrium is achieved primarily by flow of water from the cell resulting in a lower solute gain by the food material.

Previous studies on the osmotic dehydration of strawberry have shown that sugar gain is not affected by the temperature increase in the range 30±50°C (Shi, 1994).

Kaymak-Ertekin and Sultanogli (2000) studied the effect of temperature on mass transfer during osmotic dehydration of apple. To examine the effect of temperature on osmosis behaviour, experiment was carried out at 20°C, 30°C, 40°C and 50°C in 60% sucrose solution. The water loss increased with increase in temperature while solid gain did not change significantly.

Kar and Gupta (2001) experimentally studied the osmotic drying behaviour of button mushrooms in relation to temperature (25, 40 and 55°C), solution to sample ratio (4, 6 and 8) at a fixed brine solution concentration of 15%. The study revealed that osmosis could remove almost 35% of the initial moisture in one hour, using 15% brine solution.

The most commonly used temperature for osmotic solution was 25-60°C (Matusek and Meresz, 2002).

Ramallo and Mascheroni (2005) analysed the effect of temperature on water loss, solute gain and glucose and fructose leakage during the osmotic dehydration of half-ring pineapples. The process was run at 30, 40 and 50°C. As temperature was increased from 30 to 50°C, apparent moisture and sucrose diffusivities increased 3.8 and 2.8 times, respectively. The dehydration efficiency index increased with temperature.

Fernandes *et al.* (2006) optimised the osmotic dehydration conditions of banana followed by air drying and indicated that the temperature used in osmotic dehydration affected the diffusivity of water during air drying and evaluated the mass transfer rate, with an increase in the temperature of osmotic dehydration from 50 to 70°C.

Falade *et al.* (2007) studied the effect of osmotic temperature on water loss and solid gain of watermelon slabs immersed in sucrose solution (50°Brix). Water loss and solid gain increased with the solution temperature. Higher water loss and solid gain were observed at 40°C compared to those at 20°C and 30°C.

A short time of osmotic dehydration of apples (1 h) at ambient temperature 20-35°C in 25% sucrose solution caused a lowering of compression time but after a longer time (4-5 h) the highest values were achieved. The addition of calcium ions to osmotic solution during dehydration of apples had an influence on the mechanical properties mainly at low temperatures (20°C) (Kowalska *et al.*, 2009).

Devic *et al.* (2010) also studied the effect of temperature (45°C and 60°C) on mass transfer during osmotic dehydration of apples in a 60°Brix sucrose solution. The result showed that water loss increased over time and was accelerated by a higher temperature.

Mundada *et al.* (2011) studied the effect of temperature on mass transfer during osmotic dehydration of pomegranate arils. Osmotic dehydration was done in osmotic solution of sucrose having different solution temperatures (35°C, 45°C and 55°C). It was found that higher water loss and solid gain were at 55°C compared to those at 45°C and 35°C. The increase in solid gain and water loss when samples were immersed into a high temperature solution is due to the increase in the rate of diffusion.

An increased concentration of sucrose solutions is associated with increase in the dewatering effect but not with an increased uptake of sucrose, the viscosity of the solution being a limiting factor. Water loss and solute gain during osmotic dehydration were significantly influenced by sucrose concentration and temperature especially at higher temperature values above 45°C. Temperature had a positive influence on water and solids diffusivity resulting in greater water loss and solids gain (Oladejo *et al.*, 2013).

2.5.4. Concentration of osmotic solution

Bongirwar and Sreenivasan (1977) studied the osmotic dehydration of banana and observed 50 percent reduction in weight by osmosis using sugar syrup of 70 per cent concentration. George (1994) evaluated the application of osmotic dehydration technique for product development in banana and found that the weight loss of the fruits after dewatering increased with increase in sugar concentration, temperature and immersion time. Pokharkar and Mahale (2000) observed that osmotic dehydration of banana slices in sugar syrup of 65°Brix followed by cabinet drying at 46°C for 9 to 16 hours gave a bright yellow product which was chewy with moisture content of 19.4 per cent.

Veghani and Chundavat (1986) observed that sapota slices steeped in 40 per cent sugar solution containing KMS (1 per cent) for 20 minutes or dipped in sugar solution with KMS 2 per cent for 2 minutes, when dried in sun gave the most stable and quality product. The yield of dried sapota after 33 hours of sun drying ranged from 30 to 34 per cent of which woody slices accounted for 0.38 to 3.75 per cent. Osmotic dehydration of sapota slices (0.5 to 1 cm thick) using dry sugar containing 1500 ppm SO_2 and 0.3 per cent citric acid in the ratio of 1:1 for eight hours followed by oven drying for eight hours, yielded good quality sapota chunks (Maya, 1999).

Papaya slices of 15mm thickness osmotically dehydrated by moisture infusion technique by overnight soaking in a solution containing 60 per cent sucrose, 0.1 per cent citric acid 0.1 per cent potassium sorbate reached equilibrium at 44°Brix (Ahmed and Choudhary, 1995).

Lazarides *et al.* (1995) studied the effect of sucrose concentration (45%, 55% and 65%) on mass transfer during osmotic dehydration of apple. The study revealed that the increase in sucrose concentration resulted in higher rate of water loss and solid gain throughout the osmotic period.

Ertekin and Cakaloz (1996) studied the influence of osmosis on drying behaviour and product quality of peas. Peas were osmotically dehydrated using 60% sucrose solution and 40% sucrose + 20% trisodium citrate solution. Samples osmosed with sucrose + citrate solution had higher moisture diffusivity value compared to that of non-osmosed samples, which could be due to modification of water permeability of pea skin prior to drying.

Barat *et al.* (2001) studied the change in volume of apple slices due to osmotic processes using sucrose solutions of different concentrations. A study conducted by Sacchetti *et al.* (2001) in apple using 44.6 to 64.6 per cent sucrose and 0 to 2 per cent salt concentrations indicated that an increase in the sweetness and/or saltiness reduced the product acceptability. Kalsi and Dhawan (2001) prepared guava powder by osmotic dehydration. Guava slices were blanched in boiling water for two minutes and immersed in 70°Brix sugar syrup overnight followed by cabinet drying at 65°C. The recovery percentage was found to be 5.7 per cent.

Ozen *et al.* (2002) investigated the effect of salt, sorbitol concentration, agitation, tissue to solution ratio and temperature on weight loss, solid gain, salt and sorbitol uptake, water activity, tissue Brix and solution Brix, during osmotic dehydration (OD) of diced green peppers. Results showed that salt and sorbitol concentration were the most significant factors.

Rashmi *et al.* (2005) optimized sugar syrup concentration for osmo-air dehydration of 'Giant Kew' variety of pineapple by subjecting pineapple slices to osmosis for 24 hours in 50, 60 and 70°Brix sugar syrups followed by draining and drying at 60-65°C. Maximum fruit yield and highest sensory scores, after osmo-air dehydration were observed in 60°Brix sugar syrup on fresh fruit basis.

Tsamo *et al.* (2005) studied material transfer during osmotic dehydration of onion slices and tomato fruits using commercial sucrose (600g/l), commercial sodium chloride (300g/l), or a mixture of sucrose and sodium chloride (45/15% w/w). The mixed solution of salt and sugar presented higher dehydration capacity with better control of salt penetration.

Watermelon slabs immersed into 60°Brix sucrose solution showed higher water loss and solid gain compared to those immersed in 40°Brix and 50°Brix solutions (Falade *et al.* 2007).

Oztop *et al.*(2007) optimised the microwave frying of osmotically dehydrated potato slices. The osmotic dehydration was conducted using 20 per cent (w/w) sodium chloride solution.

Ispir and Togrul (2009) studied the mass transfer during osmotic dehydration of apricot. Apricot was soaked in different sucrose concentrations (40%, 50%, and 60%). They reported that increase in sucrose concentration resulted in an increase in the osmotic pressure gradients and, hence, higher water loss and solid gain uptake values throughout the osmotic period were obtained.

Pękoslawska and Lenart (2009) analyzed the effect of concentration of starch syrup solution and temperature, on osmotic dehydration of pumpkin cubes. The process was carried out in a water bath for 60, 180 and 300 min. The most significant changes of water content, water loss and solid gain took place during osmotic dehydration in 66.3% starch syrup at a temperature of 60°C. Water activity of osmotically dehydrated pumpkin decreased at higher starch syrup concentrations, and at higher temperatures.

Pattanapa *et al.* (2010) studied the effect of sucrose and glycerol mixtures in the osmotic solution on mass transfer of mandarin. Peeled mandarin samples were immersed in osmotic solution prepared from various ratios of sucrose solution (60%) to glycerol solution (60%), specifically, 9:1, 8:2, 7:3, 6:4 and 5:5 w/w. It was found that the highest water loss was obtained when the osmotic solution of 5:5 was used.

Banana slices were immersed in sucrose solutions with concentrations (30, 40 and 50°Brix) at 40, 50 and 60°C for 60, 90 and 120 minutes. Water loss, weight reduction and solid gain increased with treatment time. Longer treatment time in high concentrations of sucrose resulted in a very soft product, which is difficult to handle and unsuitable for further drying. Increasing concentration at the same temperature did not cause significant increments in weight change. Higher concentrations of sucrose caused higher rates of water removal (Renu *et al.,* 2012).

2.5.5. Duration of osmodehydration

Studies on the optimization of duration of osmotic process indicated the mass exchange took place at the maximum rate within the first two hours of the osmotic treatment (Giangiacomo *et al.*, 1987; Torregiani, 1993).

In mango and pineapple, it was observed that increase in osmotic duration resulted in increase in weight loss, but the rate at which it occurs decreases (Tiwari, 2005).

Prinzivalli (2006) studied the effect of osmosis time on structure, texture, and pectin composition of strawberry tissues and found that solid gain was constant after four hours of osmotic dehydration. Rizzolo *et al.* (2007) studied the influence of time taken for osmotic processing of strawberry and found that changes in the volatile compounds of strawberry occurred after two hours in sucrose.

2.5.6. Vacuum impregnation

Experiments were carried out to investigate the influence of vacuum treatment on water loss and sugar gain during osmotic dehydration of fruit tissue. Vacuum treatment was shown to have a significant effect on water transfer, making it possible to use lower solution temperature, to obtain higher water transfer rate and to obtain good quality dehydrated fruit products. No significant difference was found in the sugar gain under vacuum and normal pressure treatment. The sugar gain is closely related to the biological characteristics of fresh fruits; fruits with higher porosity are more suitable for vacuum treatment (Shi and Maupoey, 1993).

Mild osmotic dehydration treatments, with or without vacuum impregnation, may be an alternative to obtain minimally processed fruits, with a longer shelf life, sensorial characteristics similar to fresh products and a high nutritive value (Fito and Chiralt, 2000).

A greater respiration rate (in terms of CO_2 generation) was detected in mango slices osmotically dehydrated in a 65°Brix sucrose solution for 30 minutes, applying vacuum pressure (Tovar *et al.*, 2001).

In osmodehydrated fruits, vacuum impregnation resulted in different tissue structural development from that occurred in non-impregnated fruits due to the substitution of air by an impregnation solution (Barat *et al.*, 1999; Moreno *et al.*, 2004).

2.6. Kinetics of osmodehydraion

Panagiotou *et al.* (1998) studied the mass transfer modeling of the osmotic dehydration of apple, banana and kiwi fruit. Osmotic dehydration was carried at 20, 40 and 60°C with sugar concentrations of 30, 40 and 50% for 0.5, 2, 6 and 16 hours. The study showed that the process temperature had significant effect on the kinetic rate of water loss. The kinetic rate of solid gain did not depend significantly on process temperature.

Singh *et al.* (2007) studied mass transfer kinetics and effective diffusivity during osmotic dehydration of carrot cubes in ternary solution of sucrose, NaCl and water. The osmotic solution concentrations used were 50°Brix + 5 percent salt (w/v), 50°Brix + 10 percent salt (w/v) and 50°Brix + 15 percent salt (w/v). Water loss and solute gain increased with an increase in concentration of salt from 5 to 15% in 50°Brix sucrose solution.

Dehydration kinetics and mass transfer mechanism is very important for understanding and controlling the osmotic dehydration process (Derossi *et al.*, 2008).

Ispir and Togrul (2009) studied the mass transfer during osmotic dehydration of apricot. Apricot was soaked in 40% sucrose solution at different temperatures such as 25°C, 35°C and 45°C. It was observed that temperature had increasing effect on the osmotic dehydration of apricot. Increasing the osmotic medium temperature caused increase in water loss and solid gain.

Misljenovic *et al.* (2009) studied osmotic dehydration of red cabbage in sugar beet molasses of different concentrations (40, 60 and 80%) at 50°C and under atmospheric pressure. The best results were obtained in the sugar beet molasses of 80% as an osmotic medium. The most important kinetic parameters of the process were determined: water loss, solid uptake, weight reduction, normalised solid content and normalized moisture content. The kinetic parameters were determined after 1, 3 and 5 hours. Mass transfer coefficients were calculated and the results indicate that the diffusion of water and solids was the most intensive during the first three hours of dehydration.

The effect of sugar syrup concentration, syrup temperature and duration of osmosis during the osmotic dehydration process was investigated by Jain *et al.* (2011). The regression equations of second order polynomial were found to predict the behaviour of osmotic dehydration process of papaya cubes. If the papaya cubes were osmo-dehydrated in sugar syrup having 37°C syrup temperature, 60°Brix syrup concentration for 4.25 hours then 28% of water loss could take place with 4% solid gain which would be the good quality market acceptable product.

2.7. Varietal suitability for osmodehydration

Different species, different varieties of the same species, even different maturity levels of the same variety have been found to give substantially different responses to osmotic dehydration (Hartel, 1967).

The effect of osmotic dehydration technique on four mango varieties viz. Chausa, Dashehari, Langra and Fazari, keeping the concentration, volume and temperature of sugar syrup constant was evaluated. The only variable maintained was the percentage of added citric acid. Mango slices of Dashehari cultivar steeped for 18 hours in 70°Brix sugar syrup containing 0.5 per cent citric acid, on drying were adjudged the best, having non-significant difference with Chausa, but significant differences existed with Fazari and Langra cultivars (Amitabh *et al.*, 2000).

Lima *et al.* (2004) carried out sensory evaluation of Tommy Atkins, Haden and Kent varieties of mango processed in sucrose syrup. Among the three varieties, Kent variety showed a significant difference for appearance. Kent variety showed a trend of lower appearance for the final product.

Vani *et al.* (2009) studied the suitability for osmotic dehydration of certain popular cultivars of mango *viz,* Alphonso, Bangalora and Banganapalli. Among the cultivars studied, osmotically dehydrated Banganapalli slices retained the highest nutritive value and was adjudged best in terms of appearance and taste.

2.8. Quality and shelf life of osmodehydrated products

In the case of canning using high moisture fresh fruit and vegetables, water flow from the product to the syrup brine causes dilution and reduced flavour. This is prevented by using the osmo-canning process to improve product stability (Sharma *et al.*, 1991).

Keeping the osmotic dehydrated mango slices above 64.8 per cent and below 75.7 per cent relative humidity could prolong the shelf life. Relative humidity would be conducive to the retention of colour and flavor (Amitabh and Tomar, 2000).

Rastogi *et al.* (2002) observed inhibition of microbial growth through osmotic dehydration by reducing the water activity of food materials.

Light photomicrographs of osmodehydrated strawberry tissues revealed that the cell links deteriorate, and the cell walls already lose their shape after 4 hours of osmotic treatment, with a consequent texture decrease (Rizzolo *et al.*, 2007).

The effect of calcium lactate (2%) on osmotic dehydration kinetics and on the respiration rate, mechanical properties and shelf-life of fresh, vacuum impregnated (VI) and pulsed vacuum osmodehydrated (PVOD) grapefruit was studied (Moraga *et al.*, 2009). An isotonic solution was used for VI and a 55°Brix sucrose solution for PVOD treatments. Vacuum pulse was carried out at 50 mbar for 10 minutes and osmotic treatment was extended to 180 minutes. An increase from 5 to 8 days in the shelf-life of grapefruit was achieved due to sample dehydration and to 11 days if calcium is added to the osmotic solution, with no effect on the mechanical properties of the sample.

Osmoactive substances such as sucrose and sodium chloride could preserve and even increase the lycopene and β-carotene content of cherry tomato by affecting the integrity of the cellular matrix (Heredia *et al.*, 2009). Koprivica *et al.* (2009) evaluated the texture and mineral content of apple, osmotically dehydrated in sugar beet molasses as compared to apples treated in saccharose solution. Osmotic dehydration was conducted at constant temperature of 55°C and atmospheric pressure. During the experiment, the concentration of sugar beet molasses was varied 40 to 80%, the concentration of saccharose solutions was varied in the range of 30 to 70%, and the most important kinetic parameters of the osmotic dehydration, after 1, 3 and 5 hours of immersion were observed. During osmotic dehydration, in the samples which were treated in sugar beet molasses, the content of minerals was increased to a great extent that enhanced their nutritive value.

Osmotic dehydration has been proposed in combination with air dehydration to improve quality attributes of air dried fruit pieces. The influence of the osmotic step and of the syrup composition on the chemical-physical properties, structure collapse and colour changes of osmo-air-dehydrated lychees were studied. Colour attributes and geometric features were evaluated by image analysis to estimate volume reduction related to absolute moisture content. Sugars added during the osmotic step help to slightly decrease shrinkage during the first phase of the subsequent air dehydration, furthermore the osmo-dehydrated lychees showed the lowest structure collapse, retaining a better superficial appearance. The incorporation of sugars improved the colour stability during air dehydration, with fructose showing the highest protective effect (Khan *et al.,* 2012).

2.9. Packaging and storage of osmodehydrated products

Packaging of dehydrated fruit must protect the product against moisture, light, dust, microflora, foreign odour, insects and rodents; provide strength and stability to maintain original product size, shape and appearance. According to Silverman and Goldblith (1965) improper packaging and storage conditions may assist microbial survival.

Studies on the effect of modified atmosphere packaging in Sopota by Mohamed *et al.* (1996) have shown that minimum spoilage due to pathogens was seen in the vacuum packed fruits.

Ahemed and Choudhary (1995) used high density polyethylene pouches for osmo-dried papaya. Dried products were kept at room temperature for six months and it was accepted with little changes.

Aluminium foil laminated polyethylene pouches are suggeseted as ideal packing materials for osmotically dehydrated fruits (Sagar and Khurdiya, 1999).

A study conducted by Habeeba (2005) revealed that between the packaging materials tried, aluminium foil laminated pouches was better than polyethylene and among the packaging methods, vacuum packed samples in aluminium foil laminated pouches retained the maximum quality of osmodehydrated fig throughout the storage period.

Kumar *et al.* (2008) discovered that Osmo-vac dehydrated mango slices could be stored for six months with better nutritional quality after packing in 250 guage COEX pouches with nitrogen flushed followed by storage at low temperature (7±1 °C).

Bongirwar and Sreenivasan (1977) reported that the osmotically dehydrated banana products can be preserved up to one year or more depending upon the storage conditions and packaging materials used. Good quality, food grade and air tight containers can be used to store osmotically dried foods (Chavan and Amarowicz, 2012).

Materials and methods

3. MATERIALS AND METHODS

The research work on "Process standardisation and varietal screening for osmodehydration in mango (*Mangifera indica*.L)." was conducted at the Department of Processing Technology, College of Horticulture, Vellanikkara during 2011-2013.

The study was divided into three different experiments:

Experiment I : Standardisation of process variables for osmodehydration of mango

Experiment II : Evaluation of varietal suitability for osmodehydration

Experiment III : Storage studies of osmodehydrated mango

3.1. Chemical composition of mango fruit

The chemical constituents of fresh mango fruit *viz.*TSS, ascorbic acid and acidity were estimated.

3.1.1. TSS

The total soluble solids (TSS) content of fresh mango fruits was determined using hand refractometer.

3.1.2. Acidity

Acidity of the fruits was determined by titration with standard sodium hydroxide solution (0.1N NaOH), and expressed as per cent of citric acid (Ranganna, 1997).

Procedure: One gramme of the sample was weighed accurately and placed in a 250 ml conical flask. 100ml of water was added and boiled it for 15 minutes on the gas burner. The extract was cooled and made up to 250 ml in a volumetric flask. It was mixed well and filtered through filter paper and 30ml of supernatant was collected in 250ml conical flask. Few drops of phenolphthalein indicator was added and titrated with 0.1N NaOH. End point of titration was pink colour of solution in the beaker. Acidity was expressed in per centage.

3.1.3. Ascorbic acid

Five grammes of fruit sample was taken and extracted with four per cent oxalic acid. Ascorbic acid content of the fruit was estimated by using standard indicator dye 2, 6-dichlorophenol indophenol and expressed as mg/100g of fruit sample (Sadasivam and Manikam, 1992).

3.2. Standardisation of process variables for osmodehydration of mango

The temperature of osmotic solution, concentration of immersion solution, duration of immersion and fruit to solution ratio were standardised under this experiment. Local mango variety 'Muvandan' was selected for the process standardisation.

3.2.1. Temperature of osmotic solution

Fresh, firm ripe mango fruits were procured from the local market in Thrissur district in the state of Kerala. Fruits were thoroughly washed, peeled and sliced into pieces of about 1cm^3 size with a stainless steel knife. Samples weighing 200 grammes were taken for each set of experiments. The solute used for osmodehydration was sugar. Different ranges of temperatures (ambient, 20°C, 30°C, 40°C) were tried for osmodehydration process. Temperature higher than ambient was maintained by keeping the containers in a water bath. The sugar concentration for osmodehydration was 50°Brix and duration of immersion was 6 hours. Potassium metabisulphite (KMS) and citric acid were added to the osmotic solution at the rate of 0.1% each. Quality of the product was judged by sensory evaluation.

The different treatments were:

T_1- Ambient temperature

T_2- 20°C

T_3- 30°C

T_4- 40°C

The trial was conducted in Completely Randomized Design (CRD). There were four treatments with equal number of replications.

3.2.2. Concentration of immersion solution and duration of immersion

The temperature of osmotic solution standardised in the preliminary trial (40°C) was used for this experiment. The mango slices were soaked in sugar syrup of varying concentrations for different durations. The slices were then taken out of osmotic solution, gently blotted with absorbent paper and dried in a cabinet drier.

The trial was conducted in Completely Randomized Design (CRD). The number of treatments were twenty with three replications for each treatment.

Table 1. Quantity of ingredients for the standardisation of concentration of immersion solution and duration of immersion

Treatments	Fruit weight (g)	Duration of immersion (Hours)	Sugar solution concentration (°Brix)	Citric acid (%)	KMS (%)
T_1	200	4	40 °B	0.1	0.1
T_2	200	4	50 °B	0.1	0.1
T_3	200	4	60 °B	0.1	0.1
T_4	200	4	70 °B	0.1	0.1
T_5	200	6	40 °B	0.1	0.1
T_6	200	6	50 °B	0.1	0.1
T_7	200	6	60 °B	0.1	0.1
T_8	200	6	70 °B	0.1	0.1
T_9	200	8	40 °B	0.1	0.1
T_{10}	200	8	50 °B	0.1	0.1
T_{11}	200	8	60 °B	0.1	0.1
T_{12}	200	8	70 °B	0.1	0.1
T_{13}	200	10	40 °B	0.1	0.1
T_{14}	200	10	50 °B	0.1	0.1
T_{15}	200	10	60 °B	0.1	0.1
T_{16}	200	10	70 °B	0.1	0.1
T_{17}	200	12	40 °B	0.1	0.1
T_{18}	200	12	50 °B	0.1	0.1
T_{19}	200	12	60 °B	0.1	0.1
T_{20}	200	12	70 °B	0.1	0.1

3.2.3. Fruit to osmotic solution ratio

The fruit to solution ratio was standardised by comparing different ratios of fruit sample and osmotic solution. The concentration of sugar solution (70°Brix) and duration of immersion (12 hours) standardised in the previous trial were used for this study.

The different treatments were:

T_1- 1:1 (Dry sugar)

T_2- 1:1 (Sugar syrup)

T_3- 1:2 (Sugar syrup)

T_4- 1:3 (Sugar syrup)

T_5- 1:4 (Sugar syrup)

The trial was conducted in Completely Randomized Design (CRD). The number of treatments were five and replications taken were three.

3.2.4. Observations

3.2.4.1. Fresh weight

The initial fresh weight of the samples was recorded by a .weighing balance.

3.2.4.2. TSS

The total soluble solids (TSS) content of fresh mango fruits was determined using hand refractometer.

3.2.4.3. Acidity

Acidity of the fruits was determined by titration with standard sodium hydroxide solution (0.1N NaOH), and expressed as per cent of citric acid (Ranganna, 1997).

3.2.4.4. Moisture content

Moisture content of the product was estimated by oven dry method. Ten grammes of the product was kept in hot air oven and dried until its weight became constant. The moisture content was calculated and expressed in percentage.

3.2.4.5. Weight loss per cent, solid gain per cent and water loss per cent

Changes in weight loss per cent (WTL), water loss per cent (WL) and solid gain per cent (SG) during the process of osmodehydration were observed. For calculation, following equations were used:

$$WTL = \frac{(M_0 - M) \times 100}{M_0}$$

$$SG = \frac{(m - m_0) \times 100}{M0}$$

$$WL = \frac{(M_0 - m_0) - (M - m) \times 100}{M_0}$$

Where,

M_0= initial mass of fresh sample (g) prior to osmodehydration

M = mass of sample after time 't' of osmodehydration (g)

m = dry mass of sample after time 't' of osmodehydration (g)

m_0= dry mass of fresh sample prior to osmodehydration (g)

(Singh *et al.*, 2008)

3.2.4.6. Organoleptic evaluation

Organoleptic evaluation of mango chunks was carried out using the 9 point hedonic scale score card by a panel of ten selected judges (Jellinek,1985).

3.2.4.6.1. Preparation of score card

Score card including the quality attributes like appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability was prepared for sensory evaluation of mango chunks. Each of the above mentioned qualities were assessed by a 9 point hedonic scale. The score card used for the evaluation of mango chunks is given in Appendix II.

3.3. Evaluation of varietal suitability for osmodehydration

The following varieties of mango were evaluated for their suitability for osmodehydration.

T_1- Priyur

T_2- Muvandan

T_3- Neelum

T_4- Bangalora

T_5- Bennet Alphonso

T_6- Ratna

T_7- Banganapalli

T_8- Vellaikolumban

Osmodehydrated mango was prepared by the method standardised in the first experiment. The size of mango slices used for this experiment was $3\times 1\times 0.5$ cm. Size of the mango slices was increased compared to the first experiment. Considerable shrinkage was observed when mango slices of $1cm^3$ size were used for the study. The trial was conducted in Completely Randomized Design (CRD). The number of treatments/ varieties were eight and replications taken were three.

3.3.1. Observations

3.3.1.1. TSS

The total soluble solids (TSS) content of fresh mango fruits was determined using hand refractometer.

3.3.1.2. Acidity

Acidity of the fruits was determined by titration with standard sodium hydroxide solution (0.1N NaOH), and expressed as per cent of citric acid (Ranganna, 1997).

3.3.1.3. Ascorbic acid

Five grammes of sample was taken and extracted with four per cent oxalic acid. Ascorbic acid content of the pulp was estimated by using standard indicator dye 2, 6-dichlorophenol indophenol and expressed as mg/100g of pulp (Sadasivam and Manikam, 1992).

3.3.1.4. β- carotene content

β- carotene was estimated by procedure as suggested by De Ritter and Purcell (1981).

Samples were extracted using hexane. To one gramme of mango fruit in a mortar, 15ml of hexane was added, the mixture crashed into a paste and transferred immediately into an amber bottle to prevent destruction by light. More hexane (15ml) was added, the bottle shaken for 5-10 minutes, allowed to stand and the extract filtered into 50ml volumetric flask using Whatman filter paper No.1. The residue was treated with another 15ml of hexane and the above procedure has repeated to extract any remaining β-carotene pigments. All the extract was made up to 50ml mark with more hexane and the absorbency was observed by spectrophotometry.

The standard curve for all spectrophotometric readings was derived using absorbency readings obtained for standard β-carotene dissolved in hexane at concentrations of 0.005-0.02 mg/ml. All β-carotene measurements were at 450 nm. The calculation of β-carotene was as follows:

$$\beta\text{-carotene content } (\mu g/100g) = \frac{\text{observed } \beta\text{-carotene content } (\mu g/ml) \times V \times D \times 100 \times 100}{W \times Y}$$

Where,

V = total volume of extract

D = dilution factor

W = sample weight

Y = percentage *dry matter content of the sample*

3.3.1.5. Moisture content

Moisture content of the product was estimated by oven dry method.

3.3.1.6. Sensory evaluation

Organoleptic evaluation of mango chunks was carried out using the 9 point hedonic scale score card by a panel of ten selected judges.

3.4. Storage studies of osmodehydrated mango

The best variety identified in the 2^{nd} experiment (Ratna) was used for storage studies. The effect of the following packaging materials on quality and shelf life of osmodehydrated mango were studied.

Plate 1. Instruments used for chemical analysis

Hand refractometer

Spectrophotometer

T_1- Packaging in 200 gauge polyethylene (PE) cover

T_2- Vacuum packaging in PE cover

T_3- Packaging with nitrogen gas in PE cover

T_4- Packaging in metalized polyester cover

T_5- Packaging in aluminium foil laminated cover

T_6- Packaging in rigid plastic container

The osmodehydrated mango was packaged in the above materials and stored for a period of three months at ambient temperature. The quality parameters were assessed at monthly intervals during storage.

The trial was conducted in Completely Randomized Design (CRD). The number of treatments were six and replications taken were three.

3.4.1. Microbial count

Microbial count at the beginning and end of storage was enumerated. Serial dilution plating technique was used for isolation and enumeration of bacteria, yeast and fungi. One gramme of sample was extracted using a sharp knife from the above treatments under aseptic conditions. The sample was suspended in 9 ml of distilled water which gave a dilution of 10^{-1}. The serial dilutions of 10^{-2} and 10^{-3} were made by pipetting 1 ml to the dilution blanks containing 9 ml distilled water. Finally, these dilutions were added to sterile petridish containing sterilized media *viz.* Nutrient Agar for bacteria, Potato Dextrose Agar for fungi and Sabourod Dextrose Agar for yeast. Dilution of 10^{-3} was selected for enumeration of bacteria, 10^{-2} and 10^{-1} were selected for fungi and yeast respectively.

Upon solidification, plates were incubated for 2-3 days at room temperature. After incubation, the plates were observed for growth of yeast, fungi and bacteria. Colony counts were taken and colony forming units (cfu) per gramme of sample were calculated.

$$\text{cfu/g of sample} = \frac{\text{Number of colonies} \times \text{Dilution factor}}{\text{Volume of sample plated}}$$

3.4.2. Insect infestation during storage

By examining the product, the occurrence of any insect infestation during storage was assessed at monthly intervals.

3.4.3. Changes in chemical constituents

Chemical constituents like TSS, acidity, ascorbic acid and β-carotene *etc.* were estimated initially and at monthly intervals during storage.

3.4.4. Sensory evaluation

Organoleptic evaluation of the products was done initially and at monthly intervals till the end of three months of storage.

3.5. Analysis of data

The observations were recorded and tabulated and the data were analysed statistically as Completely Randomised Design (CRD). The scores of sensory evaluation were analyzed by Kruskal Wallis test and Kendall's coefficient of concordance.

Results

4. RESULTS

The results of the study entitled "Process standardisation and varietal screening for osmodehydration in mango (*Mangifera indica* .L)" are presented in this chapter.

4.1. Process standardisation for osmodehydration

The concentration of immersion solution, duration of immersion, temperature of osmotic solution and fruit to solution ratio were standardised under this experiment. The results of the experiment on process standardisation for osmodehydration are presented here.

4.1.1. Temperature of osmodehydration process

The temperatures of the osmotic solution tried were (T_1) ambient, (T_2) 20°C, (T_2) 30°C and (T_2) 40°C. Sugar was used as the osmotic agent. Concentration of osmotic solution and duration of osmotic dehydration were 50° Brix and 6 hours respectively.

4.1.1.1. Dry weight (g)

T_4 (40°C) recorded highest dry weight (56.83g) followed by T_3 (55.94g) and T_1 (55.47 g). The minimum dry weight (54.60g) was observed in T_2 (20°C). The difference recorded in dry weight, however was not significant (Table 2).

4.1.1.2. Weight loss per cent

Significant differences were not observed between treatments in weight loss per cent. Weight loss per cent was high in T_4 (17.38 per cent) followed by T_1 (15.22 per cent) and T_3 (14.58 per cent). T_2 (14.19 per cent) possessed the least weight loss per cent.

Table 2. Effect of process temperature on physical and biochemical characteristics

Treatments		Dry weight (g)	Weight loss %	Water loss %	Solid gain %	Titrable acidity (%)	TSS (°Brix)	Moisture content (%)
T_1	Ambient	55.47	15.22	21.58	6.35	2.39	24.9	25.95
T_2	20°C	54.60	14.19	20.10	5.92	2.86	24.3	33.56
T_3	30°C	55.94	14.58	21.17	6.59	3.04	31.2	27.63
T_4	40°C	56.83	17.38	24.97	7.59	3.12	40.6	26.43
CD		NS	NS	NS	NS	NS	9.26	NS

NS- Non significant

4.1.1.3. Water loss per cent

The recorded water loss per cent was highest in T_4 (24.97 per cent), which was on par with other treatments. The minimum water loss (20.10 per cent) was recorded in T_2.

4.1.1.4. Solid gain per cent

The highest solid gain per cent was recorded in T_4 (7.59 per cent) which was on par with other treatments. Solid gain per cent showed increasing trend with increase in temperature.

4.1.1.5. TSS (°Brix)

Significant differences were observed between treatments in total soluble solid content (TSS). T_4 (40°C) recorded the maximum TSS (40.6°Brix) followed by T_3 (31.2°Brix), T_1 (24.9°Brix) and T_2 (24.3°Brix). TSS was found to increase with corresponding rise in temperature from 20 to 40°C.

4.1.1.6. Titrable acidity (per cent)

The differences observed in titrable acidity between treatments were not significant. Acidity recorded in T_4, T_3, T_2 and T_1 respectively were 3.12 per cent, 3.04 per cent, 2.86 per cent and 2.39 per cent. Acidity was highest in T_4 (40°C).

4.1.1.7. Moisture content of the product (per cent)

Significant variation was not observed between treatments in moisture content. It ranged from 25.95 per cent in T_1 to 33.56 per cent in T_2.

A slight increase in all the physical and biochemical parameters except titrable acidity with increase in temperature was observed.

The best temperature for osmodehydration of mango was found to be 40°C. Weight loss, water loss and solid gain per cent were recorded at 2 hours intervals of osmodehydration for the best treatment (40°C) (Table 3). It was observed that there was gradual increase in weight loss, water loss and solid gain

Table 3. Mass transfer during osmotic dehydration at 40 °C

Duration	Weight loss %	Water loss %	Solid gain %
2 hours	8.02	10.65	2.63
4 hours	12.38	16.76	4.38
6 hours	15.37	22.40	7.03
CD	3.10	5.89	3.01

per cent with increase in duration of immersion during the osmodehydration process.

4.1.1.8. Organoleptic evaluation of osmodehydrated mango (OD mango)

The agreement regarding the scoring of judges on the various parameters like appearance, flavor, texture, odour, taste and overall acceptability for the product was analysed using Kendall's coefficient of concordance (W). It was found to be significant for all the parameters under observation (Appendix I (a)). Hence the mean scores were taken to differenciate the acceptability of the products with regard to the characters. Mango osmodehydrated in a osmotic solution at temperature 40°C (T_4) secured the highest mean rank score for appearance, flavour, texture, odour, taste and overall acceptability (Table 4). The scores obtained for the above attributes were 7, 6.3, 7.1, 5.9, 7.2 and 7 respectively. Score recorded for the sensory attribute colour was highest in T_1 (7.2) followed by T_4 (7.1). The highest mean rank score for odour was observed in T_1 and T_4 (5.9).

Osmodehydration with sugar solution of 40°C was found to be the best for mango. The highest values for dry weight, weight loss per cent, water loss per cent, solid gain per cent and TSS were observed in T_4 (40°C). Maximum scores for all sensory attributes in organoleptic evaluation were also recorded for the same treatment.

4.1.2. Concentration and duration of osmodehydration process

The temperature of osmotic solution standardized in the previous trial (40°C) was used in this experiment. The sugar concentrations tried were 40, 50, 60 and 70°Brix. Five durations of immersion (4, 6, 8, 10 and 12 hours) were evaluated. The dry weight, weight loss, solid gain per cent of each samples were recorded after immersion in osmotic solution. Titrable acidity, TSS and moisture content of the osmodehydrated (OD) mango were also recorded.

Table 4. Effect of temperature of osmotic solution on sensory attributes of OD mango

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1 Ambient	6.6	7.2	5.5	6.1	5.9	7.1	6.0	6.2
T_2 20°C	5.9	6.1	5.4	6.0	4.9	6.3	5.7	5.7
T_3 30°C	6.6	6.6	5.7	6.8	5.6	6.9	5.3	6.4
T_4 40°C	7.0	7.1	6.3	7.1	5.9	7.2	6.3	7.0

4.1.2.1. Dry weight (g)

The highest dry weight (64.21g) was observed in T_{20} (sugar solution of 70°Brix) followed by T_{16} (63.47g) and T_{12} (62.90g) at 12 hours after immersion in sugar solution. The minimum dry weight (48.66g) was recorded in T_1 (Table 5). Dry weight was highest in osmodehydrated mango immersed in sugar solution of 70°Brix and lowest in 40°Brix throughout the period of osmotic dehydration.

4.1.2.2. Weight loss per cent

T_{20} (sugar solution of 70°Brix, 12 hours after immersion) showed maximum mean weight loss per cent (17.84 per cent) followed by T_{16} (17.62 per cent) and T_{12} (17.25 per cent). The least weight loss (5.77 per cent) was observed in T_1 (sugar solution of 40°Brix, 4 hours after immersion). Weight loss per cent was the lowest in sugar solutions of 40°Brix concentration also at 6, 8, 10 and 12 hours after immersion (Table 5).

4.1.2.3. Water loss per cent

T_{20} (sugar solution of 70°Brix, 12 hours after immersion) exhibited the maximum water loss per cent (28.56 per cent) followed by T_{16} (27.97 per cent), T_{15} (26.44 per cent) and T_8 (26.30 per cent). The minimum water loss (8.72 per cent) was observed in T_1 (sugar solution of 40° Brix, 4 hours after immersion).

4.1.2.4. Solid gain per cent

An increasing trend was observed in the case of solid gain per cent with increase in concentration of sugar solution and duration of immersion. The maximum solid gain per cent (10.72 per cent) was observed in T_{20} (sugar solution of 70°Brix 12 hours after immersion) followed by T_{16} (10.35 per cent) and T_{12} (10.07 per cent). Solid gain was lowest (2.95 per cent) in T_1 (sugar solution of 40°Brix 4 hours after immersion).

Table 5. Effect of concentration of sugar solution and duration of immersion on biochemical constituents of OD mango

Treatments			Dry weight (g)	Weight loss %	Water loss %	Solid gain %	Titrable acidity (%)	TSS (°Brix)	Moisture content (%)
T_1	40 °B	4 Hours	48.66	5.77	8.72	2.95	1.74	24.9	19.09
T_2	50 °B		51.53	12.38	16.76	4.38	2.75	38.8	19.05
T_3	60 °B		54.13	12.65	18.34	5.68	2.81	40.5	19.40
T_4	70 °B		57.53	14.74	22.12	7.38	2.63	40.8	21.18
T_5	40 °B	6 Hours	53.26	13.48	18.73	5.25	2.58	32.0	18.51
T_6	50 °B		56.80	15.37	22.40	7.03	3.07	40.3	25.33
T_7	60 °B		58.77	15.80	23.80	8.00	2.38	40.8	24.67
T_8	70 °B		61.71	16.83	26.30	9.47	2.88	41.7	20.40
T_9	40 °B	8 Hours	57.61	13.66	21.08	7.42	2.12	40.9	17.27
T_{10}	50 °B		60.21	14.32	23.04	8.72	2.12	44.8	17.37
T_{11}	60 °B		60.71	14.87	23.84	8.97	0.78	56.5	18.60
T_{12}	70 °B		62.90	17.25	27.32	10.07	0.92	56.7	16.93
T_{13}	40 °B	10 Hours	57.85	14.34	21.88	7.54	1.46	46.7	18.57
T_{14}	50 °B		60.54	15.27	24.12	8.84	1.37	51.5	21.46
T_{15}	60 °B		60.90	17.36	26.44	9.08	0.83	61.1	21.11
T_{16}	70 °B		63.47	17.62	27.97	10.35	0.96	65.5	22.60
T_{17}	40 °B	12 Hours	60.75	14.62	23.61	8.99	0.99	58.1	16.47
T_{18}	50 °B		60.93	15.73	24.81	9.08	0.98	61.6	20.16
T_{19}	60 °B		62.45	16.37	26.21	9.84	0.59	64.9	18.20
T_{20}	70 °B		64.21	17.84	28.56	10.72	0.64	68.5	19.87
CD($p<.05$)			NS	NS	NS	NS	0.57	6.13	NS

NS Non significant

4.1.2.5. Titrable acidity (per cent)

The variation observed between the different treatments in titrable acidity was significant. T_6 (sugar solution of 50°Brix 6 hours after immersion) registered the highest acidity (3.07 per cent) followed by T_8 (2.88 per cent) and T_3 (2.80 per cent). The least titrable acidity was observed in T_{19} (0.59 per cent). An initial increase in acidity upto 4 hours of immersion in sucrose solution and thereafter a decreasing trend was noted.

4.1.2.6. TSS (°Brix)

Significant variation was recorded between treatments in TSS content. T_{20} showed the maximum TSS (68.5°Brix) followed by T_{16} (65.5°Brix) and T_{19} (64.9°Brix). TSS was minimum (24.9°Brix) in T_1 (40°Brix, 4 hours after immersion). TSS was found to increase with increase in concentration of sugar solution and increase in duration of immersion.

4.1.2.7. Moisture content (per cent)

Moisture content recorded was highest (25.33 per cent) in T_6 (sugar solution 50°Brix, 6 hours duration) followed by T_7 (24.67 per cent), and T_{16} (22.60 per cent). T_{17} (sugar solution 40°Brix, 12 hours duration) possessed the lowest moisture content (16.47 per cent).

Immersion for 12 hours in sugar solution of concentration 70°Brix was found to be the best for the preparation of osmodehydrated mango. Variation was observed in weight loss, water loss and solid gain per cent when recorded at 2 hours interval during osmodehydration in 70°Brix for 12 hours duration. Weight loss, water loss and solid gain per cent gradually increased with immersion time of osmotic dehydration (Table 6).

4.1.2.8. Organoleptic evaluation

The mean ranks for appearance, colour, taste, odour and overall acceptability (7.2, 7.6, 7.8, 6.4, 7.9 respectively) was highest in T_{20} (osmotic

Table 6. Mass transfer during osmotic dehydration in 70°Brix sugar solution

Duration	Weight loss %	Water loss %	Solid gain %
2 hours	11.48	17.00	5.52
4 hours	14.74	22.12	7.38
6 hours	16.83	26.30	9.47
8 hours	17.25	27.32	10.07
10 hours	17.62	27.97	10.35
12 hours	17.84	28.56	10.72
CD	3.67	5.8	2.25

solution of 70°Brix, 12 hours after osmotic dehydration). Maximum score for texture (7.2) was observed in T_{17} (osmotic solution of 40°Brix, 12 hours after duration). The highest score for the parameter after taste (6.4) was in T_4 (70°Brix, 4 hours after osmotic dehydration and T_{11} (60°Brix, 8 hours duration). Score for flavor was maximum (6.6) in T_{15} (60°Brix, 10 hours duration) and T_{20} (Table 7 and Appendix I (b)).

T_{20} (70°Brix with 12 hours duration) was found to be the best treatment with highest weight loss (17.84 per cent), water loss (28.56 per cent) and solid gain (10.72 per cent). Maximum TSS (68.5°Brix) was also recorded for the same treatment.

4.1.3. Standardisation of fruit to solution ratio

The effect of fruit to solution ratio on osmodehydration process was studied using different solution ratios. T_1-1:1 dry sugar, T_2- 1:1 sugar syrup, T_3-1:2 sugar syrup, T_4-1:3 sugar syrup and T_5-1:4 sugar syrup. Significant variation was observed between treatment in physical and biochemical parameters (Table 8).

4.1.3.1. Dry weight (g)

T_3 (fruit to solution ratio of 1:2 sugar syrup) recorded highest dry weight (64.97g) followed by T_4 (63.43g), T_5 (60.57g) and T_2 (59.72g). The lowest dry weight of 59.22g was observed in T_1 (1:1 dry sugar) (Table 8).

4.1.3.2. Weight loss per cent

Weight loss per cent was maximum (19.91 per cent) in T_3 (1:2 sugar syrup) followed by T_4 (17.58 per cent), T_2 (17.25 per cent) and T_5 (16.78 per cent). The minimum weight loss (16.66 per cent) was observed in T_1 (1:1 dry sugar).

Table 7. Effect of concentration of osmotic solution and duration of immersion on sensory attributes

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	6.0	6.8	5.3	6.3	4.2	6.9	5.7	6.5
T_2	6.2	7.1	5.4	5.5	5.8	7.1	6.0	5.7
T_3	6.3	7.0	5.9	6.3	5.6	6.6	6.2	6.0
T_4	5.7	6.6	4.9	7.0	6.0	6.9	6.4	6.9
T_5	6.9	7.2	5.7	5.9	5.7	7.1	5.3	6.7
T_6	6.0	6.9	5.4	6.0	5.0	7.3	5.7	7.0
T_7	6.6	7.1	6.2	6.3	6.0	7.0	6.1	5.9
T_8	7.0	7.3	5.7	7.1	6.2	6.9	5.4	7.1
T_9	6.1	7.0	6.5	6.6	5.7	7.1	6.1	7.0
T_{10}	5.9	6.6	4.9	5.7	4.9	7.2	5.3	6.2
T_{11}	6.6	7.1	6.3	7.0	6.1	7.3	6.4	6.9
T_{12}	7.1	7.3	6.0	6.2	5.3	7.6	6.0	7.0
T_{13}	6.9	7.0	6.1	6.3	6.2	7.2	6.6	6.1
T_{14}	7.0	7.2	6.3	6.6	6.0	6.9	5.7	6.2
T_{15}	7.1	7.3	6.6	6.1	5.7	7.0	5.9	6.4
T_{16}	7.1	6.8	5.9	6.1	5.6	7.7	6.3	7.1
T_{17}	6.9	7.0	6.0	7.2	6.0	7.0	6.1	7.0
T_{18}	6.3	7.1	6.2	7.1	6.1	7.2	5.9	6.9
T_{19}	7.0	7.3	6.0	7.1	5.7	7.3	5.7	7.3
T_{20}	7.2	7.6	6.6	7.0	6.4	7.8	6.0	7.9

Table 8. Effect of fruit to solution ratio on physical and biochemical parameters of OD mango

Treatments		Dry weight (g)	Weight loss %	Water loss %	Solid gain %	Titrable acidity (%)	TSS (°Brix)	Moisture content (%)
T_1	1:1 (Dry sugar)	59.22	16.66	24.89	8.23	1.45	51.9	19.64
T_2	1:1 (Syrup)	59.72	17.25	25.73	8.48	1.76	59.3	21.53
T_3	1:2 (Syrup)	64.97	19.91	31.02	11.11	0.92	63.1	20.27
T_4	1:3 (Syrup)	63.43	17.58	27.92	10.33	1.35	61.6	18.59
T_5	1:4 (Syrup)	60.57	16.78	25.70	8.92	0.87	59.0	21.31
CD		2.61	2.32	4.18	2.07	0.25	8.13	NS

NS- Non significant

4.1.3.3. Water loss per cent

The highest water loss per cent was observed in T_3 (31.02 per cent) followed by T_4 (27.92 per cent), T_2 (25.73 per cent) and T_5 (25.70 per cent). The lowest water loss was observed in T_1 (24.89 per cent).

4.1.3.4. Solid gain per cent

Solid gain per cent was maximum (11.11 per cent) in T_3 (1:2 sugar syrup) followed by T_4 (10.33 per cent), T_5 (8.92 per cent) and T_2 (8.48 per cent). Minimum solid gain per cent (8.23 per cent) was in T_1 (1:1 dry sugar).

4.1.3.5. Titrable acidity (per cent)

The lowest value for titrable acidity (0.87 per cent) was recorded in T_5 (1:4 sugar syrup). Titrable acidity was highest in T_2 (1.76 per cent) followed by T_1 (1.45 per cent) and T_4 (1.35 per cent).

4.1.3.6. TSS ($^\circ$Brix)

Highest TSS (63.1°Brix) was observed in T_3 (1:2 sugar syrup). Lowest value for TSS was observed in T_1 (51.9°Brix). The variation between treatments in total soluble solid content was significant.

4.1.3.7. Moisture content (per cent)

Significant variation in moisture content was not observed between treatments in moisture content. It ranged from 18.59 per cent in T_4 (1:3 sugar syrup) to 21.53 per cent in T_2 (1:1 sugar syrup).

T_3 (Fruit to solution ratio1:2) recorded the highest dry weight, weight loss, water loss and solid gain per cent. The maximum TSS (63.1°Brix) was also recorded for this treatment. Increase in fruit to solution ratio beyond this level resulted in decrease in dry weight, weight loss, solid gain per cent and TSS.

Hence a fruit to solution ratio of 1:2 was identified as the best for osmodehydration in mango. Weight loss, water loss and solid gain per cent of the

Plate 2. Osmodehydrated mango at different temperature

te 3. Osmodehydrated mango with different fruit to solution ratios

selected treatment were recorded at 2 hours interval (Table 9). Weight loss, water loss and solid gain per cent gradually increased with duration of immersion.

4.1.3.8. Organoleptic evaluation

Maximum scores for all of the attributes was recorded in T_3 (1:2 sugar syrup). The score recorded in T_3 for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability were 7.4, 7.4, 6.9, 6.5, 6.5, 7.4, 6.6 and 7.4 respectively (Table 10). Kendall's coefficient of concordance (W) was significant for all the parameters indicating an agreement between judges in evaluation of these parameters (Appendix I (c)).

4.2. Varietal screening for osmodehydration in mango

Eight varieties of mango *viz.* Priyur, Muvandan, Neelum, Bangalora, Bennet Alphonso, Ratna, Banganapalli and Vellaikolumban were selected for evaluating their suitability for osmodehydration.

4.2.1. Chemical constituents of fresh mango fruits

The chemical constituents *viz.* TSS, titrable acidity, ascorbic acid and β-carotene of the ripe fruits were analysed (Table 11).

4.2.1.1. Total Soluble Solids (TSS)

Total Soluble Solids content differed significantly between the different varieties of mango. The maximum TSS of 23.6 °Brix was observed in the variety Ratna followed by Bennet Alphonso (21.5°Brix) and Banganapalli (20.2 °Brix). The minimum TSS was recorded in Muvandan (13.2 °Brix).

4.2.1.2. Titrable Acidity (Per cent)

There was significant difference with respect to acidity between the eight varieties. Variety Bangalora recorded the mean maximum acidity (1.14 per cent) followed by Vellaikolumban (0.71 per cent) and Muvandan (0.64 per cent). Priyur recorded the lowest acidity (0.27 per cent). The acidity recorded in varieties

Plate 4. Mango varieties used for osmodehydration

Priyur

Muvandan

Neelum

Bangalora

Bennet Alphonso

Ratna

Banganapalli

Vellaikolumban

Table 9. Mass transfer during osmodehydration at 1:2 fruit to solution ratio

Duration	Weight loss %	Water loss %	Solid gain %
2 hours	4.86	6.30	1.44
4 hours	12.36	15.98	3.62
6 hours	13.48	18.77	5.29
8 hours	17.64	27.98	10.33
10 hours	17.88	28.45	10.57
12 hours	19.91	31.08	11.10
CD	3.3	4.8	1.59

Table 10. Effect of fruit to solution ratio on sensory attributes of osmodehydrated mango

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1 1:1 (Dry sugar)	6.4	6.9	5.5	5.2	5.2	6.8	5.3	6.0
T_2 1:1 (Syrup)	6.0	6.5	5.6	5.1	5.1	6.0	5.1	6.1
T_3 1:2 (Syrup)	7.4	7.4	6.9	6.5	6.5	7.4	6.6	7.4
T_4 1:3 (Syrup)	7.0	7.1	6.4	6.0	6.0	7.2	6.5	7.2
T_5 1:4 (Syrup)	6.8	7.0	5.8	5.6	5.6	7.2	6.1	6.9

Table 11. Chemical constituents of different mango varieties

Varieties		TSS (° Brix)	Titrable acidity (%)	Ascorbic acid content (mg/ 100g)	β-carotene (μg/100g)
T_1	Priyur	15.7 [de]	0.27 [b]	23.17 [bc]	2459 [e]
T_2	Muvandan	13.2 [e]	0.64 [b]	7.32 [d]	2407 [e]
T_3	Neelum	18.1 [cd]	0.55 [b]	19.80 [c]	4590 [c]
T_4	Bangalora	16.5 [d]	1.14 [a]	30.53 [ab]	3554 [d]
T_5	Bennet Alphonso	21.5 [ab]	0.47 [b]	29.47 [ab]	5827 [b]
T_6	Ratna	23.6 [a]	0.32 [b]	30.95 [a]	7219 [a]
T_7	Banganapalli	20.2 [bc]	0.44 [b]	33.60 [a]	1302 [f]
T_8	Vellaikolumban	19.5 [bc]	0.71 [b]	17.30 [c]	1884 [e]

Neelum, Bennet Alphonso, Banganapalli and Ratna respectively were 0.55 per cent, 0.47 per cent, 0.44 per cent and 0.32 per cent.

4.2.1.3. Ascorbic acid (mg/ 100g)

The different mango varieties exhibited significant differences in ascorbic acid content. The maximum ascorbic acid content was observed in Banganapalli (33.60mg/ 100g) followed by Ratna (30.95mg/ 100g) and Bangalora (30.53mg/ 100g). Variety Muvandan recorded the lowest amount (7.32mg/ 100g) of ascorbic acid.

4.2.1.4. β-carotene (μg/ 100g)

Significant variation in β-carotene content was recorded between varieties. The maximum β-carotene level 7219 μg/100g was observed in variety Ratna. The minimum β-carotene was observed in Banganapalli (1302 μg/100g).The β-carotene content in the other varieties were Bennet Alphonso (5827 μg/100g), Neelum (4590 μg/100g), Bangalora (3554 μg/100g), Priyur (2459 μg/100g), Muvandan (2407 μg/100g) and Vellaikolumban (1884 μg/100g).

4.2.2. Chemical constituents of osmodehydrated mango

4.2.2.1. Total Soluble Solids (TSS)

The highest TSS content was recorded in osmodehydrated mango prepared from variety Ratna (73.4°Brix) followed by Bennet Alphonso (71.0°Brix) and Muvandan (68.5°Brix). Lowest TSS was observed in variety Bangalora (60.1°Brix) (Table 12). The varieties Ratna and Bennet Alphonso recorded the highest values for TSS. Though the TSS of variety Muvandan was the lowest (13.2°Brix), the osmodehydrated product prepared from it recorded comparatively high TSS (68.5°Brix).

4.2.2.2. Titrable Acidity (per cent)

Titrable acidity was maximum in osmodehydrated mango prepared from the variety Bangalora (1.60 per cent) followed by Vellaikolumban (0.93 per cent), Muvandan (0.81 per cent) and Neelum (0.96 per cent). Acidity was lowest in the variety Priyur (0.57 per cent). Titrable acidity increased with increase in immersion time.

4.2.2.3. Ascorbic acid (mg/ 100g)

Highest amount of ascorbic acid was found in variety Banganapalli (12.10 mg/ 100g) followed by Ratna (11.71 mg/ 100g) and Priyur (10.13 mg/ 100g). Minimum amount was recorded in Muvandan (3.90 mg/ 100g). Ascorbic acid content was slightly reduced by the osmodehydration process.

4.2.2.4. β-carotene (µg/ 100g)

Osmodehydrated mango made from different mango varieties exhibited significant difference in β-carotene content (Table 12). The maximum β-carotene was observed in Ratna (5463 µg/ 100g) followed by Bennet alphonso(4160 µg/ 100g) and Neelum (3297 µg/ 100g). Variety Banganapalli (1089 µg / 100g) recorded the lowest amount of β-carotene. There was considerable reduction in β-carotene due to osmodehydration process. The β-carotene content in variety Ratna was 7219 µg/ 100g whereas in the osmodehydrated product prepared from the variety it was 5463 µg/ 100g.

4.2.2.5. Organoleptic evaluation

All the eight varieties were organoleptically evaluated by a selected panel of judges. Highest score was observed in osmodehydrated mango prepared from Ratna variety of mango. The scores for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability were 7.3, 8.0, 7.4, 7.3, 6.7, 7.5, 7.3 and 7.2, respectively (Table 13 and Appenix 1 (d)). Variety Neelum was also rated superior in sensory attributes. This variety recorded mean score of 6.5 for overall acceptability. The least score for sensory attributes were recorded for variety Priyur.

The results of the experiment on varietal screening revealed that among the varieties evaluated, variety Ratna was the most suitable for osmodehydration.

Table 12. Chemical composition of osmodehydrated mango

Mango varieties		TSS (° Brix)	Titrable acidity (%)	Ascorbic acid content (mg/ 100g)	β-carotene (µg/100g)
T_1	Priyur	60.5 [d]	0.57 [b]	10.13 [ab]	1903 [d]
T_2	Muvandan	68.5 [b]	0.81 [b]	3.90 [d]	2038 [d]
T_3	Neelum	63.7 [cd]	0.96 [b]	7.62 [c]	3297 [c]
T_4	Bangalora	60.1 [d]	1.60 [a]	10.59 [ab]	3033 [c]
T_5	Bennet Alphonso	71.0 [ab]	0.89 [b]	9.32 [bc]	4160 [b]
T_6	Ratna	73.4 [a]	0.68 [b]	11.71 [ab]	5463 [a]
T_7	Banganapalli	60.4 [d]	0.52 [b]	12.10 [a]	1089 [e]
T_8	Vellaikolumban	64.8 [c]	0.93 [b]	9.43 [ab]	1431 [de]

Table 13. Mean scores for sensory attributes of OD products from different mango varieties

Varieties	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
Priyur	4.0	3.9	5.1	5.4	5.1	5.4	5.1	4.7
Muvandan	6.8	7.1	5.5	4.6	5.1	5.4	5.4	5.9
Neelum	6.3	6.1	5.5	6.2	5.6	6.4	6.1	6.5
Bangalora	6.0	5.7	6.3	6.0	6.0	5.3	5.0	6.0
Bennet Alphonso	6.2	6.0	6.0	5.7	5.0	5.8	5.6	5.8
Ratna	7.3	8.0	7.4	7.3	6.7	7.5	7.3	7.2
Banganapalli	5.9	6.2	6.4	5.8	5.6	6.1	5.5	6.1
Vellaikolumban	6.4	6.1	6.0	6.5	5.9	6.5	5.8	5.9

Plate 5. Osmodehydrated product from different mango varieties

Priyur

Muvandan

Neelum

Bangalora

Bennet Alphonso

Ratna

Banganapalli

Vellaikolumban

Highest values for TSS (73.4°Brix), β-carotene (5463 μg/100g) and sensory attributes were recorded in the osmodehydrated product prepared from this variety. Osmodehydrated product prepared from variety Bennet Alphonso also recorded high TSS (71°Brix) and β-carotene (4160 μg/100g).

Osmodehydrated mango product prepared by long process (in a sucrose solution of 70°Brix at ambient temperature for 48 hours) was also organoleptically evaluated by selected panel of judges. Variety Ratna secured highest scores for all the parameters. The scores recorded were 7.7, 7.8, 6.8, 7.5, 6.6, 7.3, 6.6 and 7.3 respectively for appearance, colour, flavor, texture, odour, taste, after taste and overall acceptability (Table 14 and Appendix 1 (e)).

4.3. Storage studies of osmodehydrated mango

The different packaging materials used were 200 guage polyethylene (PE) (T_1), metalized polyester (T_4), aluminium foil laminated cover (T_5) and rigid plastic containers (T_6). Vacuum packaging in PE cover (T_2) and vacuum packaging followed by nitrogen flushing in PE cover (T_3) were also tried. Chemical constituents *viz.* TSS, titrable acidity, ascorbic acid and β-carotene were analysed initially and at month at intervals for three months.

4.3.1. TSS (°Brix)

Highest value for TSS (73.3°Brix) was recorded in T_5 (packaging in aluminium foil laminated cover) after three months of storage followed by T_2, T_4 and T_6 (73.2°Brix). Lowest value was observed in T_1 and T_3 (73.1°Brix) (Table 15). However the differences were not significant.

4.3.2. Titrable acidity (per cent)

Titrable acidity was retained more in T_5 (0.66 per cent) followed by T_1 (0.65 per cent). Acidity reduction was most recorded in T_3 (0.55 per cent) (Table 15). Acidity was found to decrease with increase in storage period.

Table 14. Mean scores for sensory attributes of osmodehydrated product prepared by long process

Varieties	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
Priyur	4.4	4.8	5.4	5.5	5.0	5.8	5.1	5.4
Muvandan	6.7	6.6	6.1	5.1	5.6	5.5	5.4	5.8
Neelum	6.4	6.0	5.3	5.7	5.2	5.2	5.4	5.6
Bangalora	6.3	5.9	5.6	5.6	5.6	5.4	5.1	5.7
Bennet Alphonso	4.7	4.8	5.4	4.9	4.6	4.9	5.1	5.0
Ratna	7.7	7.8	6.8	7.5	6.6	7.3	6.6	7.3
Banganapalli	5.1	5.8	5.7	4.6	5.1	5.2	5.2	5.4
Vellaikolumban	5.6	5.9	5.7	5.6	5.0	5.3	5.0	5.5

Plate 6. Packaging materials and packaging methods used

PE 200 gauge

Metalized poly ester

PE aluminium laminated

Rigid plastic container

Vacuum packaging cum nitrogen flushing machine

4.3.3. Ascorbic acid (mg/ 100g)

Maximum amount of ascorbic acid (5.91%) was recorded in T_1 (Packaging in 200 guage polyethylene (PE) cover) followed by T_4 (5.68%) at the end of storage. Minimum ascorbic acid content (4.19%) was found in T_1 (Table 15). Ascorbic acid content also decreased with the increase in storage duration.

4.3.4. β-carotene (μg/ 100g)

Irrespective of treatments, a slight reduction in β-carotene was observed during storage. The maximum amount of β-carotene (5459 μg/ 100g) was observed in T_2 (vacuum packaging in PE cover) followed by T_5 (5455 μg/ 100g). Least value was recorded in T_1 (5246 μg/ 100g) three months after storage (Table 15). Product packaged in 200 guage polyethylene (PE) cover) exhibited browning at the end of storage period.

4.3.5. Microbial load in the osmodehydrated mango during storage

The microbial population of the stored samples was assessed at monthly intervals for a period of three months and the results are presented in Table 16. The initial population of bacteria, yeast and fungi in the osmodehydrated product were 0.67 cfu/ $g\times10^{-3}$, 1.00 cfu/ $g\times10^{-1}$ and 1.33 cfu/ g $\times10^{-2}$ respectively. A gradual increase in the population of microbes during storage was observed. Increase in microbial population was observed throughout the storage period irrespective of the packaging materials. Highest population of microorganisms was recorded in T_1 (PE 200 guage) throughout the period of storage. Lowest number of colonies were noticed in T_5 (aluminium foil laminated cover).

At the end of three month storage period, the population of microbes in T_1 were 5.67 cfu/ $g\times10^3$ (bacteria), 6.33 cfu/ g $\times10^1$ (yeast) and 7.33 cfu/ $g\times10^2$ (fungi). The microbial count recorded three months after storage in T_5 was bacteria (1.67×10^3), yeast (4.33×10^1)and fungi (3.00×10^2) and T_2 (bacteria 2.00×10^3, yeast 3.33×10^1 and fungi 3.00×10^2). Among the packaging methods,

Table 15. Changes in chemical constituents during storage of osmodehydrated mango

Months of storage	T_1	T_2	T_3	T_4	T_5	T_6	† CD
			TSS (°Brix)				
*Initial	73.4	73.4	73.4	73.4	73.4	73.4	
1 MAS	73.3	73.4	73.3	73.3	73.4	73.3	†NS
2 MAS	73.2	73.2	73.1	73.2	73.4	73.2	†NS
3 MAS	73.1	73.2	73.1	73.2	73.3	73.2	†NS
CD	NS	NS	NS	NS	NS	NS	
			Titrable acidity (%)				
*Initial	0.68	0.68	0.68	0.68	0.68	0.68	
1 MAS	0.67	0.66	0.63	0.67	0.68	0.62	†NS
2 MAS	0.66	0.62	0.62	0.65	0.66	0.60	†NS
3 MAS	0.65	0.58	0.55	0.61	0.66	0.56	†NS
CD	NS	NS	NS	NS	NS	NS	
			Ascorbic acid (mg/ 100g)				
*Initial	11.71	11.71	11.71	11.71	11.71	11.71	
1 MAS	7.80	8.70	8.42	8.77	9.29	8.35	†NS
2 MAS	6.01	6.65	5.95	6.79	6.89	6.63	†NS
3 MAS	4.19	5.35	5.15	5.68	5.91	5.29	†NS
CD	NS	NS	NS	NS	NS	NS	
			β-carotene (μg/ 100g)				
*Initial	5463	5463	5463	5463	5463	5463	
1 MAS	5456	5462	5460	5460	5462	5457	†NS
2 MAS	5429	5461	5450	5455	5459	5453	†NS
3 MAS	5246	5459	5444	5453	5455	5451	†NS
CD	NS	NS	NS	NS	NS	NS	

MAS- months after storage

The value represent means of 3 replications

NS- Non significant

†*NS* Non significant between treatments

* No statistical analysis is done

T_1- Packaging in 200 guage polyethylene (PE) cover
T_2- Vacuum packaging in PE cover
T_3- Packaging with nitrogen gas in PE cover
T_4- Packaging in metalized polyester bag
T_5- Packaging in aluminium foil laminated cover
T_6- Packaging in rigid plastic container

Table 16. Microbial load in the OD mango during storage

Treatments	Initial load (cfu/g)			1 MAS (cfu/g)			2 MAS (cfu/g)			3 MAS (cfu/g)		
	Bacteria $\times 10^3$	Yeast $\times 10^1$	Fungi $\times 10^2$	Bacteria$\times 10^3$	Yeast $\times 10^1$	Fungi$\times 10^2$	Bacteria $\times 10^3$	Yeast$\times 10^1$	Fungi$\times 10^2$	Bacteria $\times 10^3$	Yeast $\times 10^1$	Fungi$\times 10^2$
T_1	0.67	1.00	1.33	2.33[a]	2.67[ab]	3.00[a]	5.00[a]	3.00[ab]	4.00[ab]	5.67[a]	6.33[a]	7.33[a]
T_2	0.67	1.00	1.33	1.00[a]	1.33[b]	1.67[a]	1. 67[d]	2.00[b]	2.00[c]	2.00[b]	3.33[b]	3.00[b]
T_3	0.67	1.00	1.33	1.67[a]	2.67[ab]	2.33[a]	2.00[cd]	3.67[ab]	2.67[bc]	2.67[bc]	5.67[ab]	4.00[b]
T_4	0.67	1.00	1.33	2.67[a]	2.67[ab]	2.67[a]	2.33[bcd]	5.33[a]	2.67[bc]	3.33[b]	6.00[ab]	4.66[b]
T_5	0.67	1.00	1.33	1.67[a]	1.67[ab]	1.33[a]	3.33[bc]	3.67[ab]	2.00[c]	1.67[c]	4.33[ab]	3.00[b]
T_6	0.67	1.00	1.33	2.00[a]	3.67[a]	2.67[a]	3.67[b]	4.67[a]	4.33[a]	3.33[b]	6.67[a]	6.67[a]

MAS- months after storage

cfu- colony forming units

The value represent means of 3 replications

T1- Packaging in 200 guage polyethylene (PE) cover
T2- Vacuum packaging in PE cover
T3- Packaging with nitrogen gas in PE cover
T4- Packaging in metalized polyester cover
T5- Packaging in aluminium foil laminated cover
T6- Packaging in rigid plastic container

vacuum packaged samples and aluminium foil laminated cover packed samples recorded the lowest microbial load.

4.3.6. Insect infestation during storage

Insect infestation was not observed during storage.

4.3.7. Organoleptic evaluation during storage

Sensory evaluation of packaged samples was evaluated at monthly intervals during storage and results presented in Table 17 and Appendix I (f).

The mean ranks for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability were highest in T_5 (aluminium foil laminated pouches) (7.8, 7.4, 6.9, 7.5, 6.7, 7.9, 7.7 and 7.5 respectively) followed by T_3 (packaging with nitrogen gas in PE bag) after one month (Table 17). After two months, the maximum scores for all the parameters were recorded by T_5. Score for colour (7.3) was highest in both T_5 and T_2 (vacuum packing in PE cover) (Table 18 and Appendix I (g)). The mean rank for the sensory attributes after three months are given in Table 19 and Appendix I (h). Maximum scores for all of the attributes were recorded in T_5. The scores recorded in T_5, three months after storage for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability were 7.3, 7.2, 6.4, 7.3, 6.3, 7.3, 6.7 and 6.9.

Osmodehydrated mango packaged in aluminium foil laminated covers exhibited superior quality after three months of storage. But, better colour retention was observed in vacuum packaged samples. Highest scores in sensory evaluation was secured by the samples packaged in aluminium laminated covers. Microbial population was also the least in samples packaged in aluminium laminated cover.

Table 17. Mean scores for sensory attributes of OD products at 1 MAS

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	7.1	7.3	6.8	6.6	6.1	7.2	6.6	6.5
T_2	7.4	7.7	6.6	7.0	6.2	7.3	6.5	6.6
T_3	7.5	7.3	6.7	7.3	6.6	7.7	6.8	6.9
T_4	7.3	7.2	6.4	7.2	6.4	7.5	6.8	6.7
T_5	7.8	7.4	6.9	7.5	6.7	7.9	7.7	7.5
T_6	6.9	7.0	5.7	6.9	6.3	7.0	6.6	6.6

Table 18. Mean scores for sensory attributes of OD products at 2 MAS

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	6.6	6.9	6.3	6.3	5.8	7.0	6.4	6.3
T_2	7.0	7.3	6.2	6.7	6.0	7.1	6.3	6.7
T_3	7.2	7.1	6.6	7.2	6.4	7.3	6.5	6.8
T_4	6.8	6.7	6.1	6.8	6.0	7.0	6.3	6.5
T_5	7.5	7.3	6.7	7.4	6.6	7.4	6.8	7.2
T_6	6.8	6.7	5.6	6.5	6.1	6.9	6.4	6.5

Table 19. Mean scores for sensory attributes of OD products at 3 MAS

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	6.4	6.7	6.1	6.1	5.6	6.8	6.3	6.2
T_2	6.9	7.2	6.0	6.4	5.8	6.9	6.1	6.6
T_3	7.0	7.0	6.2	7.1	6.3	7.1	6.4	6.6
T_4	6.7	6.6	6.0	6.6	5.7	6.9	6.1	6.4
T_5	7.3	7.2	6.4	7.3	6.3	7.3	6.7	6.9
T_6	6.6	6.6	5.4	6.2	5.9	6.7	6.2	6.5

Discussion

5. DISCUSSION

Mango (*Mangifera indica* .L) is one of the most cultivated tropical fruits in the world. The fruit is an excellent source of dietary fibre and vitamins A, C and B complex (Bernardi *et al.*, 2009). Mangoes are very low in saturated fat, cholesterol and sodium. It also is a good source of dietary fibre (Pal, 1998). Mango, because of its great utility, occupies a prominent place amongst the fruit crops grown in India and is acknowledged as the "King of fruits" of this country (Bose and Mitra, 1990).

Mango fruit is popular both in the fresh and processed forms. The range of processed products includes juice, nectar, concentrate, jam, fruit bar, flakes and chutney (Schieber *et al.*, 2000; Berardini *et al.*, 2005). In Asia, mango is commonly preserved in the dried form, but conventionally dried mangoes present undesirable tough texture, poor colour and cooked flavour with loss of nutritive value, which reduce its economic importance (Tedjo *et al.*, 2002).

Osmodehydration has received greater attention in recent years as an effective method for preservation of fruits and vegetables. Osmotic dehydration is considered as a potential alternative to conventional dehydration techniques and has received considerable attention in recent years as a technique for production of intermediate/ shelf stable foods or as a pre drying treatment to reduce energy consumption and/ or heat damage in traditional drying processes (Sudheer and Dash, 1999). It is a common pre-treatment used before air drying. Intermediate moisture fruit products obtained by using osmotic dehydration are gaining increasing commercial interest. Osmotic dehydration techniques consist of immersing the fruit in a hypertonic solution to remove part of the water from the fruit (Eroglu and Yildiz, 2010).

The basis of osmotic treatment is osmosis, a physical phenomenon motivated by variation in solute concentration of two regions which are separated or divided by semi-permeable membrane, causing the water movement from low solute to higher solute concentration region. The movement of solutes from solution to material is dependent on difference in concentration between food material and solution (Shi and Le Maguer, 2003).

The mass transfer in osmotic dehydration is a complex heterogeneous system, which occurs when foods are immersed in a saline or sugar solution. It consists of a simultaneously occurring water outflow from the food tissue to the osmotic solution, a solute transfer from the osmotic solution to the food tissue and a leaching out of the food tissues own solute (Tortoe *et al.*, 2009). It involves dehydration of fruit slices in two stages, removal of water using an osmotic agent and subsequent dehydration in a drier where moisture content is further reduced to make the product shelf stable (Torres *et al.*, 2006).

Being a simple process, it facilitates processing of fruits and vegetables, with retention of initial fruit characteristics *viz.* colour, aroma, texture and nutritional composition. It has potential advantages for the processing industry to maintain the food quality and to preserve the wholesomeness of the food. Osmotic dehydration improves the nutritional and organoleptic properties of foods and has become popular in the food processing industry (Tortoe, 2007).

The present study was taken up to standardise the process variables for osmotic dehydration of mango. The results of the experiments conducted are discussed in this chapter.

5.1. Standardisation of process variables for osmodehydration

The mass transfer in osmotic dehydration has been reported to be influenced by several factors such as solution concentration, solution temperature, type of osmotic agent, process duration, level of agitation, sample size and geometry, species, variety and maturity level of plant materials. The influence of process variables such as temperature of osmotic solution, concentration of immersion solution, duration of immersion and fruit to solution ratio on mass transfer during osmotic dehydration and quality of final product was studied under this experiment.

5.1.1. Osmotic agent

The selection of solutions for osmotic treatment of food is of major importance, since it provides the driving force for concurrent flows of water and solute. It also decides the rate and extent of solute uptake and water removal as well as sensory and physical properties of the food product. The different types of solutes used as osmotic agent for osmodehydration are fructose, corn syrup, glucose and sodium chloride (Azuara and Berstain, 2002). However low molar mass saccharides like sucrose make easy sugar uptake due to high diffusion of molecules. Hence cane sugar (sucrose) was used as osmotic agent in the present study. Sugars are reported as excellent osmotic agent that provide many benefits like inhibition of polyphenol oxidases which cause oxidative browning in fruits. Sugars are beneficial in protecting the essential volatile compounds and thereby helpful in retaining the sensory properties of the original food material (Ponting, 1973). According to Ferrando and Spiess (2001), sugars contribute to stability of pigments and volatile compounds during drying of osmotically treated materials.

5.1.2. Process temperature

Environmental conditions play an important role during osmodehydration process. The important environmental factors which influence solute gain and kinetics of loss of water are temperature and duration of osmotic immersion (Khan, 2012). The temperature of osmotic solution affects the mass transfer kinetics during osmotic dehydration. The influence of four temperatures *viz.* ambient, 20°C, 30°C, 40°C on per cent of water loss, weight loss, solid gain and sensory qualities were evaluated under this experiment.

5.1.2.1. Water loss per cent

It is evident from the results of the present study that moisture loss and solid gain increases with increase in temperature of osmotic solution. The rate of water removal was higher at the temperature of 40°C (Fig.1). Highest TSS content and dry weight were also recorded for the same treatment. The results are in agreement with that obtained by Park *et al.* (2002) and Singh *et al.* (2008).

The results of the present study indicated that the most important variable affecting the kinetics of mass transfer during osmotic dehydration was temperature. Higher temperature also promoted faster water migration from the fruit. The removal of water from solid foods is a form of food conservation, inhibiting the growth of microorganisms, besides preventing a large part of biochemical reactions, which occur while the moisture is present.

Pokharkar and Prasad (1998) developed kinetic model for osmotic dehydration of banana slices and reported that the temperature of the osmotic solution influenced the parameters like water and sugar gain during the osmosis process. Higher process temperatures seem to promote faster water loss through swelling and plasticizing of the cell membranes. Azoubel and Murr (2003) also obtained similar results in the osmotic dehydration of cashew apple in sucrose and corn syrup solutions. Lima *et al.* (2004) also reported that increase in temperature of osmotic solution increased mass transfer rates till an equilibrium point.

The increase in solid gain and water loss when samples were immersed in a high temperature solution was due to the increase in the rate of diffusion. Oladejo *et al.* (2013) also observed that, temperature had a positive influence on water and solids diffusivity resulting in greater water loss and solids gain.

Chavan and Amarowicz (2012) also observed that the temperature of osmotic solution markedly affected the rate of osmosis. Although the rate increased with temperature, it was limited upto 60°C as higher temperature destroyed the cell membranes. However in the present investigation the highest temperature evaluated was only 40°C and hence effect of still higher temperatures could not be studied.

5.1.2.2. Solid gain per cent

The results of the study have revealed that solid gain per cent increase gradually with increase in temperature. Solid diffusion within the product is promoted by higher temperature.

Beristein *et al.* (1990) also noted that higher temperature increased the sugar gain. Increasing temperature accelerates all kinetic processes; thereby increasing the solid gain and water loss (Silveira *et al.*, 1996; Lombard *et al.*, 2008).

Lazarides (1994) observed substantial sugar gain (upto 55%) compared to room temperature conditions during osmotic dehydration of apples at process temperature between 30 and 50°C. Tortoe (2010) also reported that the higher uptake values at temperatures above 20°C were probably due to the membrane swelling and plasticizing effect, which improved the cell membrane permeability to sugar molecules.

5.1.2.3. Sensory quality

Maximum scores in organoleptic evaluation were also secured by osmodehydrated mango processed at 40°C (Fig. 2).

Lazarides (2001) reported that higher temperature had significant effect on the structure of tissues and cause flavour deterioration and enzymatic browning at temperature above 45°C.

5.1.3. Concentration of osmotic solution and duration of immersion

During osmotic dehydration, the kinetics of water removal, solid gain and equilibrium moisture content are strongly influenced by the kind of osmotic agent and its concentration. In the present investigation, the effect of four concentrations of sugar solution (40, 50, 60 and 70°Brix) and five durations of immersion (4, 6, 8, 10 and 12 hours) on mass transfer kinetics during osmodehydration and sensory attributes of OD mango was evaluated.

5.1.3.1. Concentration of osmotic solution

Sugar syrup concentration of 70°Brix was found to be the best treatment for osmodehydration process of mango. Highest rate of solid gain, weight loss, water loss per cent and TSS was observed in the same treatment. Nanjundaswamy (1991) and Chaudhary *et al.* (1993) also observed that mango slices can be successfully dehydrated by osmotic dehydration using sugar syrup (70°Brix) as osmotic agent. Higher the concentration of sugar solution, faster was the rate of osmosis. The results obtained in the present study corroborate with that obtained in osmotic dehydration studies in pineapple by Rashmi (2005) and in aonla by Sagar and Kumar (2006).

Rahman and Lamb (1990) and Corzo and Gomez (2004) also reported that water loss and sugar gain increased linearly with the increase in sugar concentration and temperature. In osmotic dehydration, water loss in the cells was promoted due to the differences in water chemical potential established between the external solution and the internal liquid phase of the cells (Chiralt and Flito, 2003). A study by Kumar *et al.* (2010) revealed that with the increase in sugar syrup concentration and temperature, moisture removal from the fruit piece increase during osmosis resulting in reduction in the moisture content of the fruit segments. This is attributed to the diffusion of water from dilute medium to concentrated solution through a semi-permeable membrane until the concentration equilibrium was reached. The driving force in this process is the water activity

Fig 1. Mass transfer during osmotic dehydration at 40 °C

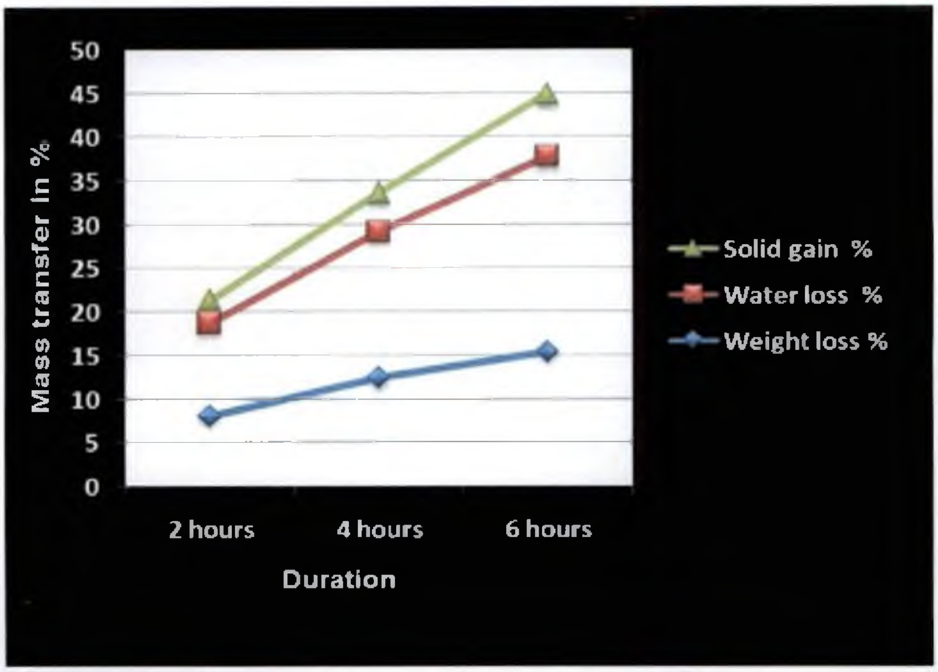
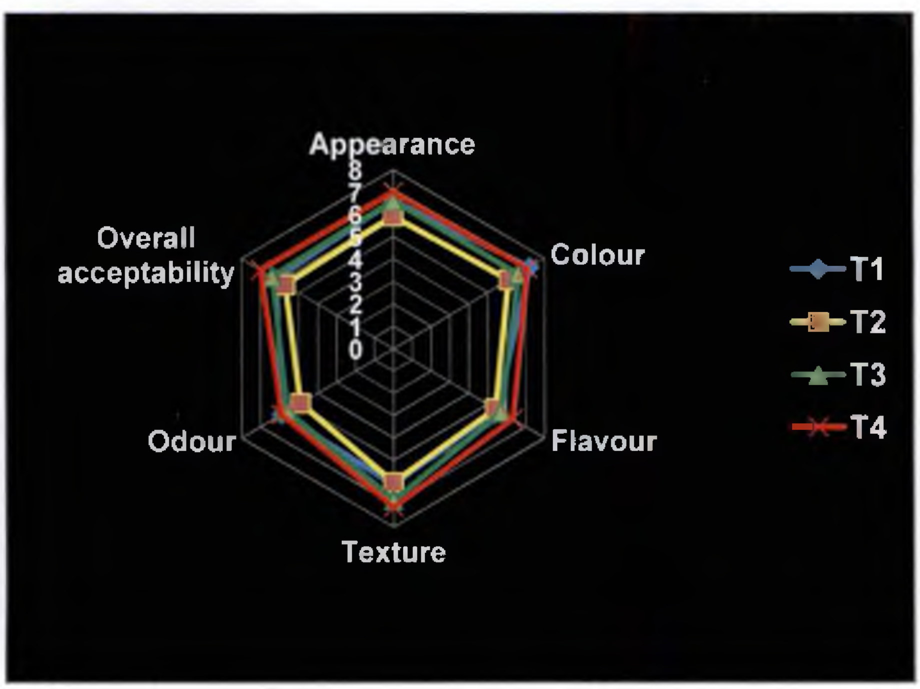


Fig 2. Effect of temperature on sensory attributes of OD mango



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Rahman and Lamb (1990) and Corzo and Gomez (2004) also reported that water loss and sugar gain increased linearly with the increase in sugar concentration and temperature. In osmotic dehydration, water loss in the cells was promoted due to the differences in water chemical potential established between the external solution and the internal liquid phase of the cells (Chiralt and Flito, 2003). A study by Kumar *et al.* (2010) revealed that with the increase in sugar syrup concentration and temperature, moisture removal from the fruit piece increase during osmosis resulting in reduction in the moisture content of the fruit segments. This is attributed to the diffusion of water from dilute medium to concentrated solution through a semi-permeable membrane until the concentration equilibrium was reached. The driving force in this process is the water activity gradient caused due to the osmotic pressure (Barat *et al.*, 2001 and Gill *et al.*, 2004).

Studies conducted by Ispir and Torgul (2009) and Kumar *et al.* (2010) also indicated that water loss, solid gain and mass reduction increase with increase in sucrose concentration and temperature of the solution at the end of osmosis. Higher concentration of sucrose caused higher rates of water removal. Sakhale and Pawar (2011) also observed higher water loss with increase in concentration of osmotic solution. Increase in osmotic concentration lead to an increase in osmotic pressure gradients and therefore a higher water loss throughout the osmotic period.

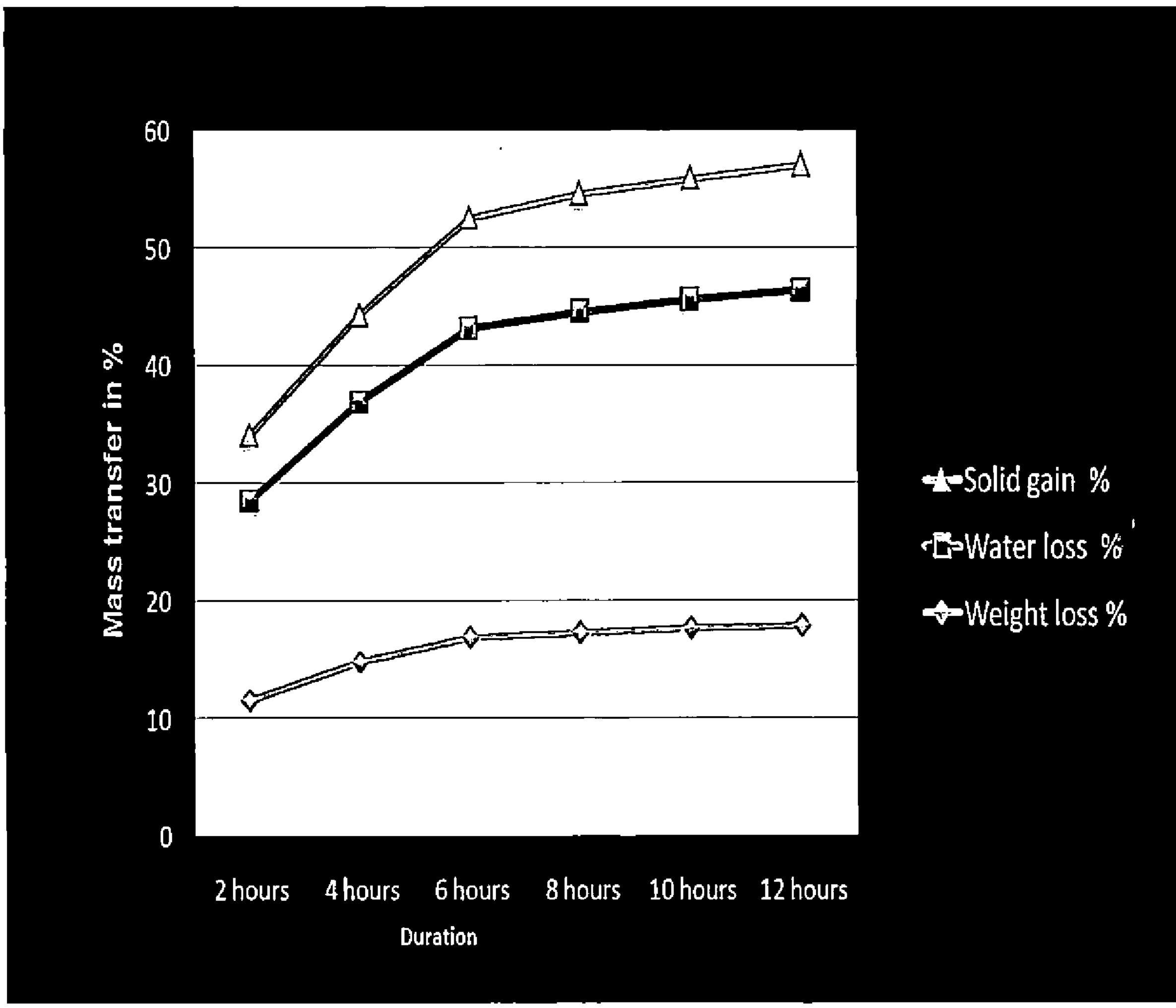
Conway *et al.* (1983) and Lenart (1992) reported that increase in osmotic solution increased weight reduction. In the present study also increased osmotic concentration was found to increase the weight loss per cent.

5.1.3.2. Duration of immersion

Solid gain, water loss and weight loss per cent recorded at 2 hours interval increased with the increase in duration of immersion time. In osmotic dehydration of mango, as the immersion time of fruit slices in the osmotic solution increased there was increase in the weight loss from the final slices. Beristein *et al.* (1990) also observed that water loss and sugar gain increased exponentially with the immersion time. Corzo and Gomez (2004) reported that immersion time had the highest effects on the response of variables (mass loss, water loss and soluble solids increase).

Studies on the optimization of duration of osmotic process indicated that the mass exchange took place at the maximum rate within the first two hours of the osmotic treatment. A study conducted by Misljenovic *et al.* (2009) also indicated that the diffusion of water and solids was the most intensive during the first three hours of dehydration (Fig. 3).

Fig 3. Mass transfer during osmotic dehydration in 70 °Brix osmotic solution



A study by Sagar and Kumar (2009) revealed that water loss increased with dip period. However, rate of water removal slowed down after 4.5 hours. Maximum water loss was observed after 6 hours in 70°Brix sugar concentration and lowest in 40°Brix sugar solution. In the present study also, water loss and solid gain were least in 40°Brix sugar solution at all durations of immersion. However according to Fazli and Ahani (2010), solid gain and water loss increased with process time but no significant difference was observed until 80 minutes.

Keeping the concentration of the solution constant, the increase of the immersion time resulted in increase of water loss. However the rate of increase was found to decrease with increase of time. Similar results were obtained by Chavan and Amarowicz (2012).

The influence of concentration of osmotic solution and duration of immersion on sensory attributes were evaluated. Maximum scores for sensory attributes were recorded in osmodehydrated mango steeped for 12 hours in 70°Brix sugar solution. It may be due to more sugar absorption taking place in samples due to prolonged immersion. A study by Markose (2005) also indicated that white watery rose apple osmotically treated in 70°Brix scored the highest overall acceptability.

5.1.4. Fruit to osmotic solution ratio

Five different fruit to solution ratios (T_1-1:1 dry sugar, T_2- 1:1 sugar syrup, T_3- 1:2 sugar syrup, T_4-1:3 sugar syrup and T_5-1:4 sugar syrup) were evaluated in the present study. A fruit to solution ratio of 1:2 was found to be the best for osmodehydration of mango (Fig. 4). In the present study solid gain, water loss and TSS was highest for fruit to solution ratio of 1:2. Highest scores for sensory attributes were also obtained for this ratio (Fig. 5). Increase in fruit to solution ratio beyond this level was found to decrease the rate of mass transfer. Tiwari (2005) also reported that, with an increase in solution to sample ratio, rate of osmosis increases upto a certain level.

Fig 4. Mass transfer during osmotic dehydration with fruit to solution ratio 1:2 (Sugar syrup)

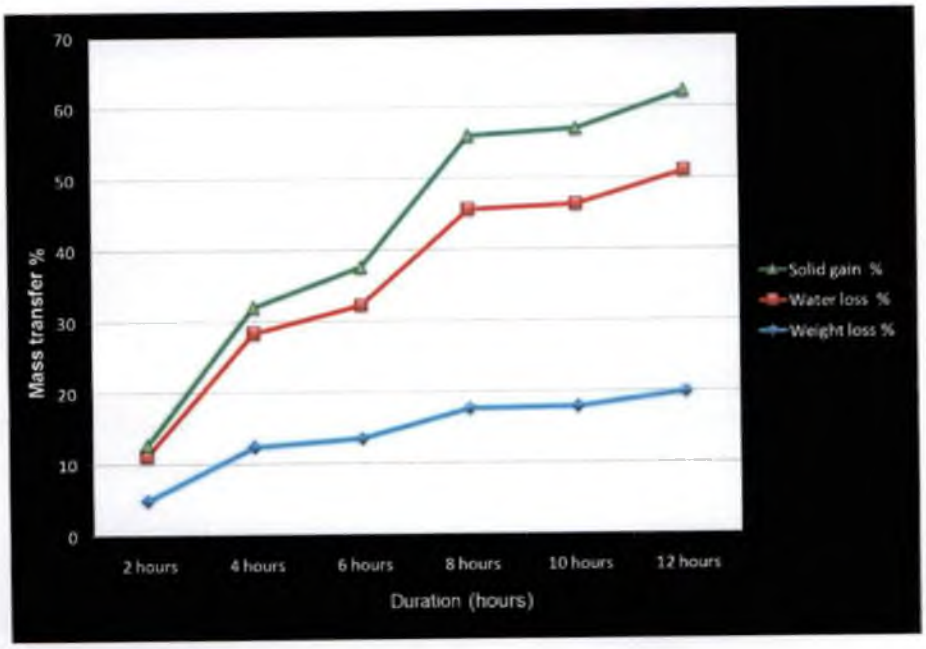
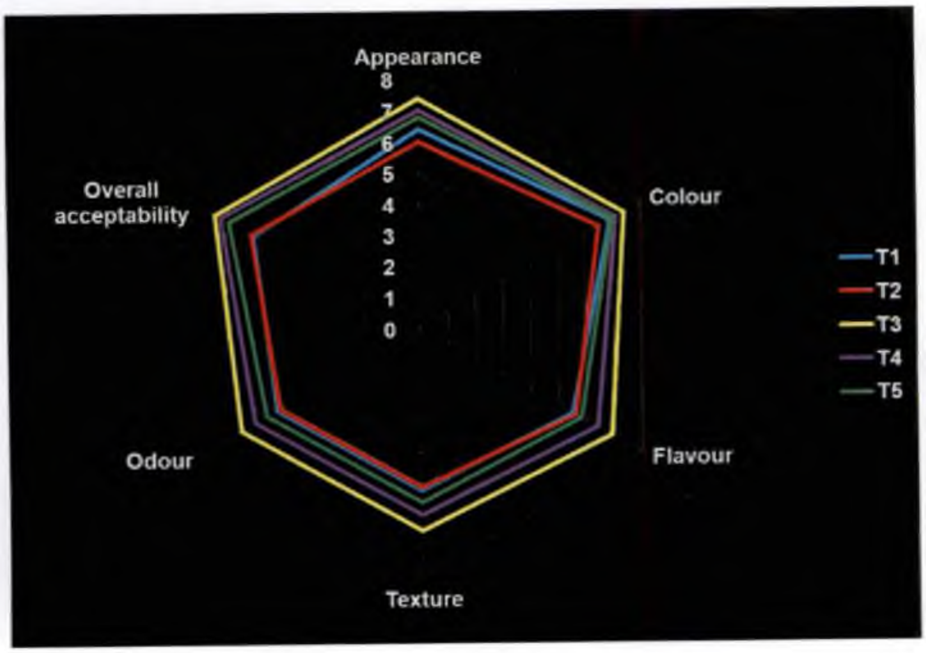


Fig 5. Effect of fruit to solution ratio on sensory attributes of OD mango



However Ponting *et al.* (1966) and Flink (1979) reported that an increase of osmotic solution to sample mass ratio resulted in an increase in both solid gain and water loss in osmotic dehydration.

The results of the present study are in conformity with that obtained by Noroes *et al.*, (2010). They also reported that 1:2 ratio achieved highest water loss which was desirable due to higher dehydration effect and less sensory changes. It is essential to use an optimum ratio since larger ratios offer practical difficulties for handling the fruit syrup mixture for processing. A ratio of 1:2 is optimum for practical purposes.

5.2. Evaluation of varietal suitability for osmodehydration

Eight varieties of mango *viz.* Priyur, Muvandan, Neelum, Bangalora, Bennet Alphonso, Ratna, Banganapalli and Vellaikolumban were evaluated for their biochemical constituents. Significant variation was observed between varieties for TSS (Fig. 6), titrable acidity, ascorbic acid (Fig. 7) and β-carotene content (Fig. 8). The mean range observed between varieties for the biochemical constituents were TSS 13.2-23.6°Brix, titrable acidity 0.27-1.14%, ascorbic acid 7.32-33.60 mg/ 100g and β-carotene 1302-7219 µg/ 100g. The variety Ratna was found to be superior in quality attributes with highest TSS (23.6°Brix), β-carotene (7219 µg/ 100g), ascorbic acid (30.95 mg/ 100g) and lowest acidity (0.32 per cent). Variety Bennet Alphonso had also superior quality attributes like high TSS (21.5°Brix) and β-carotene (5827 µg/ 100g).

5.2.1. Biochemical constituents of osmodehydrated mango

The chemical constituents TSS (Fig. 9), titrable acidity, ascorbic acid (Fig. 10) and β-carotene (Fig. 11) content were recorded in the osmodehydrated product prepared from the eight varieties of mango. The range observed for the biochemical constituents in the OD product were TSS 60.1 to 73.4°Brix, titrable acidity 0.52 to 1.60 per cent, ascorbic acid 3.90 to 12.10 mg/ 100g and β-carotene 1089 to 5463 µg/ 100g. Among the biochemical constituents evaluated, TSS and

Fig 6. TSS content in fresh mango

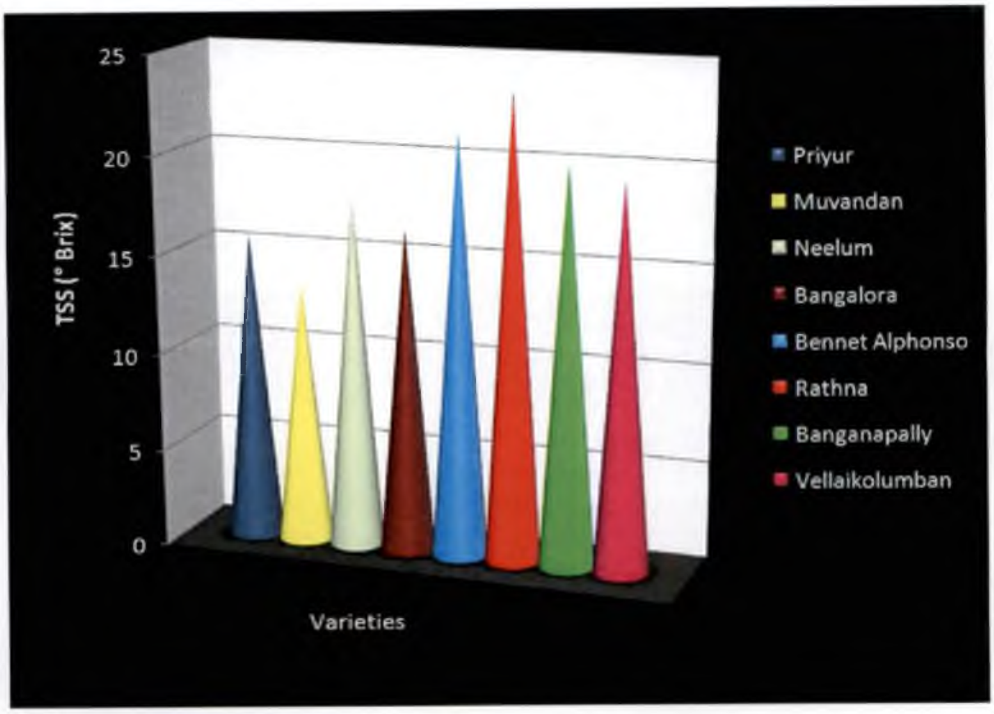


Fig 7. Ascorbic acid content in fresh mango

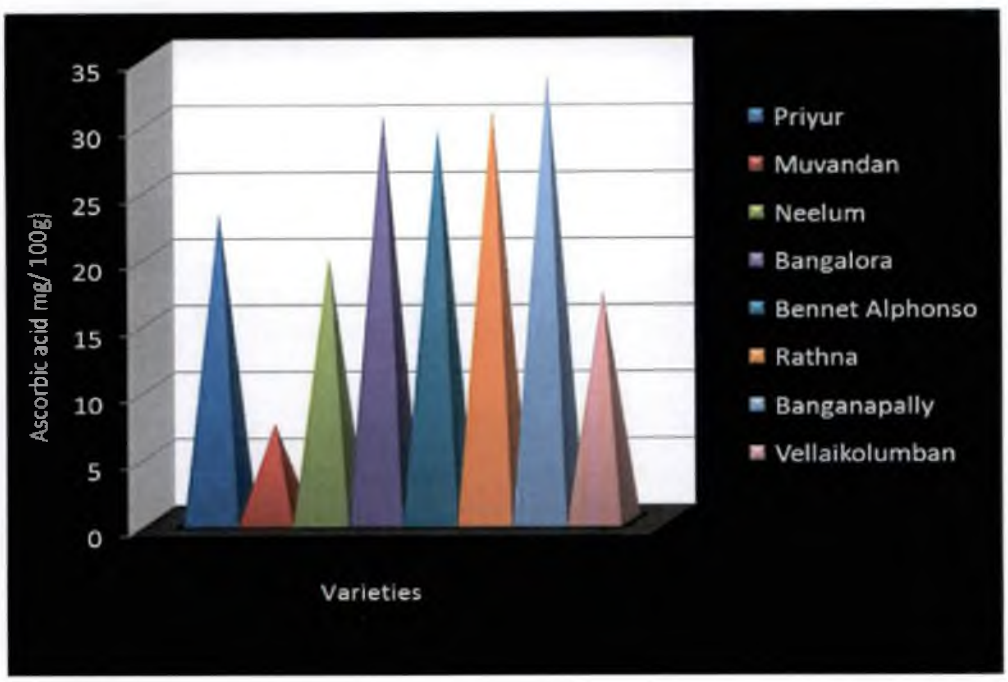


Fig 8. β-carotene content in fresh mango

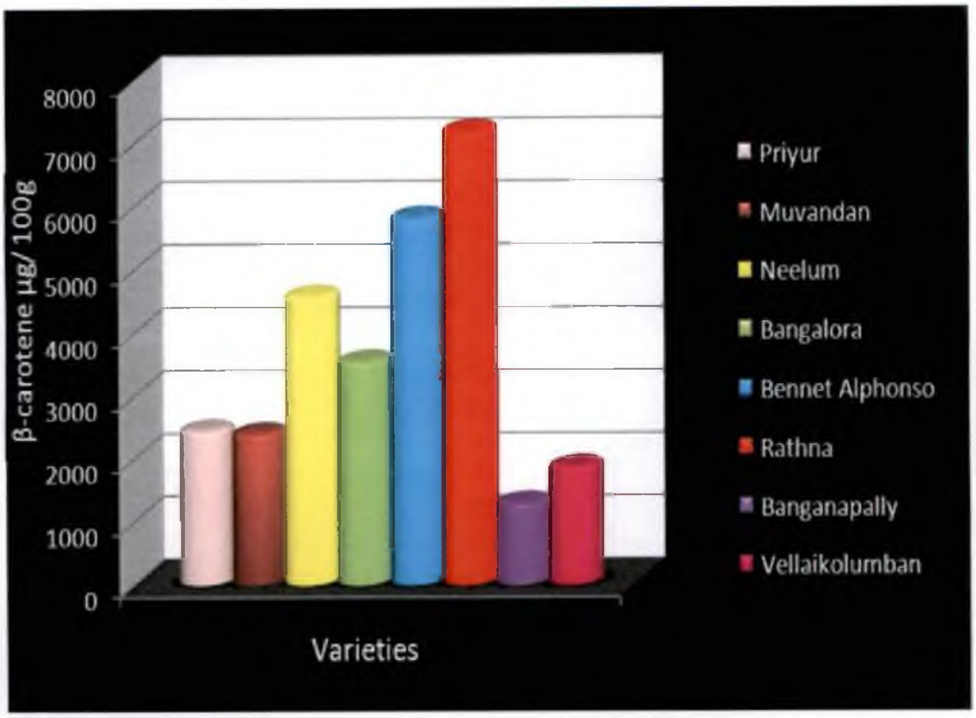


Fig 9. TSS content of osmodehydrated mango

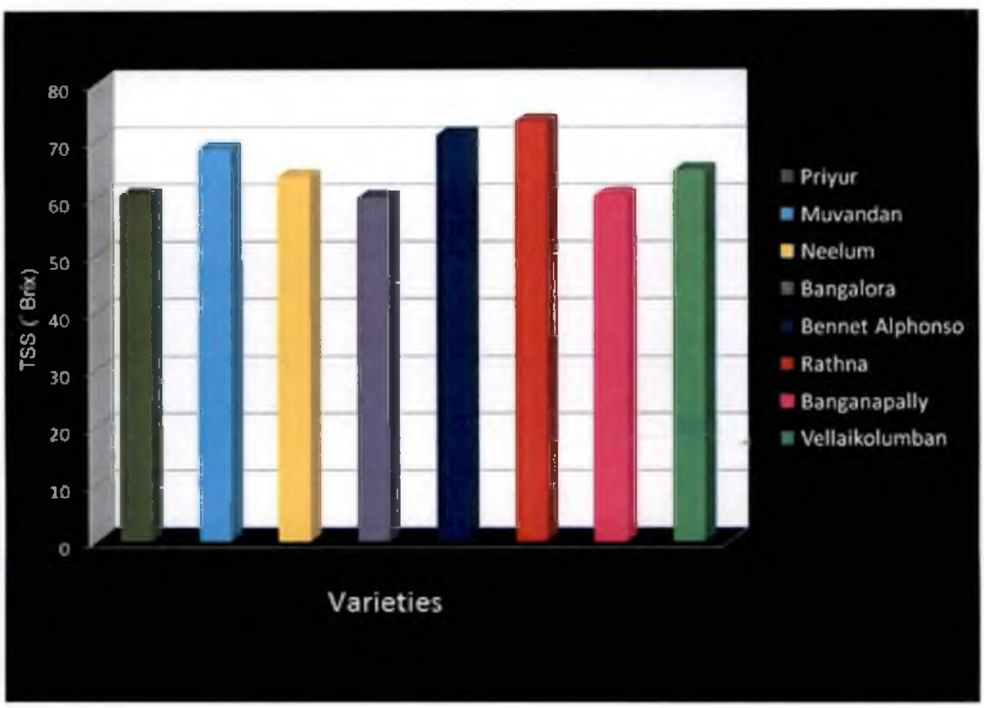


Fig 10. Ascorbic acid content of osmodehydrated mango

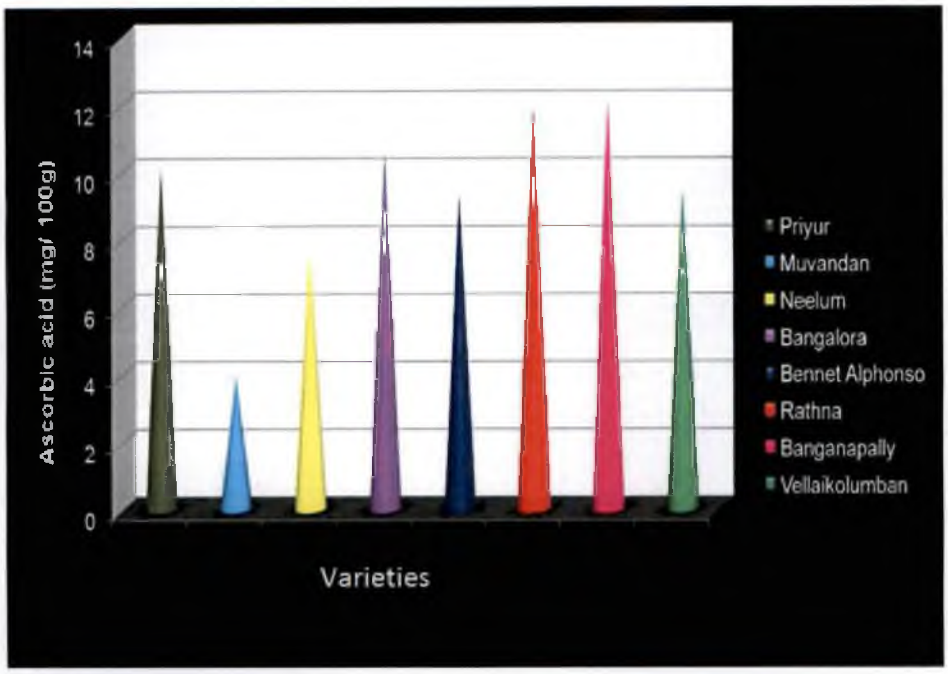
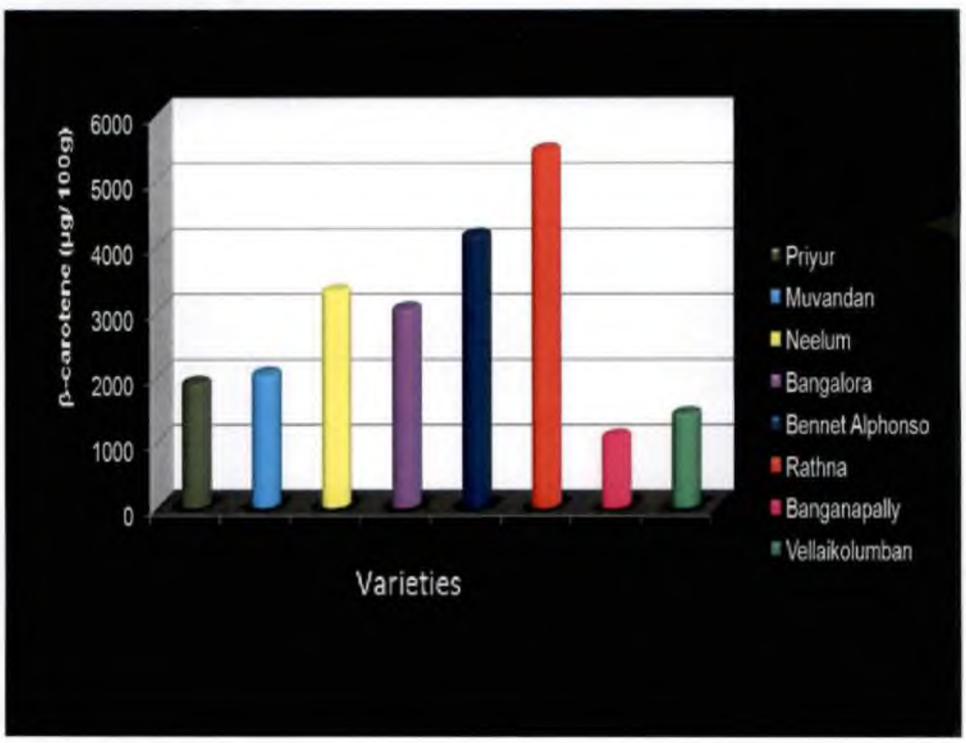


Fig 11. β-carotene content of osmodehydrated mango



acidity were found to increase while ascorbic acid and β-carotene were found to decrease consequent to osmodehydration. Solid gain during immersion in 70°Brix sugar solution account for the increase in TSS of osmodehydrated mango. The increase in acidity may be due to acidulant (citric acid 0.1 per cent) added during the osmodehydration processs. There was considerable reduction in ascorbic acid and β-carotene content in osmodehydrated mango. Ascorbic acid is a water soluble vitamin and would have leached out from the fruit pieces during the osmotic process. Ramallo and Mascheroni (2010) also observed slight reduction in ascorbic acid and β-carotene in osmodehydrated products.

Highest scores for sensory attributes colour (8.0), flavour (7.4), texture (7.3) and overall acceptability (7.2) were recorded in osmodehydrated product prepared from the variety Ratna. Maximum retention of quality attributes *viz.* TSS, ascorbic acid and β-carotene was observed in this variety. Amitabh *et al.* (2000) evaluated four mango varieties *viz.* Chausa, Dashehari, Langra and Fazari and found that Dashehari was best for osmodehydration. Sagar and Khurdia (2000) also observed that Dashehari variety of mango processed in equal weight of sugar syrup (70°Brix) containing 0.1 per cent KMS at 90°C for 2 minutes followed by drying in cabinet drier at 60°C gave the best dehydrated product.

Lima *et al.* (2004) carried out sensory evaluation of osmodehydrated product prepared from Tommy Atkins, Haden and Kent varieties of mango. Among the three varieties, Kent variety showed a trend of lower appearance for the final product. Vani *et al.* (2009) studied the suitability for osmotic dehydration of certain popular cultivars of mango *viz,* Alphonso, Bangalora and Banganapalli. Among the cultivars studied, osmotically dehydrated Banganapalli slices retained the highest nutritive value and was adjudged best in terms of appearance and taste. However in the present study, the osmodehydrated product prepared from Banganapalli ranked only third in overall acceptability. Among the eight varieties of mango evaluated, Ratna was found to be the most suitable for osmodehydration. The variety Neelum ranked second in overall acceptability for osmodehydration.

The results of the present study as well as the above studies indicated that quality of the final product was decided to a great extent by the variety used.

5.3. Storage studies of osmodehydrated mango

The rate of degradation usually depends on the type of packaging material, packaging method and storage conditions. Changes in chemical constituents, sensory attributes and microbial load during storage were analysed.

5.3.1. Packaging materials for osmodehydrated mango

Packaging is a means of providing correct environmental conditions for food during the length of time it is stored and/or distributed to the consumer. Packaging can retard product deterioration, retain the beneficial effects of processing, extend shelf-life, and maintain or increase the quality and safety of food. In doing so, packaging provides protection from three major classes of external influences: chemical, biological, and physical. After drying, packaging controls the product exposure to the effects of oxygen, light, water vapour, bacterial and other contaminants. The effect of different packaging materials on quality characteristics of osmodehydrated mango is discussed below.

The storage stability of osmotically dehydrated product varies from six months to one year (Tiwari, 2005). In the present study, samples packed in aluminium laminated pouches showed superior quality after three months of storage. This was due to the characteristic qualities of the aluminium foil pouches like good barrier properties for light, gases, oil, volatile compounds and water vapour. Lamination of two or more packaging materials improved the appearance, barrier properties and mechanical strength of a package (Kumar *et al.,* 2008). Maximum scores for sensory evaluation were also exhibited by the same treatment. Samples in polyethylene showed darkening after three months of storage. This may be due to the partial permeability of PE to gas (oxygen) and moisture. However Ahmed and Choudhary (1995) recommended use of high density poly ethylene pouches for storage of osmodehydrated papaya. There was no conspicuous variation in chemical constituents among the samples. Aluminium foil laminated pouches were found to be the best packaging material for osmodehydrated mango.

Better colour retention in vacuum packaged samples may be due to lesser moisture and absence of air in the pack. Good colour retention in vacuum packs was also observed by Mary (2005).

The results obtained in this study are in agreement with those obtained by Sagar and Khurdiya (1999). They observed that aluminium foil laminated pouches are ideal packing materials for osmotically dehydrated fruits. Habeeba (2005) also reported that aluminium foil laminated pouches with vacuum was the best packaging method for the storage of dried fig. Dehydrated products are highly hygroscopic, therefore unless stored properly will pick up moisture. This will invite microbial spoilage, thus deteriorating the products. The excellent barrier properties of aluminium foil laminated pouch protect the product against moisture ingress, discolouration and flavour loss.

Kumar *et al.* (2008) observed that osmo-vac dehydrated mango slices could be stored for six months with better nutritional quality in 250 gauge COEX pouches flushed with nitrogen followed by storage at low temperature (7 $\pm 1^{\circ}C$). Sagar *et al.* (1999) reported that nitrogen packed dehydrated ripe mango slices retained the colour and quality during storage under ambient conditions. In the present study, product stored in PE cover flushed with nitrogen ranked only second in overall acceptability. Chavan and Amarowicz (2012) reported that good quality, food grade and air tight containers can be used to store osmotically dried foods.

The highest scores in organoleptic evaluation secured by the aluminium foil laminated packs were due to the better retention of colour, flavour, texture and taste.

5.3.2. Changes in chemical constituents during storage

Irrespective of the packaging materials, the TSS content, titrable acidity, ascorbic acid and β-carotene of osmodehydrated mango gradually decreased throughout the storage period.

A gradual decrease in titrable acidity in osmodehydrated product was observed during storage. Similar trend was reported by Ranganath and Dubash, 1981; Mahajan *et al.,* 1994). The decrease in acidity may be a disadvantage in certain products which is corrected by adding a fruit acid to the osmotic solution.

Ascorbic acid content of the osmodehydrated mango was found to decrease with increased duration of storage. A study by Sagar and Kumar (2009) also revealed a significant decrease in ascorbic acid during storage. This might be due to oxidation of ascorbic acid during osmosis and dehydration process and storage at high temperature.

A decreasing trend in β-carotene was observed with increase in storage period. This may due to the oxidation and further stimulation by presence of light, enzymes and co-oxidation of carotene, which may later isomerise to mutachrone (Joseph and Mahadeviah, 1989).

In the present study, a gradual decrease in nutrients was observed during storage. It may due to the utilization of nutrients by microbes growing (Rangaswamy and Bagyaraj, 2000).

Overall sensory score of product showed a decreasing trend with advancement in storage period especially in products packaged in PE cover. The comparatively lower scores obtained for the sensory attribute colour may be due to enzymatic/ non-enzymatic browning. Vacuum packaged samples retained the colour throughout the storage period of three months. Exclusion of oxygen in the packages may have prevented oxidative deterioration of the product.

5.3.3. Changes in microbial load during storage

Several factors such as processing technique, the environment in which it is processed, *etc.* will have an effect on microbial quality of processed foods (Bryan, 1974). Microbial population in samples packed in six different types of packaging materials were analysed initially and at monthly intervals during storage.

In the present study, a gradual increase in the microbial count was observed irrespective of the packaging materials. Highest population of microbes was recorded in PE 200 gauge packaged samples. Microbial population was lowest in aluminium laminated packaged and vacuum packaged covers. This may be due to low moisture and absence of air in vacuum packs which inhibited the growth of micro organisms. Habeeba (2005) also reported an increase in microbial population throughout the storage period of osmotically dehydrated figs irrespective of the packaging materials and methods. Air packed samples showed increased microbial load due to higher moisture pick up. Microbial count was comparatively lower in osmodehydrated mango packaged in aluminium laminated and vacuum packaged covers.

Ramarjuna and Jayaraman (1980) studied the microbial population in intermediate banana at $0^{\circ}C$ and $37^{\circ}C$ and observed that it was negligible and product was microbiologically safe for direct consumption.

5.4. Protocol for osmodehydration of mango

Based on the results of the present study, the protocol for osmodehydration of mango was developed.

Plate 7. Protocol for osmodehydration of mango

Selection of firm ripe mangoes

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Washing, peeling and slicing

↓

Immersion in 70°Brix sugar solution containing 0.1% citric acid and 0.1% KMS (1:2 fruit to solution ratio)

↓

Keeping in water bath at 40°C for 12 hours

↓

Draining from sugar syrup

↓

Rinsing with lukewarm water

↓

Drying in a cabinet drier at 60°C for 6 hours

↓

Coating with powdered sugar

↓

Packaging in PE aluminium foil laminated cover

↓

Storage

Summary

6. SUMMARY

The study on "Process standardisation and varietal screening for osmodehydration in mango (*Mangifera indica.*L)." was undertaken at the Department of Processing Technology, College of Horticulture, Vellanikkara during 2011-13. The main objectives of the study were to standardise the process variables for osmodehydration in mango and to evaluate varietal suitability and storage stability of the product.

Osmotic dehydration (OD) is used to produce ready-to eat foods of intermediate moisture content with superior sensory properties. The process variables for osmotic dehydration of mango *viz.* temperature of osmotic solution, concentration of immersion solution, duration of immersion and fruit to solution ratio were standardised. Local mango variety 'Muvandan' was selected for the process standardisation. Sugar was used as the osmotic agent. The temperatures of the osmotic solution tried were ambient, 20°C, 30°C and 40°C. Concentration of sugar solution and duration of osmotic dehydration were 50°Brix and 6 hours respectively. Mango osmodehydrated in a sugar solution of temperature 40°C registered the highest values for TSS, dry weight, weight loss, water loss and solid gain per cent. The highest mean rank scores for appearance, flavour, texture, odour, taste and overall acceptability were also recorded by the same treatment. Hence T_4 (40°C) was selected as the ideal temperature for osmodehydration.

Scores recorded for the sensory attribute colour was highest in osmodehydrated (OD) mango prepared at ambient temperature.

The effect of four concentrations of sugar solution (40, 50, 60 and 70°Brix) and five durations of immersion (4, 6, 8, 10 and 12 hours) on mass transfer and sensory attributes of osmodehydrated mango were evaluated. Osmodehydration in a sugar solution of 70°Brix with 12 hours duration resulted in highest weight loss (17.84%), water loss (28.56%) and solid gain (10.72%), The highest TSS (68.5°Brix) was also recorded for the same treatment. The mean rank for appearance, colour, taste, odour and overall acceptability were highest in sugar solution of 70°Brix, 12 hours after osmotic dehydration. Maximum score for texture was observed in sugar solution of 40°Brix, 12 hours after immersion.

The optimum fruit to solution ratio was standardised by comparing different ratios of fruit sample and osmotic solution. The different ratios of fruit to solution tried were 1:1 dry sugar, 1:1 sugar syrup, 1:2 sugar syrup, 1:3 sugar syrup and 1:4 sugar syrup. Fruit to solution ratio of 1:2 was found to be the best treatment with highest dry weight (64.97g), weight loss (19.91%), water loss (31.02%) and solid gain per cent (11.11%). The TSS was also highest (63.1°Brix) for this treatment. Increase in fruit to solution ratio beyond this level resulted in decrease in dry weight, weight loss, solid gain per cent and TSS. Maximum scores for all of the attributes were recorded in 1:2 sugar syrup. The score recorded in 1:2 sugar syrup for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability were 7.4, 7.4, 6.9, 6.5, 6.5, 7.4, 6.6 and 7.4 respectively.

The process variables standardised for osmodehydration of mango were: temperature of osmotic solution (40°C), concentration of sugar solution (70°Brix), duration of immersion (12 hours) and fruit to solution ratio (1:2).

Eight varieties of mango *viz.* Priyur, Muvandan, Neelum, Bangalora, Bennet Alphonso, Ratna, Banganapalli and Vellaikolumban were selected for evaluating their feasibility for osmodehydration. Ratna variety was the most suitable for osmodehydration. Highest values for TSS (73.4°Brix), β-carotene (5463μg/100g) and sensory attributes were recorded in the osmodehydrated product prepared from this variety. A slight reduction in ascorbic acid and β-carotene was observed in osmodehydrated product compared to fresh fruits.

Storage studies were conducted in variety Ratna. The effect of four packaging materials (200 gauge polyethylene cover, metalized polyester cover, aluminium foil laminated cover and rigid plastic container) and two methods of packaging (vacuum packaging in PE cover, nitrogen flushing in PE cover) on biochemical constituents, sensory attributes and microbial count during storage were evaluated. Osmodehydrated mango packaged in different materials were stored for a period of three months at ambient temperature and quality parameters assessed at monthly intervals during storage. Significant variation was not observed in chemical constituents during storage. Highest values for all biochemical constituents except β-carotene were observed in samples packaged in aluminium foil laminated cover.

Microbial count at the beginning and end of storage was enumerated. Highest population of microorganisms were recorded in PE 200 gauge throughout the period of the storage. At the end of three months storage period the population of bacteria, yeast and fungi in PE 200 gauge were 5.67 cfu/g, 6.33 cfu/g and 7.33 cfu/g respectively. Irrespective of the packaging materials, increase in microbial population was observed throughout the storage period. The population of microbes was lowest in samples packaged in aluminium foil laminated cover. Vacuum packaged samples and aluminium foil laminated cover packed samples recorded the lowest microbial load.

The mean ranks for sensory attributes were highest in samples packaged in aluminum foil laminated covers after three months of storage. The scores recorded for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability respectively were 7.3, 7.2, 6.4, 7.3, 6.3, 7.3, 6.7 and 6.9.

Aluminium foil laminated cover was found to be the ideal packaging material for storage of osmodehydrated mango without deterioration in quality parameters.

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* Originals not seen

Appendices

APPENDIX I (a)

Effect of temperature of osmotic solution on sensory attributes of OD mango

Treatments	Mean rank scores							
	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	2.00	1.60	2.00	1.90	1.40	1.55	2.30	1.85
T_2	2.40	3.15	2.10	1.90	3.05	2.90	2.70	2.20
T_3	2.40	2.10	2.35	3.00	2.30	2.65	1.85	2.60
T_4	3.20	3.15	3.55	3.20	3.25	2.90	3.15	3.35
Kendall's W	0.160*	0.382**	0.323**	0.298**	0.441**	0.252**	0.220**	0.265**

* significant at 5% level
** significant at 1% level

APPENDIX I (b)

Effect of concentration of osmotic solution and duration of immersion on sensory attributes of OD mango

Treatments	Mean rank scores							
	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	6.55	7.65	6.50	9.05	3.40	7.95	9.40	8.90
T_2	7.15	10.70	7.50	5.10	10.70	8.65	11.00	5.55
T_3	8.05	10.35	10.65	9.70	8.75	6.35	12.15	6.10
T_4	4.95	7.15	6.75	13.65	12.65	8.50	14.10	11.10
T_5	12.55	11.35	8.70	6.35	10.15	11.25	7.30	10.60
T_6	7.25	9.10	7.65	8.10	5.95	11.55	9.40	13.00
T_7	10.35	10.45	12.35	8.50	11.10	8.35	11.60	5.60
T_8	13.70	11.40	9.15	14.95	13.40	8.60	7.50	13.30
T_9	7.40	10.10	14.30	10.95	10.45	9.95	11.95	12.25
T_{10}	6.80	6.55	5.80	5.60	6.65	12.25	7.35	7.45
T_{11}	10.00	10.55	13.40	13.55	12.90	11.25	14.00	12.00
T_{12}	14.05	12.05	11.10	8.55	8.50	13.65	10.95	12.25
T_{13}	12.35	10.10	10.50	9.35	13.70	10.55	13.30	6.40
T_{14}	12.80	11.15	12.20	10.80	12.10	9.30	9.35	6.70
T_{15}	13.15	14.25	14.25	9.15	10.70	8.90	9.30	9.20
T_{16}	13.50	9.25	10.55	8.45	10.80	14.75	11.30	13.05
T_{17}	12.90	8.65	11.70	14.30	11.95	9.25	11.70	12.55
T_{18}	8.85	11.30	11.90	15.05	12.10	11.20	9.50	12.00
T_{19}	13.30	13.10	11.05	15.05	10.45	11.80	8.75	14.55
T_{20}	14.35	14.80	14.00	13.80	13.60	15.95	10.10	17.45
Kendall's W	0.277**	0.136*	0.206**	0.308**	0.215**	0.173*	0.126*	0.329**

* significant at 5% level

** significant at 1% level

APPENDIX I (c)

Effect of fruit to solution ratio on sensory attributes of OD mango

Treatments	Mean rank scores							
	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	2.50	2.75	2.05	2.20	2.45	2.60	2.35	1.65
T_2	2.15	2.25	2.40	1.95	2.25	1.45	1.80	1.90
T_3	4.15	3.60	4.30	4.10	4.05	3.90	3.80	4.25
T_4	3.15	3.20	3.65	3.55	3.30	3.45	3.70	3.90
T_5	3.05	3.20	2.60	3.20	2.95	3.60	3.35	3.30
Kendall's W	0.255**	0.115*	0.370**	0.351**	0.220**	0.419**	0.339**	0.569**

* significant at 5% level
** significant at 1% level

APPENDIX I (d)

Mean rank scores for sensory attributes of OD product from different mango varieties

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	1.40	1.60	3.35	3.75	4.05	3.65	3.45	2.50
T_2	5.85	5.70	3.70	2.55	4.35	3.45	3.85	4.50
T_3	4.60	4.35	4.85	5.15	5.10	5.05	5.15	5.15
T_4	4.55	3.85	3.50	4.60	3.35	3.25	3.30	4.20
T_5	4.60	4.10	4.35	3.85	3.25	4.00	4.50	4.20
T_6	6.25	7.50	7.00	6.50	6.55	7.00	7.05	6.50
T_7	4.20	4.70	5.05	4.30	4.60	4.50	4.10	4.75
T_8	4.55	4.20	4.20	5.30	4.75	5.10	4.60	4.20
Kendall's W	0.383**	0.503**	0.257**	0.273**	0.231**	0.281**	0.272**	0.245**

* significant at 5% level

** significant at 1% level

APPENDIX I (e)

Mean rank scores for sensory attributes of OD product prepared by long process

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	2.25	2.55	3.85	4.25	3.70	4.95	3.85	3.80
T_2	5.85	5.55	5.20	4.00	4.80	4.40	4.55	4.80
T_3	5.25	4.55	4.05	4.40	4.50	4.25	4.80	4.70
T_4	5.05	4.70	4.10	4.50	4.60	4.00	4.00	4.45
T_5	2.80	2.80	3.65	3.45	3.40	3.15	4.15	3.05
T_6	7.30	7.35	6.35	7.40	6.70	7.55	6.65	7.55
T_7	3.25	4.20	4.45	3.40	4.30	3.80	4.15	3.75
T_8	4.25	4.30	4.35	4.60	4.00	3.80	3.85	3.90
Kendall's W	0.514**	0.433**	0.163**	0.312**	0.039^{NS}	0.337**	0.164*	0.363**

* significant at 5% level
** significant at 1% level

APPENDIX I (f)

Mean rank scores for sensory attributes of OD product 1 MAS

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	3.25	3.30	3.95	2.25	3.55	3.00	2.95	2.95
T_2	3.65	4.40	3.65	3.35	2.95	3.40	2.90	2.85
T_3	3.85	3.65	3.70	4.05	3.85	4.10	3.35	3.80
T_4	3.35	3.15	3.30	3.80	3.35	3.50	3.45	3.25
T_5	4.45	3.65	4.20	4.40	4.15	4.55	5.40	5.05
T_6	2.45	2.85	2.20	3.15	3.15	2.45	2.95	3.10
Kendall's W	0.160*	0.109*	0.175*	0.250**	0.098^{NS}	0.247**	0.333**	0.283**

* significant at 5% level

* significant at 5% level

** significant at 1% level

APPENDIX I (g)

Mean rank scores for sensory attributes of OD product 2 MAS

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability
T_1	2.60	3.30	3.45	2.50	3.15	3.35	3.25	2.85
T_2	3.65	4.05	3.50	3.20	3.05	3.55	3.30	3.60
T_3	3.95	3.85	3.95	4.25	3.95	3.80	3.65	3.85
T_4	3.10	2.90	3.45	3.50	3.20	3.15	3.20	2.95
T_5	4.65	4.00	4.45	4.85	4.35	4.25	4.25	4.50
T_6	3.05	2.90	2.20	2.70	3.30	2.90	3.35	3.25
Kendall's W	0.194*	0.113*	0.188*	0.321**	0.128*	0.084^{NS}	0.057^{NS}	0.139*

* significant at 5% level
** significant at 1% level

APPENDIX - II

Score card for organoleptic evaluation of osmodehydrated mango

Name of the judge:

Date:

Characteristics	Score			
	T_1	T_2	T_3	T_4
Appearance				
Colour				
Flavour				
Texture				
Odour				
Taste				
After taste				
Overall acceptability				

9 point Hedonic scale

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

Signature:

APPENDIX III

MEDIA COMPOSITION

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

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

2. **POTATO DEXTROSE AGAR MEDIA** (FOR FUNGUS)

Peeled potatoes	: 250 g
Dextrose	: 20 g
Agar	: 18 g
Distilled water	: 1000 ml
p^H	: 5.6

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

Mycological peptone	: 10 g
Dextrose	: 40 g
Agar	: 15 g
Distilled water	: 1000 ml
p^H	: 5.6

APPENDIX IV

BENEFIT COST RATIO OF OSMODEHYDRATED MANGO CHUNKS

Total cost of production for 1 Kg product:

Ingredients	Quantity	Rate	Amount (Rs.)
Fruit	17 Kg	Rs. 20/ Kg	340.00
Sugar	2.5 Kg	Rs. 10/ Kg *	250.00
Citric acid	2.5 g	Rs. 150/ Kg	0.37
KMS	2.5 g	Rs. 400/ 500 g	2.00
Fuel (Gas)	0.5 hour	Rs. 16/ hour	16.00
Electricity charge	6 hours (10 units)	Rs. 6/ unit	60.00
Packaging material	10 Nos	1.50/ piece	15.00
Total cost			683.37

Quantity of product : 1 Kg

Number of packets (100 g) that can be filled : 10

Cost of one packet : Rs. 75/-

Cost of ten packets of product : Rs. 750/-

B/C ratio : 750/ 683.37 = 1.09

Net returns : 750- 683.37= Rs. 66.63/ kg

* Sugar solution can be reused.

PROCESS STANDARDISATION AND VARIETAL SCREENING FOR OSMODEHYDRATION IN MANGO

(*Mangifera indica*.L)

By

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(2011-12-108)

ABSTRACT

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2014

ABSTRACT

The study on "Process standardisation and varietal screening for osmodehydration in mango (*Mangifera indica*.L)" was undertaken at the Department of Processing Technology, College of Horticulture, Vellanikkara during 2011-13. The main objectives were to standardise the process variables for osmodehydration in mango and to evaluate varietal suitability and storage stability of the product.

The temperature and concentration of osmotic solution, duration of immersion and fruit to solution ratio for osmodehydration in mango were standardised. Local mango variety 'Muvandan' was selected for the process standardisation. Sugar was used as the osmotic agent. The temperatures of the osmotic solution tried were ambient, 20°C, 30°C and 40°C. Concentration of sugar solution and duration of immersion were 50°Brix and 6 hours respectively. The highest values for dry weight (56.83 g), weight loss (17.38%), water loss (24.97%), solid gain (7.59%) and TSS (40.6°Brix) were recorded when osmodehydration was carried out at 40°C. Highest scores for sensory attributes were also recorded for this treatment.

The effect of four concentrations of sugar solution (40, 50, 60 and 70°Brix) and five durations of immersion (4, 6, 8, 10 and 12 hours) on mass transfer and sensory attributes were studied. T_{20} (immersion in 70°Brix sugar solution for12 hours) registered highest values for weight loss (17.84%), water loss (28.56%), solid gain (10.72%), TSS (68.5°Brix) and sensory attributes.

The fruit to solution ratio was standardised by comparing different ratios of fruit sample and osmotic solution. Fruit to solution ratio of 1:2 was found to be the most ideal for osmodehydration with highest dry weight (64.97g), weight loss (19.91%), water loss (31.02%) and solid gain per cent (11.11%). The maximum TSS (63.1°Brix) was also recorded for this treatment. Increase in fruit to solution ratio beyond this level resulted in decrease in dry weight, weight loss, solid gain

per cent and TSS. Maximum scores for all of the sensory attributes was recorded in 1:2 fruit to solution ratio.

Eight varieties of mango *viz.* Priyur, Muvandan, Neelum, Bangalora, Bennet Alphonso, Ratna, Banganapalli and Vellaikolumban were evaluated for their feasibility for osmodehydration. Osmodehydrated mango was prepared by the method standardised in the first experiment. Among the varieties of mango evaluated, Ratna was found to be the most suitable for osmodehydration. Highest values for TSS (73.4°Brix), β-carotene (5463 μg/100g) and sensory attributes were recorded for the osmodehydrated product prepared from this variety.

The effect of different packaging materials (200 gauge polyethylene cover, metalized polyester cover, PE aluminium foil laminated cover and rigid plastic container) and methods of packaging (vacuum packaging in PE cover, nitrogen flushing in PE cover) on biochemical constituents, sensory attributes and microbial count during storage was studied. Significant variation was not observed in chemical constituents during storage. Highest values for all biochemical constituents except β-carotene was observed in samples packaged in PE aluminium foil laminated cover. Vacuum packaged samples and aluminium foil laminated packed samples recorded the lowest microbial load. Highest population of microorganisms was recorded in 200 gauge polyethylene cover throughout the period of storage. The mean ranks for appearance, colour, taste, odour and overall acceptability were highest in samples packaged in aluminum foil laminated PE cover.