STUDIES ON OSMOTIC DEHYDRATION OF GREEN PEPPER

(*Piper nigrum* L.*)*

By

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TAVANUR - 679 573, MALAPPURAM

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(*Piper nigrum* L.)

SMITHA, K.E

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TAVANUR - 679 573, MALAPPURAM
KERALA, INDIA

DECLARATION

I hereby declare that this thesis entitled **"Studies on osmotic dehydration of green pepper (*Piper nigrum* L.)"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Tavanur
3-12-2008

Smitha, K.E.
2006-18-101

CERTIFICATE

Certified that this thesis entitled **"Studies on osmotic dehydration of green pepper (*Piper nigrum* L.)"** is a *bonafide* record of research work done independently by **Miss Smitha, K.E.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of **Miss Smitha, K.E.,** a candidate for the degree of Master of Technology in Agricultural Engineering majoring in Post-Harvest Technology and Agricultural Processing agree that the thesis entitled "**Studies on osmotic dehydration of green pepper (*Piper nigrum* L.)"** may be submitted by Miss. **Smitha, K.E.** in partial fulfillment of the requirement for the degree.

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Smitha, K.E.

Dedicated To

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SYMBOLS AND ABBREVIATIONS

%	per cent
α	alpha
°C	degree centigrade
^{0}B	Degree brix
Art.	Article
β	beta
cm	centimetre
d.b.	dry basis
Eqn.	Equation
et al.	and others
Fig.	figure
g	gram
hp	horse power
hr	hour
kg	kilogram
l/min	litre per minute
m	metre

M.C	Moisture content
mg	milligram
min	minute
ml	millilitre
mm	millimetre
MS	Mild Steel
NaCl	Sodium Chloride
rpm	revolution per minute
viz.	namely
w.b	wet basis
w/v	weight by volume
w/w	weight by weight

INTRODUCTION

CHAPTER I
INTRODUCTION

Spices have been virtually indispensable in the culinary art of flavouring foods since antiquity. They have played a major role in our lives and in the economic development of many countries for centuries. Spices, being natural substances of plant origin are more appealing to the consumers than synthetic additives. The international trade in spices is estimated about 906,700 tonnes valued at $2125 million (Nybe *et al.*, 2007).

Spices comprise of various aromatic plants, herbs and shrubs having an inherent peculiar flavour. These are obtained from different parts of these plants like the root, barks, buds, leaves, stems, flowers, fruits and seeds. It is used to enhance taste, flavour, aroma, colour, appearance delicacy, and freshness of different foods. This in turn would increase the consuming and marketing trends of different food preparations.

Since the time immemorial, spices have been mainly used as seasonings to make processed foods more delicious. Apart from their flavouring properties, spices have been accepted as potent natural antimicrobial in food preservation for extending shelf life for longer periods. The use of spices in food may also be vindicated from their medicinal and anti-microbial properties.

India is the abode of many spices. Acclaimed as the 'virtual spice bowl', India is the largest producer and consumer of spices in the world. Indian spices are considered best in the world and the demand of Indian spices and their allied products have been increasing from time to time. The importance of spices can be traced from Vasco-De-Gamma's voyage .The Indian spices still occupy a prominent role in the international trade. India commands a formidable position in world spice trade with a share of 37 % in volume and 23 % in value (Nybe *et al.*, 2007).

India occupies the place of pride in the world in the production, consumption and export of spices. The International Organization for Standardization (ISO) have recognized 109 spices all over the world, out of which 52 are grown in India .Being a predominant export item, the production, processing, packaging and marketing of spices have a prominent role in the economy of our country. It provides employment to millions of people and brings substantial foreign exchange.

The export of spices has also shown a remarkable improvement in recent years. By judging recent trends in the local consumption as well as export demand of spices there has

been allocation of export quantum of spices at a growth rate of 10% in the production and 6% in the export earning. Facing stiff global competition from other producing countries it is imperative to increase the production and export and improve post harvest technology by the quality up gradation of spices.

Black pepper, the "king of spices" is the most important and the most widely used spice in the world occupying a position that is supreme and unique. India -' the Home of spices' ranks first in its production. Black pepper (*Piper nigrum* L.) belongs to the family *Piperaceae*. It is a native of the Malabar Coast of Southern India, and Kerala is the major pepper producing state in India. During 2007-08, the export of pepper from the country has been 31,750 tonnes valued at Rs 466.38 crore, which is higher by 20 % in quantity and 68 % in value compared to last year's achievement (http://www.thehindubusinessline.com). It is of paramount importance to augment our exports through diversification of processed spices instead of exporting the whole spices notably black pepper.

Considerable advances have been made in recent years in the diversification of value-added processed products from pepper, which has a good demand. The major products are black pepper, white pepper, green pepper, oil and oleoresin. Green pepper is an important value-added product prepared from unripe but fully matured pepper berries. India offers green pepper in several processed forms such as frozen, dehydrated, freeze-dried and packed in brine. Most of the green pepper products are used by the catering sector to be served with meat dishes and by the food manufacturing industries for a variety of food products. It enhances the aroma and pungency of the food products.

Annually, the availability of tender green pepper is only for a period of two to three months. To assure round the year availability, green pepper could be better dehydrated and stored for a year or more and can be used at will by simple reconstitution. Thus there exists a good prospect for the development of dehydrated green pepper industry in India.

Now a days the dehydration of green pepper is usually carried out by blanching followed by drying. Many food industries employ different drying equipments such as freeze driers and tray driers. Being highly expensive such driers alone are not suitable for farmers or small-scale enterprises. Though sun drying is cheaper, it is unhygienic and time consuming. Hence there is a need for cheaper and quicker drying alternatives for rural areas. Osmotic dehydration is such a novel technique for the production of safe, stable, nutritious and tasty food. Osmotic dehydration is the method of partial removal of water from plant tissues by immersing it in an osmotic solution. Osmotic dehydration due to its energy and quality related advantages, is gaining popularity as a complimentary processing step in the chain of

integrated food industry. After osmotic dehydration there is a need for secondary drying. It enhances the keeping quality and increases shelf life of the product which plays a very vital role in the market value of the product.

Keeping the above cited facts, a study was conducted with the following objectives:

(a) Standardization of hypertonic solution for osmotic dehydration.
(b) To study the effect of time and solution to sample ratio on osmotic dehydration.
(c) Development of an osmotic dehydration plant.
(d) Optimization of secondary stage of drying using freeze dryer and tray dryer.
(e) Quality assessment for osmotically dehydrated green pepper.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Osmotic dehydration has received greater attention in recent years as an intermediate step in drying of several fruits and vegetables. Being a simple process, it has potential advantages in the processing industry for dehydration of tropical fruits for longer shelf life. It results in quality improvement in terms of colour, flavour, texture, product stability, nutrient retention and prevention of microbial spoilage during storage. The inclusion of osmotic dehydration in conventional dehydration has two major objectives namely quality improvement and energy savings.

A brief review of the studies on the osmotic dehydration of fruits, vegetables and milk products made by various researchers has been presented in this chapter.

2.0 Pepper

2.1 Origin

Pepper is the small berry of the pepper vines (*Piper nigrum* L.) belonging to the family *Piperaceae*. The name pepper comes from the Sanskrit word pippali meaning the vine or shrub that saves. The pepper vine thrives best in the tropics, hot climate, at elevations from 1500 feet mean sea level, with an evenly distributed rainfall of about of 100 inches. The richest growth is seen on fertile, flat or gently sloping land, rich in humus with good drainage and light shade. Fruits are botanically called drupes but generally called berries. The plant starts fruiting in three to five years. In India, pepper cultivation is mainly confined to the southern states of Kerala and Tamilnadu.

2.2 Varieties

There are many varieties of pepper developed and grown in India, including karimunda, kottanadan, panniyur-1, panniyur-2, subhakara etc. Common varieties of pepper grown in India are shown in Table 2.1.

Table 2.1 Common varieties of pepper grown in India.

Region	Name of cultivars	Green-berry-yield (kg per vine)	Remarks
North Kerala	Kalluvalli	1.0-5.6	Hardy; drought and wilt resistant; regular bearer
	Balamcotta	3.0-4.5	Dominantly bisexual; regular and heavy yielder
South Kerala	Karimunda	-	Early bearer but short lived
	Kuthiravally	-	High yielder in alternate years
Hybrids in Kerala	Uthriancotta X Kottanadan	3.5	Experimental; degenerates in yield
	Uthriancotta X Thalliparamba	4.5-5.5	Experimental; degenerates in yield
	Uthriancotta X Cheriakaniakadan (panniyur-1)	5.3-10.5	Hardy, adaptable to different soil and climate conditions; respond to nutrients; early bearing and heavy yielder
Karnataka	Malligesara	-	Regular and heavy yielder

2.3 Chemical composition of pepper

The major constituents of pepper are starch, crude fibre, fat and protein. Starch and fibre vary with maturity. Their relative propositions based on maturity affect the texture of the pepper corns. However, the significant constituents are piperine and volatile oil which contribute to pungency and aroma respectively (Mathew, 1993).

2.4 Pepper products

The products developed from pepper broadly fall in to four groups: Black pepper, White pepper, green pepper, volatile oil and oleoresin. Pepper products greatly rely up on the maturity of pepper berries (Anandan, 1997).Each end product requires a particular maturity as shown in the Table.2.2.

Table 2.2 Maturity of pepper desired at harvest for production of various end products

End-Product	Maturity at harvest
White pepper	Fully ripe
Black pepper	Fully mature and nearly ripe
Canned pepper	4 – 5 months after fruit set
Dehydrated green pepper	10-15 days before maturity
Oleoresin	15-20 days before maturity
Oil	15-20 days before maturity
Pepper powder	Fully mature with maximum starch

Source: Govindarajan (1977)

Black pepper is the whole dried fruit of the plant, while white pepper is the dried berries obtained after removing the pericarp.

Green pepper is made from the fully developed but immature berries. They are preserved in brine, vinegar or citric acid and may be dried or kept in the preservative. Europeans are fascinated by the natural green colour and fresh flavour of green pepper.

Canned green pepper: The separated green pepper berries are washed and filled in cans containing a diluted solution of sodium chloride with or without added acidity. The filled cans are then sealed and sterilized by the autoclave process, and cooled under running water.

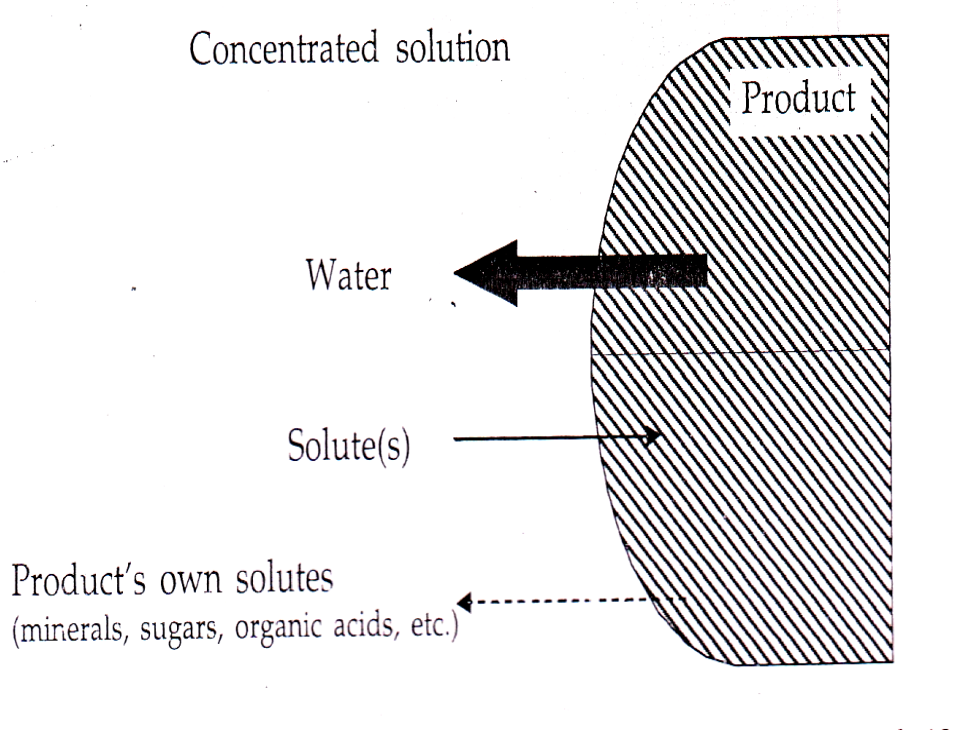
Green pepper in brine: This is made from young, green pepper berries which are carefully detached from the stalks and preserved in specially formulated solution of vinegar and brine.

Dehydrated green pepper: It has the green colour and the flavour of fresh pepper. On dehydration, the berries turn full and soft, but do not have the texture of the green pepper in brine. Freeze drying ensures better dehydration. Frozen green pepper is made by freezing the berries in a blast freezer. Europe is the major importer of frozen green pepper.

2.5 Osmotic dehydration

Osmotic dehydration process involves water rich solid products being soaked in concentrated aqueous solutions (mainly sugar or salt solutions) which create three types of counter current mass transfer as **,**

- Water out-flow from product to solution
- Solute transfer, from the solution to the product
- Leaching out of the product's own solutes in negligible quantity.



Source: (Tiwari, 2005)

Fig. 2.1 Osmotic dehydration process

2.5.1 Advantages of osmotic dehydration

- Higher retention of flavour and nutritional characteristics.
- Prevention of enzymatic and oxidative browning.
- Less energy consumption due to the reduced water removal load in the drier.
- Simple equipments are required and so the process is less expensive.
- Storage of the product for a longer period making it available to the consumer throughout the year.

2.5.2 Type and concentration of osmotic agent

The composition, nature and molecular weight of the osmotic solute have great influence on the process. The solute should reduce water activity of a solution substantially for increasing the driving force. It must be effective, convenient, cheap, and non-toxic, have a

good taste, readily soluble to form a high concentrated solution and should not react with the product. Composition of the concentrated solution is a key factor in osmotic dehydration. It is reported that higher the concentration, faster is the rate of osmosis. Optimum concentration varies with fruit type.

Baroni and Hubinge (1999) conducted a study on the kinetics of the Dehydration of onion by immersion. In this work, small squares of onion were submitted to dehydration by an immersion process in salt solution. Different concentrations of sodium chloride (5, 10 and 15% w/w) and temperatures (22, 30 and 40 ^{0}C) were tested to evaluate the kinetics, and the profiles of moisture content and salt penetration were constructed. After 1 hr of dehydration, few changes in moisture removal and solid gain were observed. The minimum water content obtained in a 4h process was 76% for the sample immersed in 15% NaCl at 40^{0}C, with a solid uptake of 9 %. The results showed that the higher the temperature and salt concentration, the higher the effective diffusion coefficient. It was also observed that the concentration of the salt solution was more important than the temperature in the process mass transfers.

Pokhakar (2001) developed a kinetic model for osmotic dehydration of green peas prior to air drying. Green peas were osmotically dehydrated in sodium chloride – water solutions at three concentrations (5, 10 and 17% sodium chloride by weight) and three temperatures (20, 30 and 40 ^{0}C). Movement of salt and water was modeled for water loss from and salt take up by the green peas. Green peas were dipped in 10% sodium chloride –water solutions at 30 ^{0}C for 30 min and air dried in a fluidized bed drier. Colour, texture, flavour and overall acceptability scores indicated that the dehydrated product was organoleptically acceptable.

Abhijit and Gupta (2001) experimentally studied the Osmotic drying behaviour of button mushrooms in relation to temperature (25,40, and 55 ^{0}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.

Rastogi *et al.* (2002) studied the effect of concentration and temperature of the osmotic solution in considerable detail and concluded that the rate of osmotic dehydration increases with both the parameters. The rate of dehydration also increases as the level of agitation is increased. Agitation is indeed one of the key factors and an adequate level of agitation ensures minimization of liquid side mass transfer effects.

Azoubel and Murr (2003) studied about the Optimisation of Osmotic Dehydration of Cashew Apple (*Anacardium Occidentale* L.) in sugar solutions. Osmotic dehydration of cashew apple in sucrose and corn syrup solids solutions as influenced by temperatures

(30-50 ^{0}C), sugar syrup concentration (40-60% w/w) and immersion time (90-240 min) was studied through response surface methodology. Responses of water loss (%) and solid gain (%) were fitted to polynomials, with multiple correlation coefficients ranging from 0.92 to 0.99. The fitted functions were optimised for maximum water loss and minimized incorporation of solids in order to obtain a product resembling non-processed fruit.

Falade and Aworh (2005) conducted a study about the sensory evaluation and consumer acceptance of osmosed and oven-dried African star apple and African mango. In this study sucrose solutions of 44, 52 and 60^o B in water bath were used at 27 and 40 ^{0}C for 8 hours. According to this study water loss and solid gain increased with increasing degree of fruit ripeness, immersion time, concentration and temperature of sucrose solution. Water loss and solid gain increased with decreasing slice thickness of fruits.

Flink (1979) conducted a study about the influence of osmotic dehydration on drying behaviour and product quality of carrot slices. This study concluded that one of the promising solution compositions was 40% sucrose and 5% salt. Result of this experiment indicates that osmotic dehydration can yield good quality product with better texture and colour stability.

Cecelia *et al.* (2003) osmotically dehydrated christophena in various syrups. The initial 30 ^{0} brix of syrup was increased daily to 70^0 brix within 3 days. Drying of the products was at 68 ^{0}C for 4 hr. It was observed that unpeeled christophena cubes immersed in 75% sucrose +25% blend of glucose +fructose had the highest overall acceptability, highest total soluble solids, lowest texture, lowest moisture content and low microbial count after 20 days of storage at 19 ^{0}C.

Rashmi (2005) determined the optimum sugar syrup concentration for osmo-air dehydration of Giant Kew variety of pineapple and quality evaluation of osmotically dehydrated product. Pineapple pieces were subjected to osmosis for 24 hr in 50^o, 60^o and 70^0 B sugar syrup.Significally higher amount of moisture was removed by 70^0 B sugar syrup closely followed by 60 ^{0} B syrup.

Chenlo *et al.* (2006) studied about the osmotic dehydration /impregnation kinetics of pardon pepper (*Capsicum annuum* L.) with sodium chloride solutions. Several sodium chloride concentrations (17 to 26.5 % w/w) and temperatures (25 to 45 ^{0}C) and contact times up to 8 hr were selected as variables. Solid gain, weight reduction, water loss, normalized moisture content and normalized solid content were calculated at each experimental condition. In all cases, solid gain, weight reduction and water loss increased with temperature and salt concentration. In all experimental conditions the colour changes were only significant at the highest temperature assayed and also depend on osmotic concentration.

2.5.3 Effect of temperature on osmosis

An increase in temperature up to a certain extent is known to increase the rate of osmosis by increasing water removal and impregnation of osmotic substances in the fruit tissues. Higher temperature affects the semi permeability of the cell walls, cause browning and flavour deterioration (Tiwari, 2005).

Anne-Lucie *et al.* (1991) reported that a temperature increase is favourable to water loss, probably related to the favourable effect of temperature of the apparent diffusivity of water molecules in the agar gel. But for solute gain, no effect of temperature can be observed in the dewatering situation. This study revealed that a temperature increases from 30 to 70 ^{0}C is favourable to water loss; a temperature increases from 30 to 50 ^{0} C is favourable; whereas a temperature increases from 50 to 70 ^{0} C is not favourable to solute gain.

Sharma *et al.* (1991) conducted a study about the application of osmosis before canning of apple rings. This study showed that different dip treatments before canning for various periods resulted in weight loss, sugar penetration and increase in the shrinkage of the apple rings. They reported that the pre treatment in the 70 % sugar solution at 50 ^{0}C for half an hour prior to canning was adjusted to be the best treatment from physico-chemical, sensory and economic point of view. The application of this technique resulted in the products of desired weight, colour and appearance, texture and sugar-acid blend compared to those canned prior as per the conventional canning technology. The pre-treatment technique being simple, cheap, without involving extra equipment is commercially feasible.

Xian and Pedro (1993) studied about the vacuum osmotic dehydration of fruits. This study showed that vacuum osmotic dehydration leads a special behaviour of mass transfer in fruit sugar solution system. The vacuum osmotic dehydration technology makes possible to use lower solution temperature to obtain higher water transfer rate so as to obtain good quality of dehydrated fruit product. Osmotic dehydration of pine apple and apricot under vacuum condition increased water loss.

Nsonzi and Ramaswamy (1998) conducted a study on osmotic dehydration kinetics of blue berries. The kinetics of moisture loss, solid gain during osmotic dehydration of blue berries under different conditions of temperature (37-60 ^{0}C), concentration of the sucrose solution (47 -70 ^{0}B) and contact time between fruit and sucrose solution (0.5hr-5.5 hr) were studied. The trend was that the magnitude of moisture loss increased with temperature, concentration of the sucrose solution and contact time. This study revealed that osmotic dehydration process minimized shrinkage of the blue berries during freeze drying.

Yu *et al.* (1999) determined the moisture sorption characteristics of freeze dried, osmo-freeze dried and osmo air dried cherries and blue berries. The equilibrium moisture content of sweet cherries and high blue berries which had been freeze dried, osmo freeze dried and osmo air dried were determined at 10, 25 and 40 ^{0}C. At 10 ^{0}C, the equilibrium moisture content of osmo air dried cherries was generally higher than that of osmo freeze dried and freeze dried cherries.

Kaleemullah *et al.* (2002) conducted a study on osmotic-air drying characteristics of papaya cubes. This study reveals the effect of solute concentration (50, 60 and 70^0 brix) and temperature (32 ^{0}C, 50 ^{0}C and 60 ^{0}C) on osmotic dehydration of papaya and concluded that the dehydration rate of papaya cubes reduced during osmosis in the first half an hour to the fourth hour with the syrup at 32 ^{0}C.

Gabriela *et al.* (2004) evaluated the water loss, weight reduction and solute (sugar) gain in osmotic dehydration of mango (Tommy Atkins variety) slices, used as a pre-treatment to a further chips production by deep fat frying process. In this case, water loss and solute uptake are desirable for the final product quality, because reduction of the initial moisture content and the presence of sugar minimize the residence time and oil incorporation during the frying process. The process variables studied were time (40- 120 min) and temperature (30-50 ^{0}C), using a central composite design. The temperature and process time affected the mass transfer phenomena in the osmotic dehydration.

Navdeep *et al.* (2006) conducted a study on osmotic dehydration kinetics of carrots. In this study carrot slices were osmo-dehydrated using sucrose, glucose and salt. The effects of immersion temperature, solute concentration and immersion duration on water loss and solid gain of carrot slices were observed. The regression analysis was carried out to develop models for water loss and solid gain of carrot slices during osmotic dehydration. The developed models can be used for predicting water loss and solid gain during osmosis of carrot slices. The models can also be used to determine the osmotic dehydration time in getting the desired level of sucrose, glucose or salt content in carrot slices.

Jefferson *et al.* (2007) analyzed the osmotic dehydration variables which have an influence on tomato drying. This work presents a study of tomato osmotic dehydration in a NaCl solution. Solution temperature and concentration, immersion time and agitation had their influences evaluated. The concentrations of the osmotic solutions used at 30 ºC were 5, 10, 15, 20, 25 and 30% (w/w). Kinetics of moisture content and solid gain was obtained. After the osmotic treatment, the fruits were dried (tray dryer) in a range of 40 to 60 ^{0}C in 10

hours. It was observed that temperature and agitation increases moisture reduction. Osmotic treatment was responsible for increasing drying rate in a subsequent convective tray drying.

2.5.4 Effect of time and solution to sample ratio on osmosis

With an increase in solution to sample ratio, rate of osmosis increases up to a 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.

Argaiz *et al.* (1994) conducted a study on osmotic dehydration of papaya with corn syrup solids. The concentration of the solution as 50%. The fruit to syrup ratio was 1: 4. For each corn syrup solids, the osmotic parameters increase as contact time increase and observed that the change in the studied parameters were more important during the first four hours. The results of the osmotic concentration show that a desired water loss and solid gain may be obtained in papaya treated with corn syrup solids solutions due to the fact that the fruit losses more water and gain less solids than in treatment with common sugar.

Vergara *et al.* (1997) analysed the drying process of osmotically dehydrated apples using the characteristic curve model .In this study the apple slices were subjected to osmotic dehydration process in sucrose syrup and then air dried at 50, 60 and 70 ^{0}C. The fruit to syrup ratio was 1: 2. According to this study an increase in temperature reduces the time needed to reach desired moisture content and also moisture transfer rate depends on drying temperatures as well as on initial solid content.

Sunjka and Raghavan (2004) assessed the pretreatment methods and osmotic dehydration for cranberries. In this research, different drying pretreatment methods were tested on cranberry fruit *(Vaccinium macrocarpon*).Mechanical and chemical pretreatments were examined, as well as osmotic dehydration. Osmotic dehydration involved evaluation of different osmotic agents, their concentrations, and different times of osmotic hydration. There were three observed parameters: mass gain, solids gain, and moisture loss. Time and concentration of osmotic agent significantly promoted the moisture removal and sugar uptake. Different methods of pretreatment can have significant influence on subsequent drying processes. All three factors of osmotic dehydration (process duration, agent type, and concentration of sugar solution) showed significant influence.

Sharma *et al.* (2004) osmosed lye peeled fruits of 5 varieties of apricot in 70 ^{0}B maintained at 50 ^{0}C for different periods of time and finally dehydrated in cabinet drier to a shelf stable product. This study showed that maximum mass reduction, solid gain and water loss recorded in the 'Farmingdale' variety during osmosis. The drying time reduced to 15 hr in the osmotically dehydrated apricot compared more than 26 hr in conventional dehydration.

Dehydrated fruits could be stored for more than 6 months after packing in laminated pouches under refrigerated as well as ambient storage conditions without much change in different quality parameters.

Singh (2001) studied the osmotic dehydration of carrot shreds for Gazraila preparation. In this study dehydration of carrot was carried out by concentrating the material in the sucrose solution (50° B) at room temperature prior to drying in cabinet drier at 55 ^{0}C. Half of the initial moisture content was removed during the initial 30 min of osmosis and additional 6 hr were required to reduce the moisture content of the osmosed carrot shreds to 5.8%. For the non osmosed carrot shreds, the drying time was 12 hr at 55 ^{0}C. Gazraila made from osmosed dehydrated shreds received higher scores for all sensory parameters.

Chormale *et al.* (2004) osmotically dehydrated the rasogolla from cow milk at various sugar to rasogolla ratios (1:1, 2:1 and 3:1) and temperatures (40, 50, 60, and 70 °C) and compared with the rasogolla dehydrated by conventional method for quality attributes before and after storage. The osmotically dehydrated rasogolla with a sugar to rasogolla ratio of 1:1 at 40 ^{0}C was found most desirable with respect to sensory quality and chemical composition. The osmotically dehydrated rasogolla could be stored at room temperature for a period of about 1 month with out much deterioration in chemically and sensory quality after dehydration in 25% sugar syrup concentration for 4.5 min, whereas the rasogolla dehydrated by conventional method though resulted in selective removal of water but lost the colour and become hard which was not amenable to rehydration and was found unacceptable.

Ghosh *et al.* (2006) osmosed carrot slices of 5 mm thick for 10, 20, 30, 40, 50, 60, 90, 120, 150 and 180 min in an osmotic solution at 30 ^{0}C at a sample to solution ratio of 1:5 and a constant agitation of 150 rpm.The osmotic solution was prepared by 5,10 and 15 % concentration of salt along with 50^{0}B sugar and 0.1% sodium metabisulphate.Carrots were osmosed for 1 hr and then dried at 50,60 and 70^{0}C with an air velocity of 0.6m/s. The study revealed that osmo-hot air dried carrot slices received higher scores at 5% significance level in both its dried and rehydrated forms, compared to the conventional air dried carrots.

2.5.5 Osmotic dehydration apparatus

Lemaguer and Sharma (1998) designed and installed a pilot-scale belt type osmotic contactor in a continuous osmotic dehydration process to obtain maximum water removal from fruits and vegetables with minimum contact time. The carrot was chosen as a representative vegetable and a ternary mixture of sucrose/sodium chloride/water with total solids concentration of about 50 to 55% was chosen for the osmotic solution. The experimental results showed that the optimum condition was found to require a 44%

sucrose/7% sodium chloride aqueous solution with 16 min of contact time which gave a water loss of 26% and a highest ratio of water loss over solids gain (about 9) among different treatments. It is concluded that the continuous type of contactor can have potential applications in the food industry.

Marouze *et al.* (2001) defined the functions required by users of osmotic dehydration equipment and presented seventeen principles used to contact foods with a concentrated solution. This study concluded that conveyor belt devices that drench the treated food with the concentrated solution present a good response, even though they appear difficult to adapt to vacuum processing. With this type of equipment, there can also be problems of the sprays clogging if high-concentration solutions, particularly sugar solutions, are used.

Kumar *et al.* (2002) designed and developed an osmotic dehydration pilot plant for the dehydration of fruits. The plant consists of a fruit holding pan, osmotic reactor, mixing chamber with heater, pumping system and drying unit. The mixing chamber was used for the preparation of osmotic syrup and also for mixing and heating of osmotic syrup during osmotic dehydration. The osmotic syrup was circulated at a flow rate of 12 l/min from mixing chamber to osmotic reactor by means of a pumping unit to maintain uniformity of concentration of osmotic syrup during osmotic dehydration. The drying unit was used to remove the existing water content in the fruit slices after osmotic dehydration for safe storage. This plant was evaluated using banana and papaya. The maximum water removal of 42.5 and 60.08 percent respectively for banana and papaya were observed.

Michèle *et al.* (2004) conducted a study on dilution and aging of sugar solution after its multiple uses in an osmotic dehydration process of low bush blue berries. The objective of the study was to osmotically dehydrate batches of low bush blueberries. Baskets of blueberries were immersed in a batch reservoir that was either opened or closed. The process was performed at 60 ^{0}C for 3 hours. The sucrose solution was recirculated (30 l/min) with a ratio of 10:1 (solution: blueberries). Various chemical changes (e.g. pH, sucrose, glucose, fructose, anthocyanins) were measured. The pH of the solution decreased to reach an equilibrium value of 3.6. It was found that there was a significant inversion of sucrose into glucose and fructose in the solution. If the osmotic process was performed using an open reservoir, the natural evaporation was sufficient to compensate for the dilution of the solution.

2.5.6 Quality of the product

Kumar *et al.* (1991) conducted osmotic dehydration of bitter gourd rings. The study revealed that blanching 1cm thick rings for 2 min in boiling water inactivated all the enzymes present in the rings. Blanching rings in 5% Nacl and drying them in a tray drier for 3 hr at

70 ^{0}C followed by 4 hr drying at 60 ^{0}C gave dark green, soft textured, slightly salty and less bitter product.

Thomas and Gopalakrishnan (1993) reported that green pepper blanched in boiling water for two minutes gave black colour. Less intense black colour was observed when boiled for five minutes in water and the colour could be improved by 15 min boiling in water.

Thomas and Gopalakrishnan (1994) developed a process for the production of unwrinkled dry ball shaped green pepper. The cleaned pepper berries were subjected to blanching in boiling water till the enzymes responsible for blackening the pepper are inactivated and polyphenols washed out of the berries. The pepper then subjected to conditioning and drying. The dry pepper when soaked in water at ambient temperature absorbs water and is almost similar in appearance to that of fresh green pepper.

Lopez *et al.* (1997) studied the moisture sorption characteristics of blanched and osmotically treated apples and papaya at 25 ^{0}Cwith 25% sucrose content. The initial moisture content of the apples and papayas osmotically treated were approximately 15 % lower than those of the blanched fruits. The experimental results proved that osmotically treated papaya maintained a better appearance.

Jawahar *et al.* (2001) reported that bitter guard slices blanched either in 5% NaCl at 100 ^{0} C for 3 min or in a two-stage blanching process in 5% NaCl at 70-80 ^{o} C for 20 min followed at 100 ^{0}C for 3 min was most effective in removing bitterness and maintaing firmness. On storage colour changed from dark green to olive green with no microbial growth.

Jasim and Shivhare (2001) investigated the effect of selected pre treatments on drying characteristics and colour of green chilly. Pre treatments resulted in increasing the drying rate, while pre treating blanched chillies in 1% lye solution containing 0, 25% magnesium carbonate retained maximum colour of the product.

Rajkumar and Sreenarayanan (2001) conducted studies on dehydration of white and red colour onion varieties in cross flow drier at different temperatures viz.,50,60 and 70 ^{0}C with different sulphitation levels as pretreatment viz 0.2%, 0.3%, 0.4% in order to control the discolouration and to produce value-added products with increased shelf life. The time required for dehydration was compararatively lesser for the sulphited than control samples of

white onion at all the selected temperatures. It was observed that the onion flakes dehydrated at 60 ^{o}C with 0.3% sulphitation level scored the maximum points. A progressive increase in moisture content and decrease in ascorbic acid were observed during storage.

Karthika *et al.* (2004) osmosed potato slices with different pre treatments. This study concluded that the better colour,flavour and taste was obtained for the osmosed potato slices with blanching followed by soaking in KMS.

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

Marco *et al.* (2005) studied the structure–property relationships in osmo-air-dehydrated apricot cubes. 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 apricot cubes was studied. Osmotic dehydration was performed for 30 and 60 min at 25 ^{0}C in a glass tank filled with 60% (w/w) sucrose or sorbitol syrup, supplemented with ascorbic acid (1%) and NaCl (0.5%) as antioxidants. Incorporation of sugars and partial concentration of apricot cubes, through an osmotic pre-treatment, increased drying rate during the first falling rate phase of the air dehydration step, improving colour stability. The osmotic pre-treatments also slightly decreased shrinkage and caused a better retention of surface smoothness during the first phase of air dehydration.

Kumar *et al.* (2004) investigated the quality of dehydrated onion slices produced by combination drying technique. Appearance, colour, flavour and rehydration characteristics of combination drying onion slices were compared with those of hot air dried and freeze dried products.The hot air dried samples exhibited shrinkage, case-hardening, browning and poor rehydration properties. The freeze dried samples appeared wholesome, more volatile content and good rehydration properties. The combination drying sample was comparatively superior to hot air dried sample and nearer in quality to freeze dried sample in appearance, colour, rehydration properties and volatile content.

MATERIALS AND METHODS

CHAPTER III
MATERIALS AND METHODS

In this chapter the preparation of raw materials, osmotic agent and the experimental procedures are presented. The materials required and the development of a pilot plant for osmotic dehydration is also explained. The study also involves standardization of the concentration of osmotic solution, effect of temperature and time on osmotic dehydration and the quality of the product.

3.1 Raw material

Pepper (*Piper nigrum* L.) variety (Panniyur and Karimunda) harvested 10-15 days before maturity (moisture content 70% wb) were procured from the instructive farm of a progressive farmer at Tavanur were used for this study. These berries were separated from the spikes and cleaned manually. The initial moisture content was determined by the standard method (AOAC, 1975).

3.2 Treatments

The different treatments used for the study were:

Control sample

Fresh green pepper berries of uniform size were taken as the control sample for the osmotic dehydration.

Blanched sample

Blanching was done by dipping the green pepper berries in boiling water for 15 minutes and immediately cooled (Pruthi, 1993). These berries were drained and spread on a cotton cloth for removal of surface moisture.

3.3 Osmotic dehydration

3.3.1 Preparation of osmotic solution

Preliminary studies using NaCl were done for concentrations ranging from 10 to 50 %. It was observed that water loss was considerable in the range of 20 to 40 %, and hence three concentrations of 20, 30 and 40% were selected for further studies.

3.3.2 Optimization of concentration of solution

Fresh pepper berries were washed and immersed in the NaCl solutions of 20%, 30% and 40% concentration at different temperature and time period and in different sample to solution ratios. The optimisation of the concentration was done based on water loss and solid gain.

3.3.3 Time for osmotic dehydration

From the preliminary studies it was seen that the water loss was considerable within the range of 1 to 4 hr. The optimization study for osmosis time was conducted by dipping fresh pepper berries in osmotic media for 1 hr, 2hr, 3hr and 4hr of optimised concentration.

3.3.4 Sample to solution ratio

It is important to use an optimum ratio of sample to solution for economic considerations. Different sample to solution ratio (1:2, 1:4, and 1:6) were used and suitable one was determined by calculating the water loss and solid gain.

3.4 Experimental set up

The osmotic dehydration set up was developed and tested. The main components of the experimental set up were:

- Osmotic dehydration chamber
- Heating chamber
- Stirrer assembly
- Base plate and frame.

3.4.1 Osmotic dehydration chamber

This is a double walled cylindrical vessel made of stainless steel having an inner diameter of 27.5 cm and a depth of 27 cm. The space between the walls is 2 cm. The water outlet is provided to carry the hot water from the heating chamber to the osmotic dehydration chamber and used water is recirculated towards the heating chamber, with the help of a 0.06 KW centrifugal pump.

Water temperature inside the osmotic dehydration chamber was maintained with the help of a thermostat and a cut off mechanism. The hot water was carried through pipes with an inner diameter of 1.4 cm. Connectors were provided at the inlet and outlet of the chamber for conveying water without leakage.

3.4.2 Heating chamber

The heating chamber consists of a stainless steel vessel having a diameter of 26.5 cm and a depth of 28 cm. A 220 V, 1500 W heater was provided to heat the water in the heating chamber. The heated water was circulated through the pipes to the annular space provided in the dehydration chamber. The flow rate of the heated water was controlled by a control valve.

3.4.3 Stirrer assembly

A stainless steel mechanical stirrer with three vanes was used to provide agitation within the dehydration chamber. The stirrer was directly coupled to a 12 V DC motor by bracing. The motor takes power from a 220 V, 50Hz domestic AC port through a

DC converter. This arrangement provides uniform agitation with in the osmotic dehydration chamber.

3.4.4 Base plate and frame

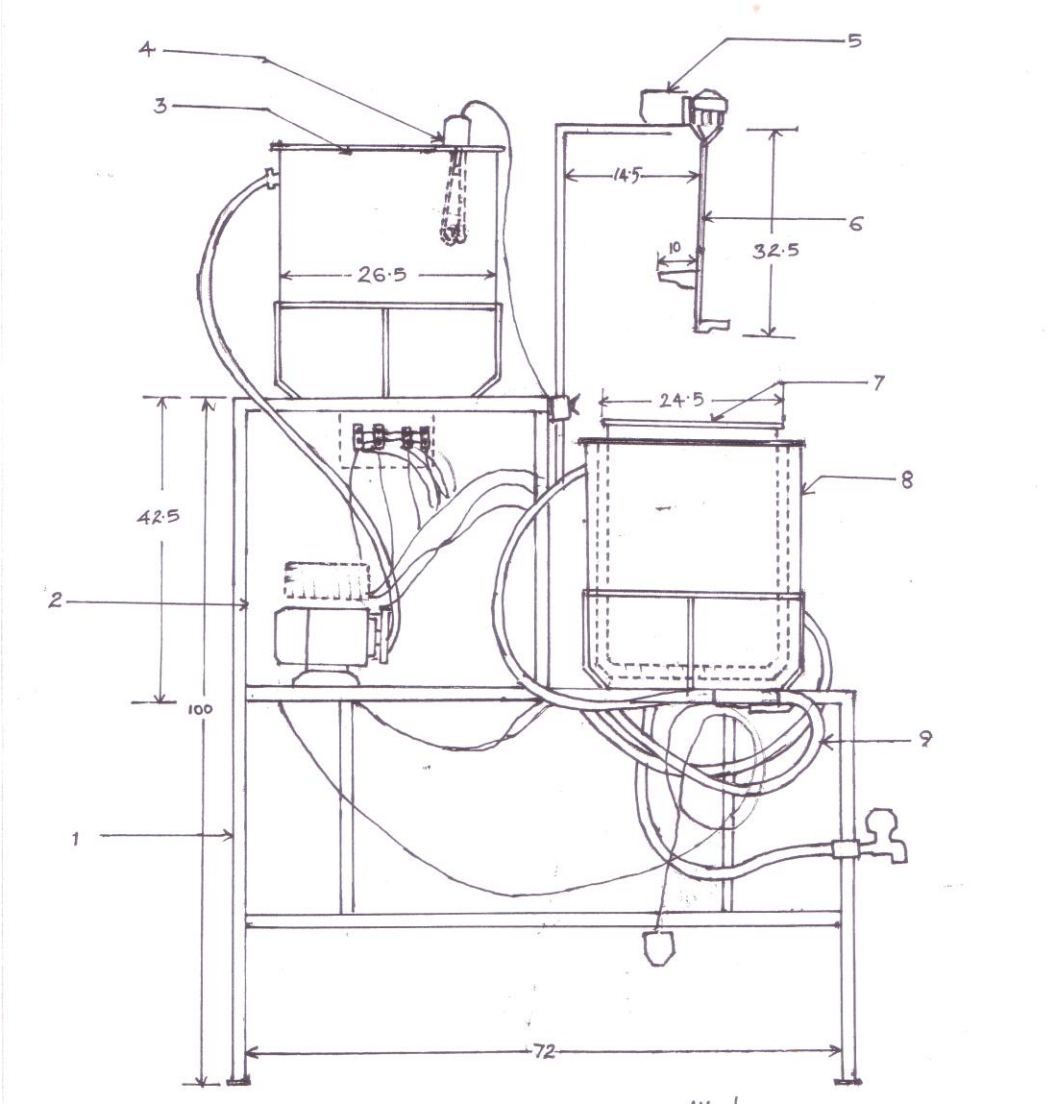
The whole osmotic dehydration set up was supported on a mild steel plate and angle iron frame work with an over all length of 72 cm, breadth 37 cm and height 100 cm. Base plate and frame work was shown in plate 3.1 **.**

3.4.5 Experimental procedure

The complete experimental set up was shown in plate 3.1. The heating chamber was filled with water and the osmotic dehydration chamber was filled with hypertonic solution. The filled water was heated and circulated through the space between the walls of the osmotic dehydration chamber so as to heat the solution. When the temperature of the solution inside the chamber reaches the desired temperature ($40 \pm 2\ ^0C$), the heater will be cut off automatically. Then the fresh green pepper berries were put in to this solution. A perforated stainless steel vessel was used as a pepper holding pan. A stainless steel mechanical stirrer with three vanes was used to cause uniform mixing within the dehydration chamber. The stirrer was directly coupled to a motor .The continuous pumping of hot water was maintained for different time periods. At the end of the immersion period, the samples were withdrawn from the osmotic solution, drained and gently blotted with the filter paper to remove the adhering solution.The samples were weighed by using an electronic balance with an accuracy of 0.001mg. All experiments were replicated thrice. The elevation and top view of the osmotic dehydration plant was shown in fig.3.1 and 3.2 respectively. Fig.3.3 shows the flow chart of the production of osmotically dehydrated green pepper.

Statistical analyses of the samples were carried out using ANOVA to test the significant difference of each factor. From the analysis, selected osmotic conditions were chosen for the subsequent drying studies.

Plate 3.1 Experimental set up

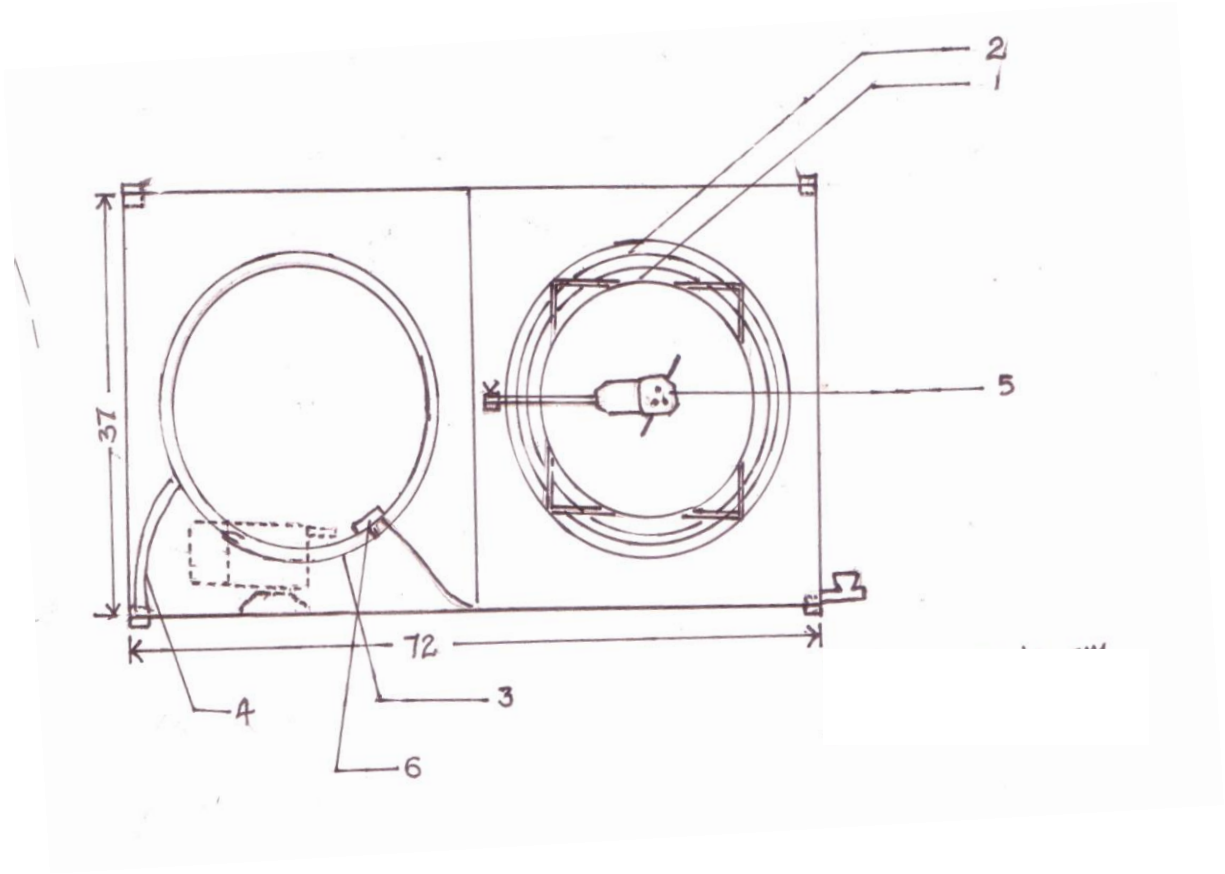


All dimensions in mm

Scale 1:6

Fig.3.1 Osmotic dehydration plant –Front view

Sl. No	Particulars	Specifications
1	Frame	length (100cm)
2	Base plate	Width (72cm)
3	Heating chamber	26.5 cmϕ
4	Heater	220 V, 1500 W
5	Motor	0.6 hp
6	Impeller	Length (32.5 cm)
7	Holding Chamber	24.5 cmϕ
8	Osmotic dehydration Chamber	27.5cm ϕ
9	Hose	1.4 cm ϕ



All dimensions in mm

Scale 1:6

Fig.3.2 Osmotic dehydration plant –Top view

Sl. No	Particulars	**Specifications**
1	Holding Pan	(24.5 cm ϕ)
2	Osmotic dehydration chamber	(27.5 cm ϕ)
3	Heating chamber	(26.5 cm ϕ)
4	Hose for water supply	(1.4 cmϕ)
5	Agitator	Length 32.5 cm
6	Heater	(220 V, 1500 W)

3.5 Dehydration parameters

In osmotic dehydration, there is a simultaneous counter-current mass transfer of water from sample to concentrated solution and solute in to the sample. Hence in order to analyze the data, three parameters namely water loss, solid gain and weight reduction were calculated for each sample using the following formulas.

$$\text{Water loss} = \frac{\text{Initial moisture-Final moisture}}{\text{Initial gross weight}} \quad \text{-------(3.1)}$$

$$\text{Weight reduction} = \frac{\text{Initial weight-Final weight}}{\text{Initial weight}} \quad \text{---------- (3.2)}$$

$$\text{Solid gain} = \text{Water loss-Weight reduction} \quad \text{-------(3.3)}$$

3.6 Experimental design

The experiment was conducted as a 4-factor experiment in completely randomized design. Three concentrations, four osmotic time and three temperatures and three sample to solution ratios were chosen .The details of the concentrations, three times and three temperatures and three ratios are given below. For each CRD, the number of replications was three.

1 Independent variables	**Levels of treatment**
NaCl (%)	20 30 40
Soaking time (hr)	1 2 3 4
Temperature (^{0}C)	30 40 50
Ratio	1:2, 1:4, 1:6

II Dependent variable:

- Water loss
- Solid gain
- Weight reduction
- Drying rate

3.7 Secondary Drying

Osmotic dehydration generally will not give a product of low moisture content to be considered shelf stable. Consequently osmosed product should be further dried to obtain shelf stable product. Since the initial moisture content of green pepper is 70 % wb, there is a need for further drying to reduce the moisture content to 10 to 12 % wb. In this study drying was achieved by tray drier and freeze drier.

3.7.1 Tray drier

The samples after the osmotic dehydration were dried in a tray dryer (Plate 3.3) at 40, 50 and 60˚C. The temperature inside the chamber was regulated using a thermostat. The weight of the sample was taken at an interval of one hour. Drying was stopped until the moisture content of the samples become constant.

Plate 3. 2 Tray drier

3.7.2 Freeze drier

The study was conducted using DELVAC freeze drier (Plate 3.4) which had the specifications of, condenser capacity- 5 kg, condenser volume- 7.3 liters, condenser temperature - (-55°C ±5°C), heat extraction rate- 180/kcal, digital vacuum and digital temperature display, 220/230 volt, 50 hertz single phase through servo stabilizer. The drying chamber is a cylindrical acrylic enclosure, which consists of a shelf of five circular stainless steel plates of diameter of 250mm .The trays are provided with heating coils at their bottom and are connected to a product heater. The chamber is made vacuum tight by means of the rubber sealing provided in the acrylic enclosure.

The temperature of the trays can be maintained and controlled using thermostat in the product heater. Temperature of the trays can be varied from 0 ^{0}C to a maximum of 100 ^{0}C using the product heater. The cold trap is used to condense the vapors that are formed due to sublimation in to ice. A refrigeration system, with a 0.5 hp compressor, is provided to maintain a low temperature of - 40 ^{0}c in the cold trap. Since the chamber is air tight, the only means of the removal of vapors is by condensing them in the cold trap. The vapour pressure in the cold trap is lower than that in the drying chamber, due to the lower temperature maintained in the cold trap, which facilitates the movement of the vapours to the cold trap, and they are condensed in to ice. A vacuum pump is provided to maintain low pressure of 5 m Torr within the chamber. This high vacuum facilitates the direct sublimation of ice in to vapour as well as removes the non-condensable gases in the chamber.

The samples of green pepper, after pre treatments were frozen initially to -10 ^{0}C in the deep freezer. The refrigeration unit of the freeze drier was switched on first, so that the cold trap attains the temperature of – 40 ^{0}C. Then the blanched pepper was loaded on to the plates. The chamber was then closed air tight. Vacuum was created in the chamber by means of the vacuum pump provided. Once the vacuum pump was started, after 10 min, the value of 999 mTorr on the vacuum gauge was reduced to approximately 5 m Torr.Heat was given to the product by the heating coils provided at the bottom of the trays on which the sample were kept. After that the vacuum was released by purging.

Plate 3.3 Freeze drier

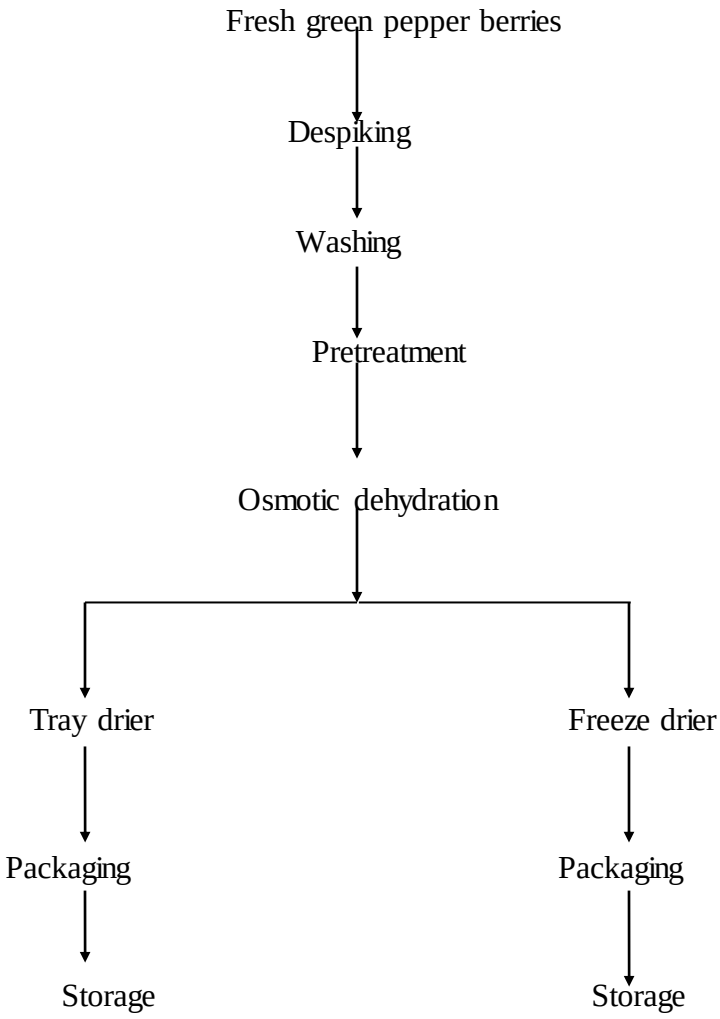


Fig. 3.3 Flow chart of the production of Osmotically dehydrated green pepper

3.8 Quality analysis of osmotically dehydrated green pepper

3.8.1 Moisture content

Moisture content was determined by toluene distillation method using Dean Stark apparatus as per Associates of Official Analytical Chemists (AOAC, 1975) method (Plate 3.5). Toluene, measuring 100 ml, was taken in a distillation flask containing 5 g of ground green pepper sample. The flask was attached to the Dean Stark apparatus with the condenser. On boiling, the water vapour along with toluene got distilled from the flask, condensed, and was trapped in the receiver of the apparatus, which contained toluene. Distillation was continued till the volume of moisture collected remained constant. The apparatus was cooled at room temperature and weight of moisture collected was noted. The moisture content was calculated by,

$$\text{M.C. (w.b), \%} = \frac{W_w \times 100}{W} \quad \text{-------- (3.4)}$$

Where,

W_w = Weight of water collected, g

W = Initial weight of sample, g

M.C (w.b) = Moisture content, % wet basis

The moisture content on dry basis of pepper was found out using the following formula

$$\text{Moisture content (d.b), \%} = \frac{100 \times \%w.b}{(100 - \%w.b)} \quad \text{-------- (3.5)}$$

(www.sgrl.csiro.au/index.html)

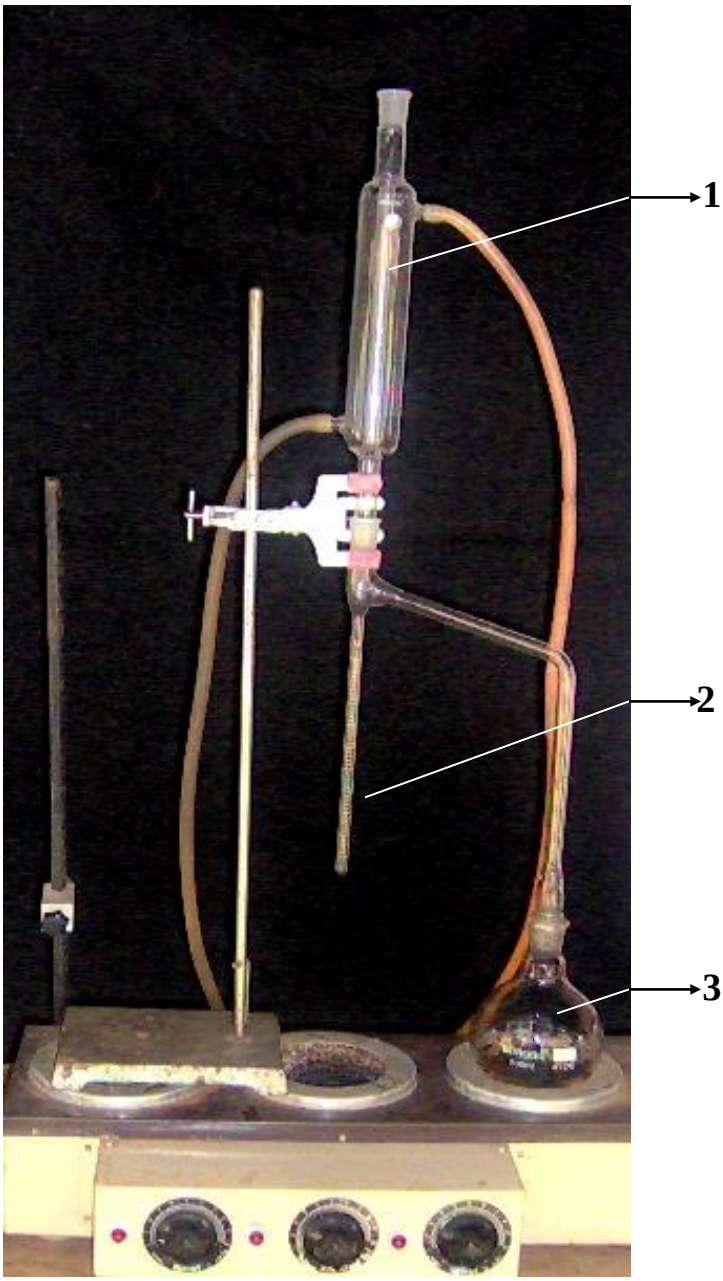


Plate 3.4 Dean Stark Apparatus

1. **Condenser**
2. **Dean Stark Apparatus (moisture collected)**
3. **Round Bottom Flask (Sample + Toluene)**

3.8.2 Rehydration ratio

Rehydration characteristics of dehydrated foods are of great importance. About 5 gm of dried product were taken and immersed in boiled water. The rehydration ratio was computed as the ratio of rehydrated sample to that of the dehydrated sample.

$$\text{Rehydration ratio} = \frac{W_2}{W_1} \quad \text{---------- (3.6)}$$

Where,

W_2 = weight of the rehydrated sample, g

W_1 = weight of the dehydrated sample, g

(Lin *et al.*, 2006)

3.8.3 Estimation of volatile oil

The volatile oil content was estimated by distillation method using Clevenger apparatus as shown in Plate 3.6. About 50 g powder and 500 ml distilled water were taken in a round bottom flask and attached to the Clevenger apparatus with a condenser. On boiling, the oil was collected in the receiver of the apparatus which contained distilled water. The distillation was carried out for 2 to 4 hours. Volume of oil collected after cooling was expressed as,

$$\text{Volatile oil, \% (v/w)} = \frac{V}{W} \times 100 \quad \text{-------- (3.7)}$$

Where,

V = Volume of oil collected ml, assumed g

W = Total weight of the sample, g

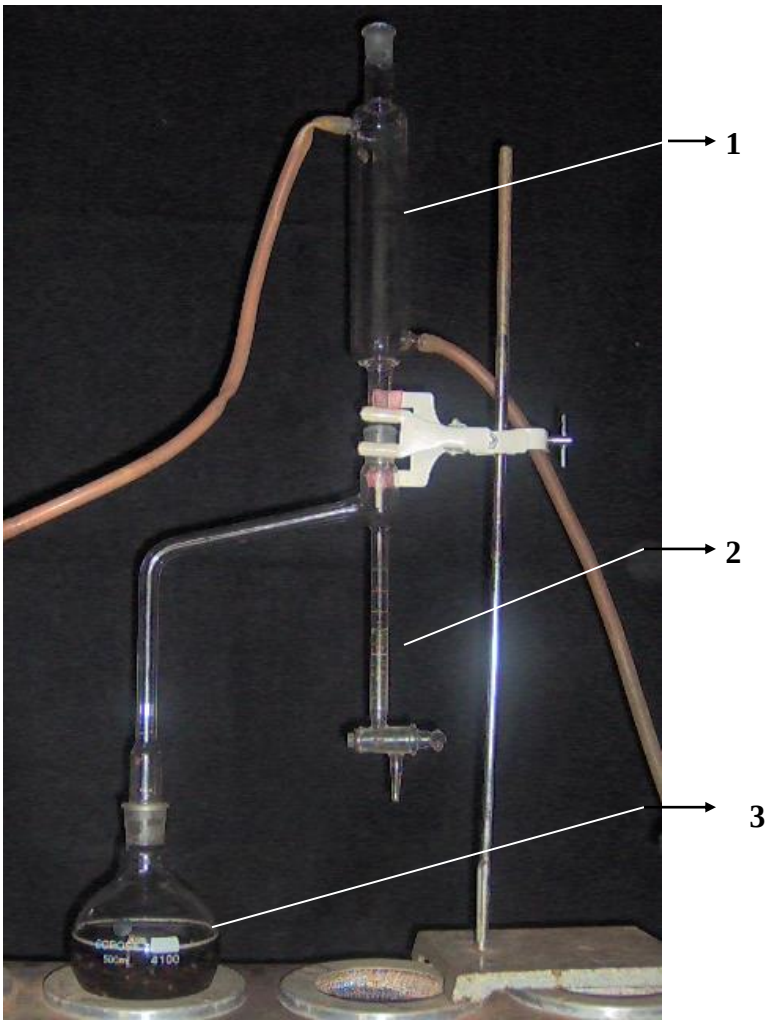


Plate 3.5 Clevenger apparatus

1. **Condenser**
2. **Clevenger Apparatus (oil collected)**
3. **Round Bottom Flask (Sample + Distilled water)**

3.8.4 Estimation of volatile oil components

Gas chromatographic analysis of volatile components

The volatile components of pepper were extracted and analyzed by Gas chromatograph (Plate 3.7). The model GC–Shimadzu-17A equipped with Flame Ionization Detector (FID) was used. The pepper oil of 0.5 µl was injected under the following conditions.

Column : DB-1
Type of column : Capillary
Column temperature : 70 to 225^{0}C at the rate of 5 ^{0}C/ min
Detector temperature: 275^{0}C
Injector temperature : 250^{0}C
Nitrogen flow : 11ml/min.

Concentration and quantification of major constituents of pepper oil were carried out using the reference standards obtained from Sigma Chemical Company, United States of America (U.S.A.).

Plate 3.6 Gas chromatograph

3.8.5 Estimation of colour

Hunter Lab colour flex meter(Make:Hunter Associates Laboratory, Reston, Virginia, USA) was used for the measurement of colour changes in dried pepper. It works on the principle of focusing the light and measuring the energy refleced from the sample across the entire visible spectrum.The colour meter has filters that rely on "Standard Observer curves" which,define the amount of red,yellow,blue and green colours.It Provides readings in terms of L, a, and b. These parameters indicate the degree of brightness(L),the degree of redness (+a) or greenness (-a) and the degree of yellowness (+b) or blueness (-b), respectively.

The colour of fresh and dried pepper sample were measured by using Hunter lab scale at 10^{0} observer at D65 illuminant.Before measuring the colour of the samples, the instrument was standardized by placing the black and white standard ceramic plates.The sample colour was measured by filling the pepper in the transparent cup provided,without any void space at the bottom. The deviation of the colour of the samples to standard were observed and recorded.

The total colour difference (ΔE) was defined as:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad \text{--------} \ (3.8)$$

Where ,

ΔE = Total colour difference

$\Delta L = L - L_0$

$\Delta a = a - a_0$

$\Delta b = b - b_0$

Here a and b are the measured values of the dried samples and L_0,a_0 and b_0 are the values of the fresh green pepper.

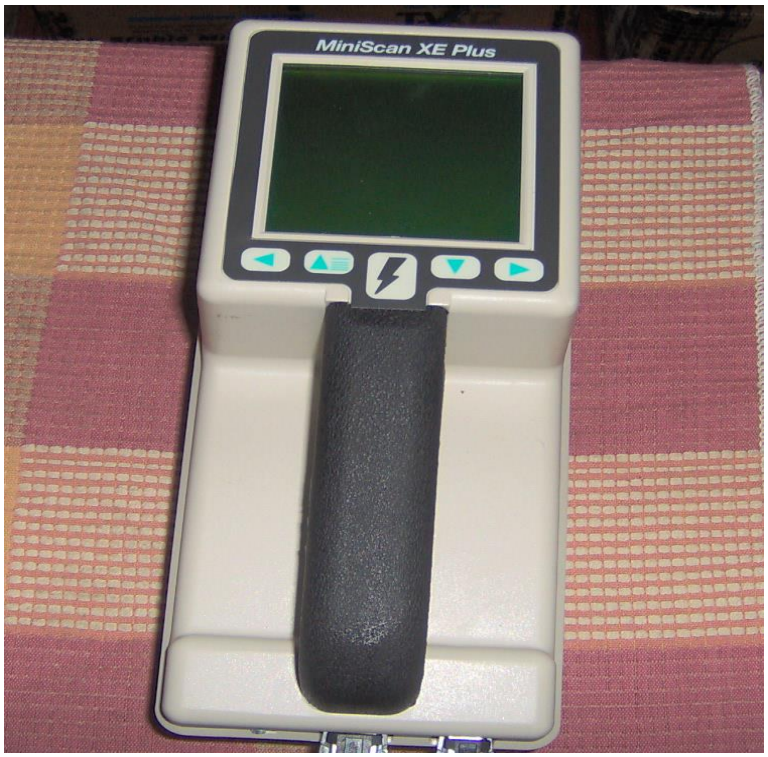


Plate 3.7 Hunter Lab colour flex meter

RESULTS AND DISCUSSION

CHAPTER IV
RESULTS AND DISCUSSION

Results and discussion of the experiments carried out on the osmotic dehydration of green pepper are presented in this chapter. In this study, Panniyur and Karimunda varieties were used for the osmotic dehydration process. The effect of process temperature, time, sample to solution ratio and concentration of the osmotic agent were studied and discussed. In addition, the effect of osmotic dehydration on secondary stage of drying using tray drier and freeze drier were also studied. Quality of osmotically dehydrated green pepper in terms of volatile oil, components, colour and rehydration ratio are studied and discussed.

4.1 Test samples

Green pepper procured from an instructive farm of a progressive farmer was used for the experiments. The initial moisture content, colour and volatile oil of the test samples were estimated by the standard methods explained in chapter III and the results are tabulated in Table 4.1.

Table 4.1 Composition of test samples

Composition	Variety					
	Panniyur			Karimunda		
Moisture content, (wb)	70.14 %			69.38 %		
Colour	DL	a	b	DL	a	b
	10.72	-0.67	9.76	11.23	-0.92	10.86
Volatile oil	2.5 %			2.64 %		

4.2 Osmotic dehydration process

The standardization of osmotic conditions such as concentration, time, temperature and sample to solution ratio were carried out in the newly developed osmotic dehydration plant. The mass transfer occurring in the osmotic dehydration process for blanched and unblanched samples of Panniyur and Karimunda varieties were measured in terms of water loss, solid gain and weight reduction.

4.3 Effect of solute concentration on mass transfer during osmotic dehydration

4.3.1 Effect of solute concentration on water loss

The results obtained for water loss in panniyur and karimunda were statistically analysed and presented in Appendix B. It was inferred that the water loss wa significantly

influenced by concentration of the solute, osmosis time and sample to solution ratio. The interaction effect of ratio, time and concentration had also favoured water loss. The time also had a highly significant effect on water loss compared to sample to solution ratio and concentration.

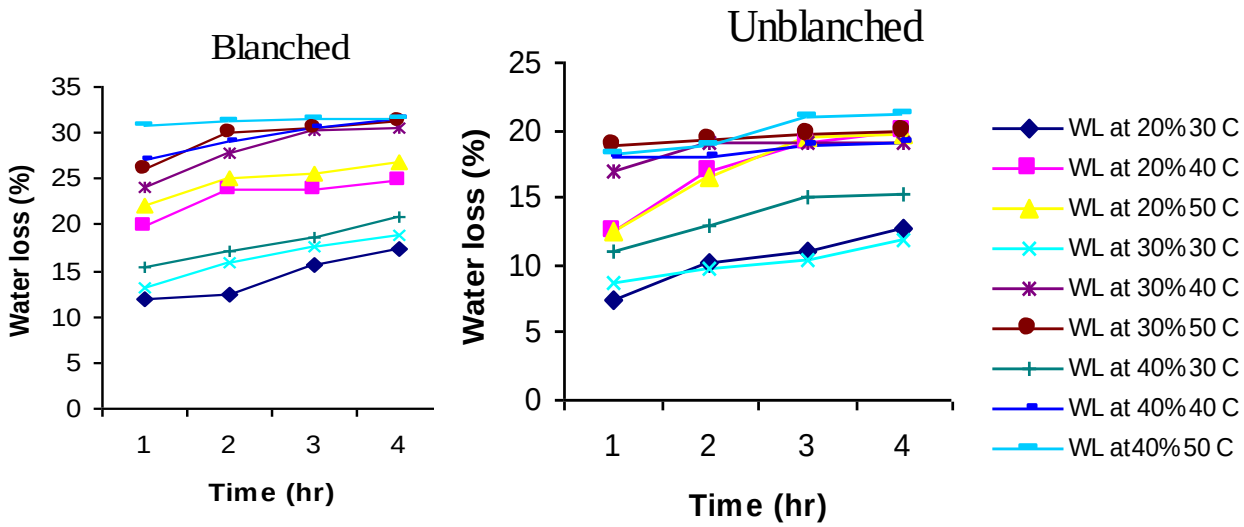


Fig.4.1 Effect of solute concentration on water loss for blanched and unblanched panniyur samples with 1:6 sample to solution ratio

It can be observed from the Fig.4.1 that for blanched Panniyur samples, the maximum water loss of 31.53% was achieved with 40 % salt concentration at 50 ^{0}C in 1: 6 sample to solution ratio.

Same trend of water loss was also observed in the case of unblanched samples with same condition (fig. 4.1). The percentage of water loss in unblanched samples was less when compared to blanched samples (Table A.1). This may be because of the reason that the unblanched pepper samples have tough outer skin and tissues than that of the blanched samples. This reduces the water loss through it. For all blanched and unblanched samples it was observed that when concentration increased water loss also increased. Analogue observations have been reported by Nsonzi and Ramaswamy (1998) for blue berries. This study concluded that the magnitude of moisture loss increased with temperature, concentration of the sucrose solution and contact time.

From the fig.4.2 it is seen that karimunda variety had also shown the same trend for water loss. But from the Table A.2, the percentage of water loss was less than the panniyur, for both blanched and unblanched samples.

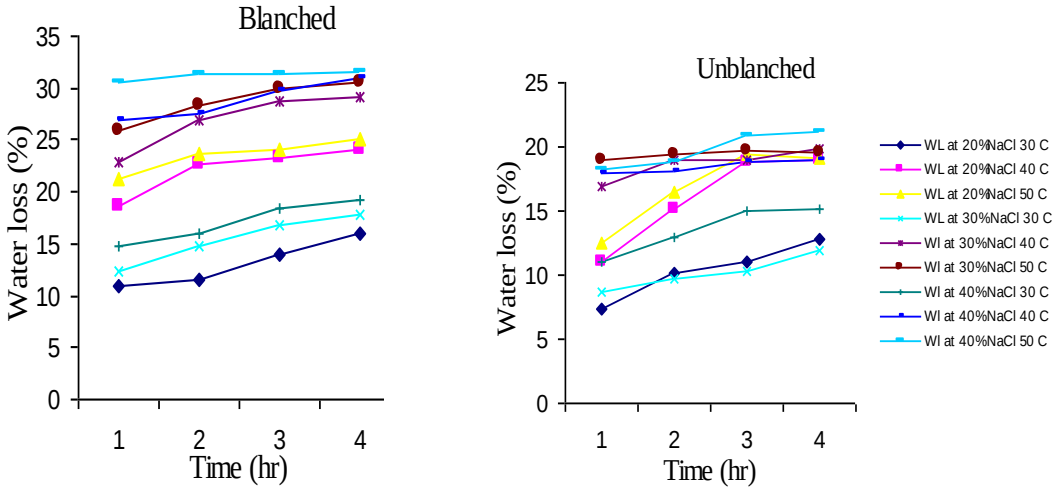


Fig.4.2 Effect of solute concentration on water loss for blanched and unblanched karimunda variety

According to Sharma *et al.* (2004) the difference in water loss among different varieties of apricot is attributed to the variation in cell structure and composition of the cell wall which is a genetic character of each variety.

4.3.2 Effect of solute concentration on solid gain

Figure 4.3 shows the effect of solute concentration on solid gain for blanched Panniyur samples. It was observed that, for blanched Panniyur variety, solid gain increased with increase in concentration of osmotic solution. The solid gain was higher in 40% solution at 50 ^{0}C in 1:6 sample to solution ratio for the blanched samples (Table A.3).

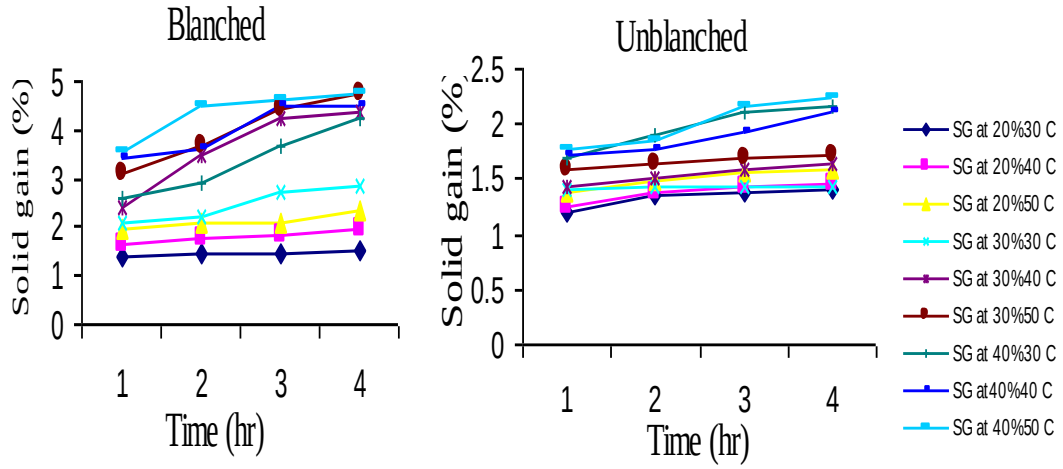


Fig.4.3 Effect of solute concentration on solid gain for blanched and unblanched samples of Panniyur variety.

Unblanched samples also showed a similar trend at same condition with low solid gain percentage .This might be due to the enhanced passage of solids through the softened skin owing to blanching.

It was seen from figure 4.4 that, the same trend was also observed for karimunda variety for both blanched and unblanched samples. From the TableA.4 it was observed that karimunda varieties showed a lower solid gain percentage. Sharma *et al*. (2004) reported for apricot that solid gain is attributed to longer time by osmosis to approach equilibrium between cellular fluid and osmotic solution along with volume and compactness of fruits, which varied from variety to variety.

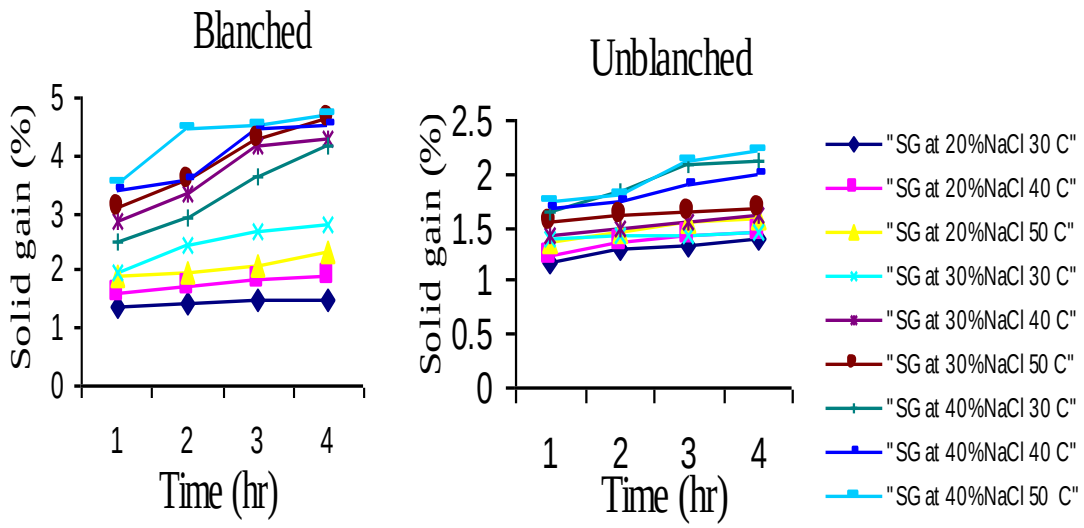


Fig.4.4 Effect of solute concentration on solid gain for blanched and unblanched samples of Karimunda variety

The water loss at 40 % salt solution was higher than 30 % salt solution but only by a quantify margin .At the same time the solid gain was less in 30 %. Since a higher water loss and a lower solid gain was desirable, 30 % concentration was selected.

4.3.3 Effect of solute concentration on weight reduction

It is seen from the fig 4.5 that for panniyur variety, weight reduction increased with increase in concentration of the osmotic solution at all temperatures. Samples treated at 50 ^{0}C with 30 % for 4 hour had higher weight reduction; where as those treated with 20 % had lower weight reduction.

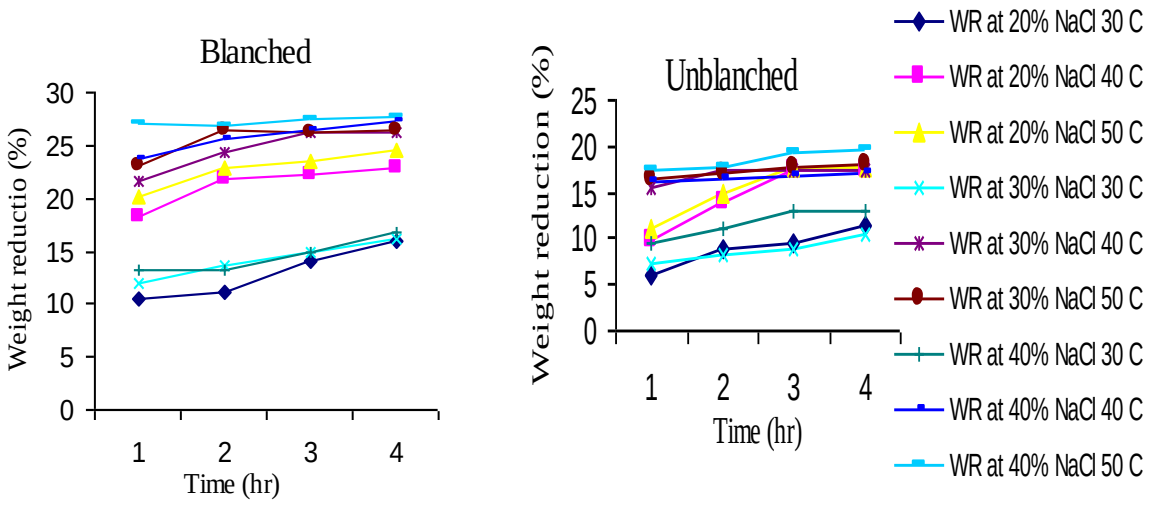


Fig.4.5 Effect of solute concentration on weight reduction for blanched and unblanched samples of panniyur variety.

From fig.4.6, it was observed that karimunda variety also shows the same trend with a lower value. Similar trend was also observed by Sharma *et al* (2004) for apricot. The weight reduction is attributed to the osmosis which caused removal of water from fruits. The difference in cell wall permeability and compactness of fruit might be a cause of variation in weight reduction among different varieties.

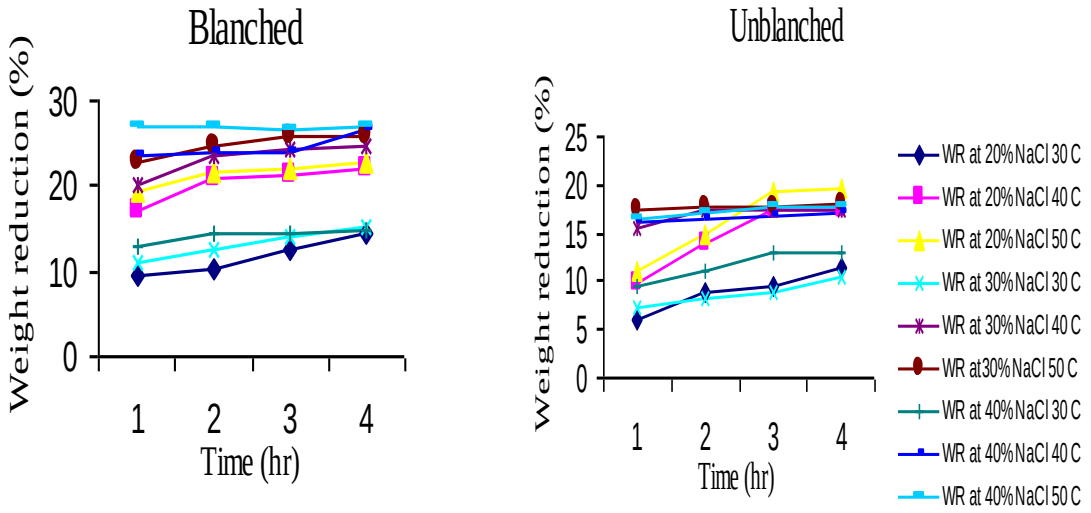


Fig.4.6 Effect of solute concentration on weight reduction for blanched and unblanched samples of karimunda variety

By considering the effect of concentration on mass transfer like water loss, solid gain and weight reduction, 30% solute concentration was selected for further studies.

4.4 Effect of osmotic time on mass transfer during osmotic dehydration

4.4.1 Effect of time on water loss

The effect of osmotic time on water loss in Panniyur variety is depicted in fig. 4.7. During the period of osmosis, the water loss increased with increase in osmosis time, at all temperatures for both blanched and unblanched samples.

Blanched **Unblanched**

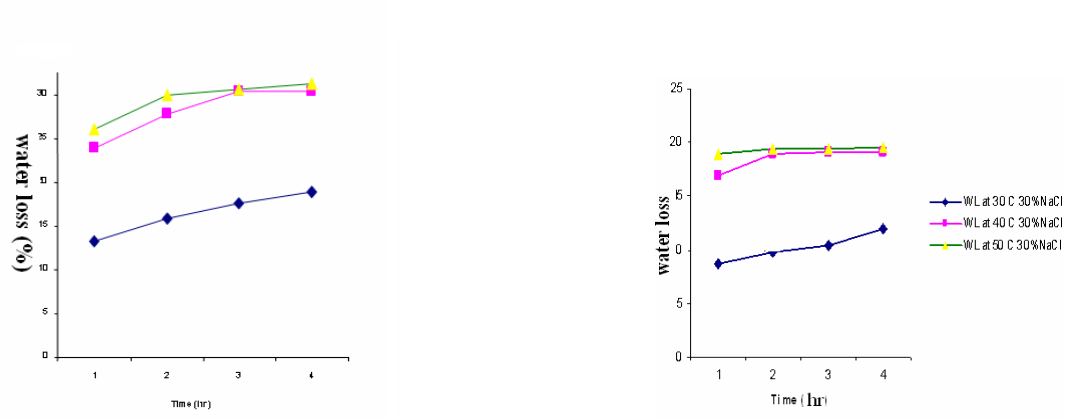


Fig.4.7 Effect of time on water loss for blanched and unblanched samples of panniyur variety

It was observed from Fig.4.8 that, Karimunda variety also followed the same trend but with a lesser value.

Blanched **Unblanched**

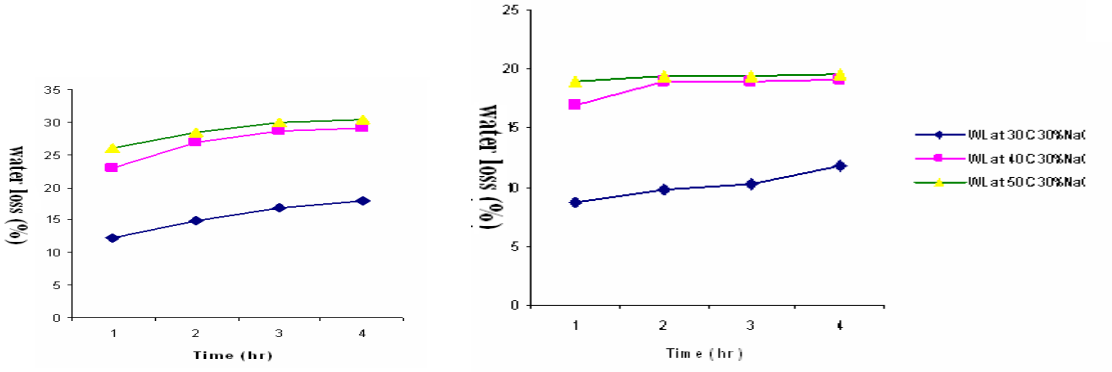


Fig. 4.8 Effect of time on water loss for blanched and unblanched karimunda variety.

Sharma *et al.* (1991) also reported a similar trend for apple rings. For all sample to solution ratio and temperature, the water loss was higher in the third and fourth hour compared to the first and second hour. It was observed that the water loss at third hour was approximately equal to fourth hour. So as to reduce the time, a period of 3 hr had been selected.

4.4.2 Effect of time on solid gain

The effect of osmosis time on solid take of blanched and unblanched samples of panniyur and karimunda varieties is shown from the fig.4.9. Similar to water loss, the rate of solid take up increased when dipping time is more in all samples of both varieties. But for unblanched samples solid gain was less compared to blanched samples. The increasing trend of solid gain may be due to the possible tissue damage in different pretreatment which affect the integrity of the natural tissue and thus favour high uptake of solids. Nsonzi and Ramaswamy (1998) reported a steady increase in solid gain until the end of the dehydration process in the case of blue berries.

Blanched **Unblanched**

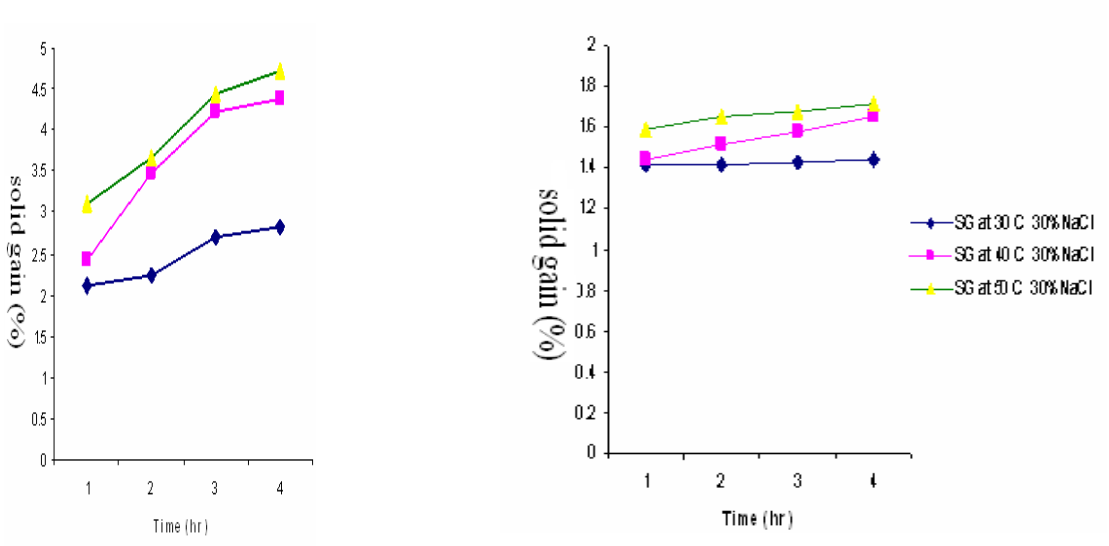


Fig.4.9 Effect of time on solid gain for blanched and unblanched panniyur variety

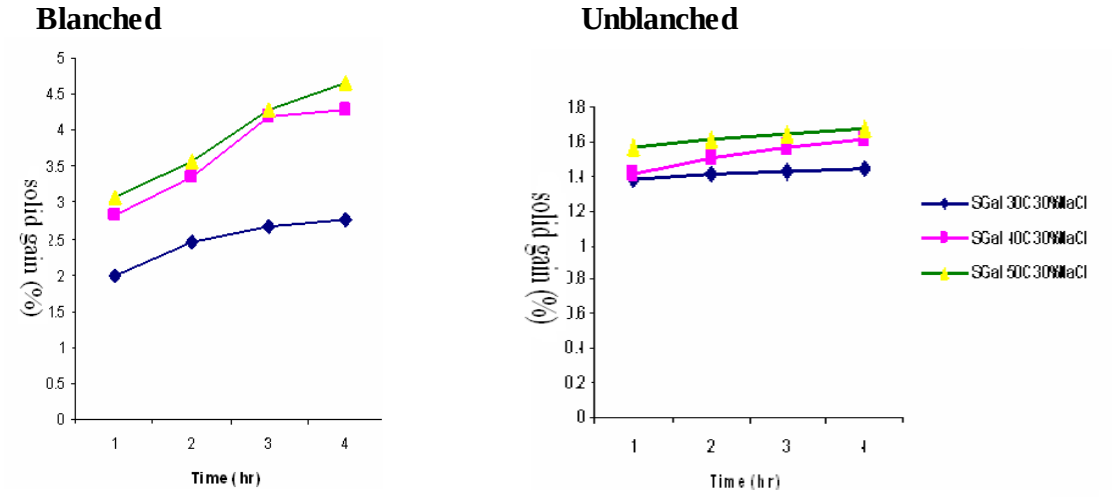


Fig.4.10 Effect of time on solid gain for blanched and unblanched Karimunda variety.

The solid gain was lesser at third hour than at the fourth hour for all the samples. To avoid further solid uptake a period of 3 hr was selected.

4.4.3 Effect of time on weight reduction

Fig.4.11 shows that the weight reduction increased with increase in osmotic time for both blanched and unblanched panniyur samples. Blanched samples show comparatively higher value than the unblanched samples. Table A.6, indicate that the trend was same for karimunda variety but with a lower value.

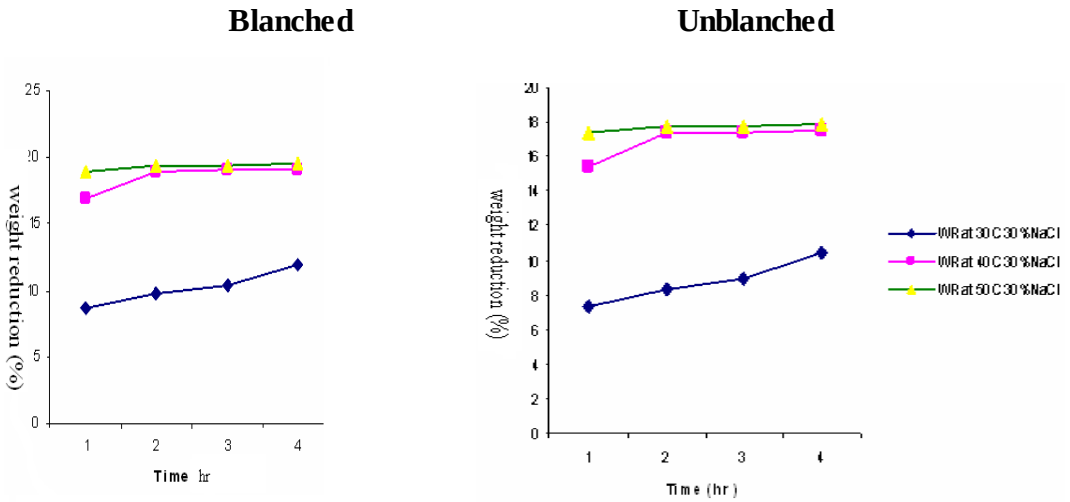


Fig.4.11 Effect of time on weight reduction for blanched and unblanched Panniyur variety

By considering the effect of time on mass transfer like water loss, solid gain and weight reduction, 3hr was selected for the further studies.

4.5 Effect of sample to solution ratio on mass transfer during osmotic dehydration

4.5.1 Effect of sample to solution ratio on water loss

Table 4.2 shows the effect of sample to solution ratio on water loss for blanched and unblanched samples of panniyur and karimunda varieties. It could be clearly seen from the tables that water loss increased with increase in sample to solution ratio for all the samples.

Table 4.2 Effect of sample to solution ratio on water loss of panniyur and Karimundavarieties

		Water loss (%)					
		Blanched			Unblanched		
	Temperature(^{0}C)	30	40	50	30	40	50
Varieties	Ratio						
Panniyur	1: 2	14.72	28.89	29.34	10.28	17.32	19.21
	1: 4	16.51	30.14	30.32	11.1	18.73	19.32
	1: 6	17.62	30.34	30.56	11.15	19.03	19.45
Karimunda	1: 2	13.14	27.16	28.03	9.26	17.3	19.18
	1: 4	13.16	27.54	28.73	10.36	18.69	19.29
	1: 6	16.82	28.64	28.93	10.87	19	19.43

When the sample to solution ratio increased from 1: 2 to 1: 4, the water loss increased considerably for both samples at all temperatures.

Since the increase in water removal percentage with 1: 4 ratio was nearly equal to

1: 6, the former was preferred from the economical point of view.

4.5.2 Effect of sample to solution ratio on solid gain

The effect of sample to solution ratio on solid gain for panniyur and karimunda varieties is shown in Table 4.3 .The solid gain increased with increase in sample to solution ratio for all the samples. The solid gain is higher for the sample with a ratio of 1: 4 compared to that of 1: 2 and it is closely followed by 1:6. In order to have a higher percentage of water loss with less solid gain, 1: 4 ratio was selected.

Table 4.3 Effect of sample to solution ratio on solid gain of panniyur and karimunda varieties

Varieties		Solid gain (%)					
	Temperature (^{0}C)	Blanched			Unblanched		
		30	40	50	30	40	50
	Ratio						
Panniyur	1: 2	2.48	3.98	4.13	1.38	1.58	1.66
	1: 4	2.69	4.14	4.35	1.41	1.59	1.67
	1: 6	2.71	4.22	4.44	1.43	1.60	1.68
karimunda	1: 2	1.98	3.06	3.34	1.36	1.53	1.64
	1: 4	2.23	3.08	3.85	1.38	1.56	1.65
	1: 6	2.68	4.18	4.28	1.42	1.58	1.65

4.5.3 Effect of sample to solution ratio on weight reduction

Table 4.4 indicates the relationship between ratio and weight reduction. Similar to water loss and solid gain weight reduction also increased with increase in ratio, for both blanched and unblanched samples of both the varieties. The samples shows considerable change in weight reduction, when the ratio changes from 1: 2 to1: 4.

Table 4.4 Effect of sample to solution ratio on weight reduction of panniyur and karimunda varieties

Varieties		Weight reduction (%)					
	Temperature (^{0}C)	Blanched			Unblanched		
		30	40	50	30	40	50
	Ratio						
Panniyur	1: 2	12.24	24.91	25.21	8.9	15.74	17.55
	1: 4	13.82	26	25.97	9.69	17.14	17.65
	1: 6	14.91	26.12	26.12	9.72	17.43	17.77
karimunda	1: 2	11.16	24.1	24.69	7.9	15.74	17.54
	1: 4	10.93	24.75	24.88	8.98	17.13	17.64
	1: 6	14.14	24.75	25.74	9.45	17.42	17.78

According to the effect of sample to solution ratio on mass transfer like water loss, solid gain and weight reduction, 1: 4 ratio was selected for the further studies.

4.6 Effect of osmotic temperature on mass transfer during osmotic dehydration

4.6.1 Effect of temperature on water loss

The table 4.5 represents the water loss, at various process temperatures for panniyur and karimunda varieties. The water loss was higher at 50 ^{0}C when compared to 30 ^{0}C and 40^{0}C with 30 % solute concentrations in 1:4 ratio and 3 hours. This is observed for both blanched and unblanched samples of panniyur and karimunda varieties.

Table 4.5 Effect of temperature on water loss of panniyur and karimunda varieties

Temperature (^{0}C)	Water loss (%)			
	Panniyur		Karimunda	
	Blanched	unblanched	Blanched	unblanched
30	16.51	11.1	13.16	10.36
40	30.14	18.73	27.54	18.69
50	30.32	19.32	28.73	19.29

The increase in water loss at higher temperature might be due to the changes in semi permeability of the cell membrane of the pepper. This allows more water to diffuse out in a short period. Apart from that, the inactivation of enzymes takes place which results retention of green color. As temperature increases, the volatile oil components may lost from the pepper resulted a poor quality product. So a medium temperature of 40 ^{0}C was selected. Falade and Aworh (2005) reported that water loss and solid gain increased as the osmotic solution temperature increased.

4.6.2 Effect of temperature on solid gain

Table 4.6 shows the effect of temperature on solid gain for Panniyur and Karimunda varieties. Table indicates that there is a steady increase of solid intake with increase in temperature in all the samples. The solid gain for the samples treated at 30 ^{0}C was lower compared to 40 ^{0}C.

Table 4.6 Effect of temperature on solid gain of panniyur and karimunda varieties

Temperature (^{0}C)	Solid gain (%)			
	Panniyur		Karimunda	
	Blanched	unblanched	Blanched	unblanched
30	2.69	1.41	2.23	1.38
40	4.14	1.59	3.08	1.56
50	4.35	1.67	3.85	1.65

Solid gain at 50 ^{0}C was higher than the solid gain at 40 ^{0}C. Thus higher osmosis temperature resulted in significant solid gain. To get a better product with medium solid gain and maximum water loss a temperature of 40 ^{0}C was selected. Abhijit and Gupta (2001) also reported that both temperature and sample to solution ratio significantly influenced the salt uptake of osmosed samples.

4.6.3 Effect of temperature on weight reduction

The effect of temperature on weight reduction for panniyur and karimunda are shown in Table 4.7.

Table 4.7 Effect of temperature on weight reduction of panniyur and karimunda varieties

Temperature (^{0}C)	Weight reduction (%)			
	Panniyur		Karimunda	
	Blanched	unblanched	Blanched	unblanched
30	13.82	9.69	10.93	8.98
40	26	17.14	24.75	17.13
50	25.97	17.65	24.88	17.64

As temperature increases from 30 ^{0}C to 50 ^{0}C the weight reduction increased for all the samples. At 40 ^{0}C, the weight reduction was nearly equal to the weight reduction at 50 ^{0}C. For unblanched samples; the weight reduction was lower than the blanched samples owing to tougher outer skin.

Based on the effect of temperature on mass transfer like water loss, solid gain and weight reduction, 40 ^{0}C was selected for the further studies

4.7 Selection of suitable osmotic condition

Even though study was conducted with panniyur and karimunda varieties with blanched and unblanched samples, blanched sample was selected. Blanching done at 100 ^{0}C, provides complete inactivation of the enzymes which resulted retention of green colour. More over it softens the tissues. So blanched samples selected. Maximum water loss and minimum solid gain was observed for panniyur variety. So for secondary drying blanched panniyur samples treated with 30 % salt solution at temperature of 40 ^{0}C for 3 hr with 1: 4 sample to solution ratio was selected.

4.8 Secondary Drying process

4.8.1 Hot air drying

Osmosed samples and non osmosed samples were uniformly spread on perforated stainless steel trays and dried at different air temperature of 40, 50 and 60 ^{0}C .The Fig.(4.12) shows the drying curve of tray dried samples. It can be observed that, for osmosed samples the time periods taken to attain constant moisture content were 8, 6 and 5hr at 40, 50 and 60 ^{0}C whereas for non osmosed samples the durations were 10, 7 and 7 hours respectively.

After a drying period of 6 hour, drying rate of osmosed samples at 40 ^{0}C and 50 ^{0}C were 0.0142 and 0.0328 (g/min) respectively (Appendix C.3). At 60 ^{0}C, after a period of 5 hour it was 0.0328. For non osmosed samples, drying rate at 40 ^{0}C after a time period of 10 hour was 0.0123.The drying rate at 50 and 60 ^{0}C were 0.0218 and 0.0398 after 8 hour. As temperature increases, drying rate also increases which indicates that higher temperature promotes faster drying. But the higher temperature may cause the loss of volatile oil.

Osmosed **Non osmosed**

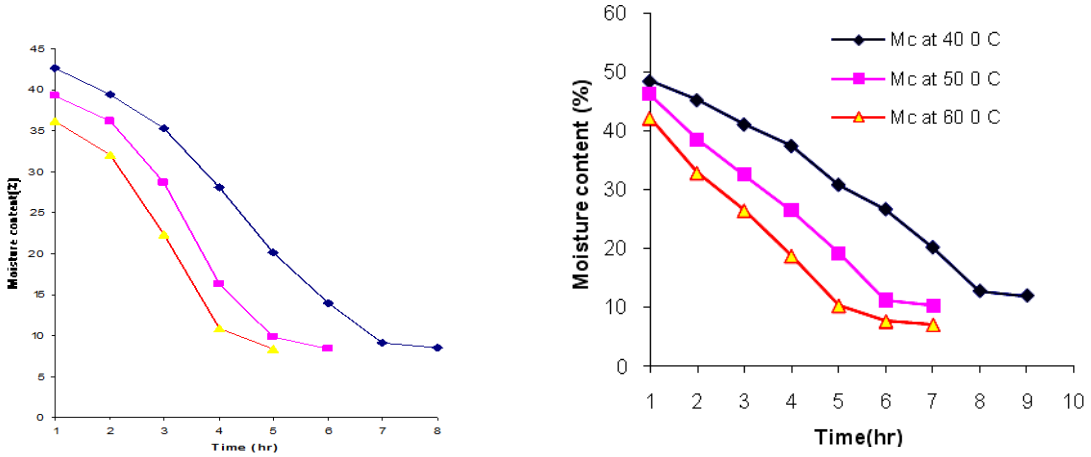


Fig.4.12 Hot air drying of osmosed and non osmosed samples

4.8.2 Freeze drier

Fig. (4.13) shows that moisture content of the osmosed samples at 40, 50 and 60 ^{0}C were 4.88, 4.62 and 3.92 during different time period of 12hr, 10hr and 8hr respectively. At the same temperatures, for non osmosed samples, the moisture content were 8.53, 5.8 and5.6

for 12hr, 10 hr and 10hr respectively. The non osmosed samples achieve the desired moisture content with more time period than osmosed samples.

After a drying period of 12 hour at 40 ^{0}C, the drying rate of osmosed sample was 0.02518. At 50 ^{0}C and 60 ^{0}C the drying rates of osmosed samples after 8 hour were 0.0323 and 0.0348 respectively. For non osmosed samples, the drying rates were 0.0141, 0.0162 and 0.0241 at 40 and 50 ^{0} C after a period of 14 and 12 hour respectively. The drying rate after a period of 10 hour was 0.0241 at 60 ^{0}C (Appendix C.4).

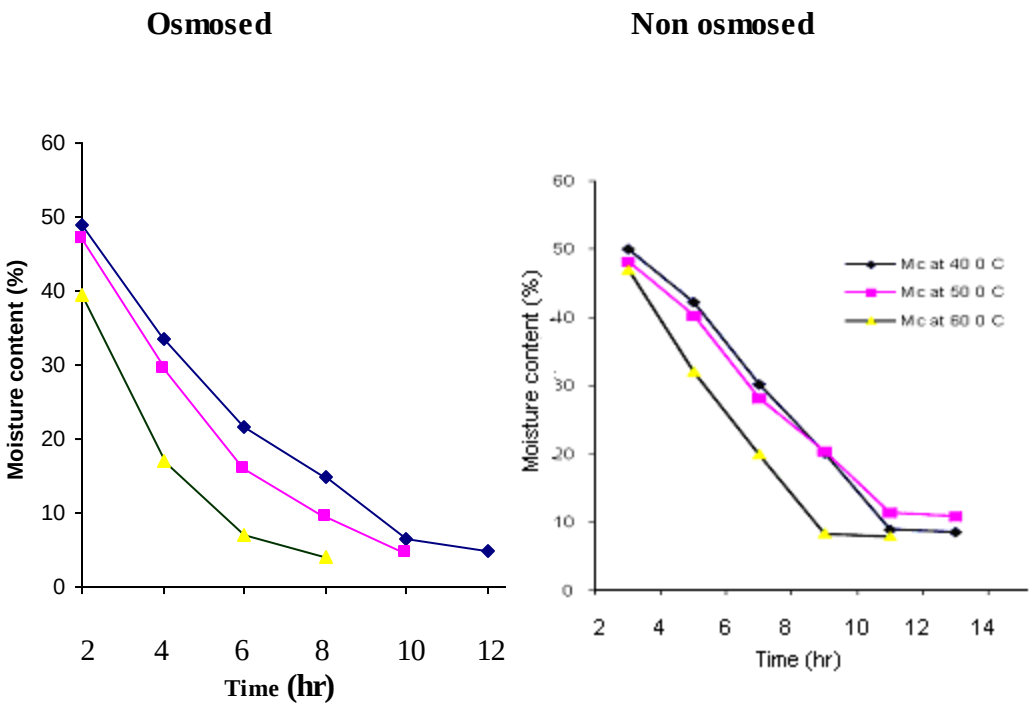


Fig. 4.13 Freeze drying of osmosed and non osmosed samples

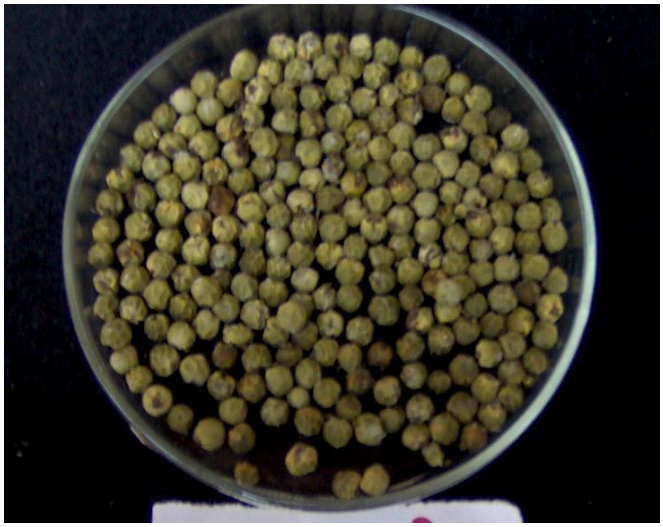


Plate 4.1 Tray dried pepper

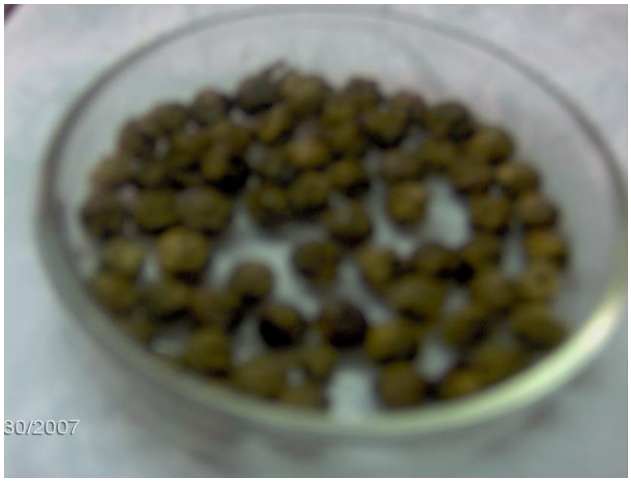


Plate 4.2 Rehydrated tray dried pepper

Plate 4.3 Freeze dried pepper

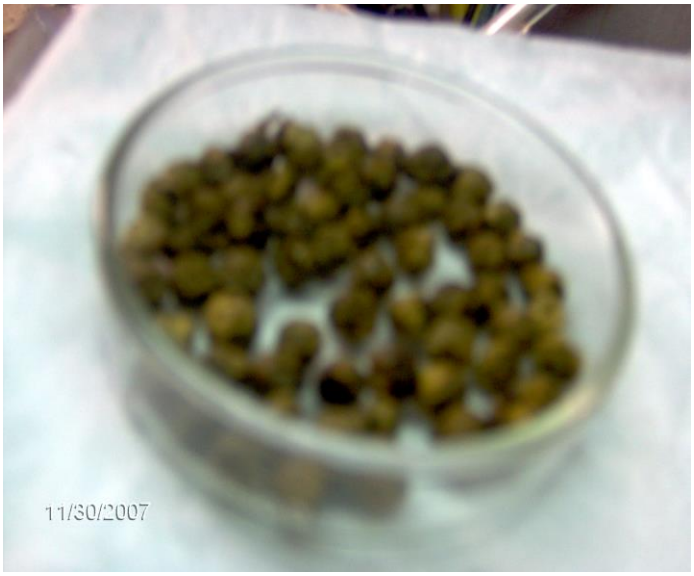


Plate 4.4 Rehydrated freeze dried pepper

Plate 4.5. Non osmosed dried pepper

4.9 QUALITY OF DRIED PRODUCT

4.9.1 Rehydration ratio

From the Table 4.8 it can be observed that for hot air dried osmosed samples, the maximum rehydration ratio (2.04) was achieved for pepper dried at 40 ^{0}C and minimum (1.84) at 60 ^{0}C respectively. For non osmosed samples the maximum rehydration ratio (1.72) and minimum rehydration ratio (1.42) were observed at 40 and 60 ^{0}C respectively.The values of rehydration ratio decreased with increase in temperature. The rehydration ratios of the osmosed samples were higher than the non osmosed samples. Analogue observations have been reported by Karthiga *et al.(* 2004) for potato slices. This might be due to the presence of salt on the surface of the material which enhanced the water permeability of the skin. The high temperature drying cause internal structure stress and hence it is compacted more as compared to material dried at low temperature which supported that low temperature dried pepper relatively reconstituted more.

Table 4.8 Rehydration ratio of dried samples

Temperature(^{0}C)	Rehydration ratio		
		Tray dried sample	Freeze dried samples
40	OD	2.04	3.16
	NOD	1.72	1.63
50	OD	1.86	2.49
	NOD	1.52	1.76
60	OD	1.84	2.44
	NOD	1.42	1.74

For freeze dried pepper the rehydration ratio was found to be maximum at 40 ^{0}C (3.16) and minimum (2.44) at 60 ^{0}C for osmosed pepper. The rehydration value decreased with increase in temperature. Osmotic dehydration softens the tissue and facilitates easy moisture removal during drying as well easy reabsorption of water during rehydration. In case of non osmosed pepper the rehydration ratio was found to be at 1.63 40 ^{0}C and at 1.74

at 60 ^{0}C. The non osmosed pepper becomes very hard on drying and allows minimum transferring of water and so giving a lower rehydration ratio.

4.9.2 Colour

The colour of dried product was recorded using Hunter lab colour flex meter and the values are represented as color difference (ΔE) .The colour difference (ΔE) from that of the fresh samples was calculated using the equation given in 3.8.

From the Table 4.9 it can be observed that for tray dried osmosed pepper, the maximum (5.39) and minimum (4.62) were obtained at 60 ^{0}C and 50 ^{0}C respectively. For freeze dried osmosed samples maximum (3.59) and minimum (3.16) colour difference were seen at 60 and 50 ^{0}C, respectively.

The maximum value of 20.57 was observed for nonosmotic try dried samples at 60 ^{0}C and minimum of 3.16 at 50 ^{0}C for osmosed freeze dried samples. The higher value of ΔE for both osmosed and nonosmosed samples was observed at a higher temperature of 60 ^{0}C and this may be due to the fact that higher the temperature lowers the color which results higher the value of ΔE. The lower value of ΔE was observed for osmosed freeze dried samples at

50 ^{0}C. It may be due to the combined effect of blanching and osmosis, which inactivate the enzymes. The black colour of non osmosed pepper may be due to the presence of active enzymes in it.

Table 4.9 Colour of dried samples

Colour			
Temperature(^{0}C)		Tray dried sample	Freeze dried samples
40	OD	5.13	3.42
	NOD	19.6	16.83
50	OD	4.62	3.16
	NOD	18.79	16.43
60	OD	5.39	3.59
	NOD	20.57	19.83

Friedman's test was conducted and presented in Appendix C.2 and it reveals that maximum colour is for the osmosed samples treated at 50 ^{0}C for both hot air drying and freeze drying. The minimum colour is given to the nonosmosed samples treated at 60 ^{0}C.

4.9.3 Volatile oil content

It can be observed from the Table 4.10 that for non osmosed tray dried samples the maximum volatile oil content (1.93%) and minimum (1.38%) were at 50 and 60 ^{0}C ,respectively. For osmosed samples the maximum (1.6%) and minimum (1.36%) were obtained at 50 and 60 ^{0}C respectively. For osmosed freeze dried samples the maximum (1.73%) and minimum (1.40%) were obtained at 50 and 60 ^{0}C respectively.

For non osmosed freeze dried samples the maximum (2.14%) and minimum (1.42%) were observed at 50 and 60 ^{0} C respectively. In the case of osmosed samples, apart from blanching another heat treat treatment took place during osmosis which may effect the volatile oil percentage. The increase of oil content at 50 ^{0}C as compared to 40 ^{0} C may be due to less contact time of pepper with hot air at 50 ^{0}C. As the temperature increases from 50 ^{0} C to 60 ^{0}C, the volatile oil content decreases. This may be due to loss of volatile oil content at higher temperature. The same trend was observed for freeze drying also. According to Friedman test (Appendix C.1) highest rank was given to nonosmotic samples at 50 ^{0} C. It is almost equal to non osmosed samples at 40 ^{0}C. Lowest rank was given to the osmosed samples treated at 60 ^{0}C.

Table 4.10 Volatile oil content (%) of dried green pepper sample

Temperature(^{0}C)	Tray dried samples		Freeze dried samples	
40	OD	1.48	OD	1.51
	NOD	1.86	NOD	2.0
50	OD	1.6	OD	1.73
	NOD	1.93	NOD	2.14
60	OD	1.36	OD	1.40
	NOD	1.38	NOD	1.42

4.9.4 Volatile oil components

GC analyses were done for the volatile oil components and are tabulated in Table 4.11

Table 4.11 Volatile oil components from GCanalysis

Components	Percentage (%)	
	Tray dried samples	Freeze dried samples
α - pinene	8.884	9.360
β - Pinene	10.583	11.455
β - Caryophyllene	7.883	8.101

Verghese *et al.*, 2001 had similar findings about the constituents of the GC analysed Green pepper oil and according to the study , β- Caryophyllene moulds the physio-chemical pattern of Green pepper oil. Low value of β - Caryophyllene may be due to the incomplete distillation of pepper.

4.10 Optimization of secondary stage of drying

Friedman's test for colour reveals that maximum colour is for the osmosed samples treated at 50 ^{0}C for both tray drying and freeze drying. At 50 ^{0}C, the moisture content could be reduced to 8.4 % with in the time period of 6 hr for hot air drying. Whereas for the freeze drying it took 10 hr to attain a moisture content of 4.62%. Even though the high rehydration ratio was obtained at 40 ^{0}C, it is usually neglected due to damage of colour. The volatile oil content was observed maximum at a temperature of 50 ^{0}C for both osmotic and nonosmotic samples. In a nutshell, the optimum conditions are 50 ^{0}C and 6 hr for hot air drying and 50 ^{0}C and 10 hr for freeze drier.

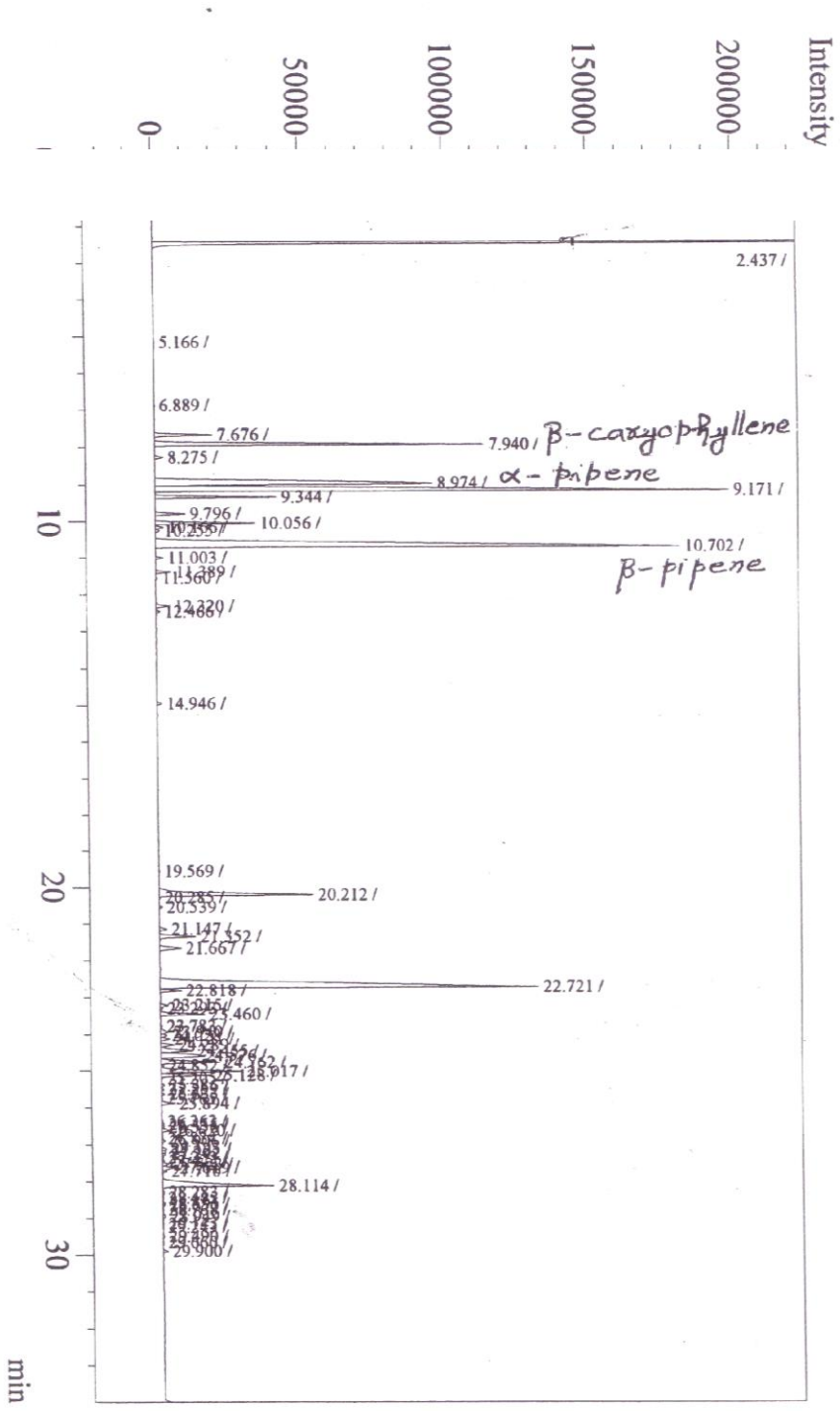


Fig. 4.14 Gas chromatogram of Green pepper oil (Freeze dried sample)

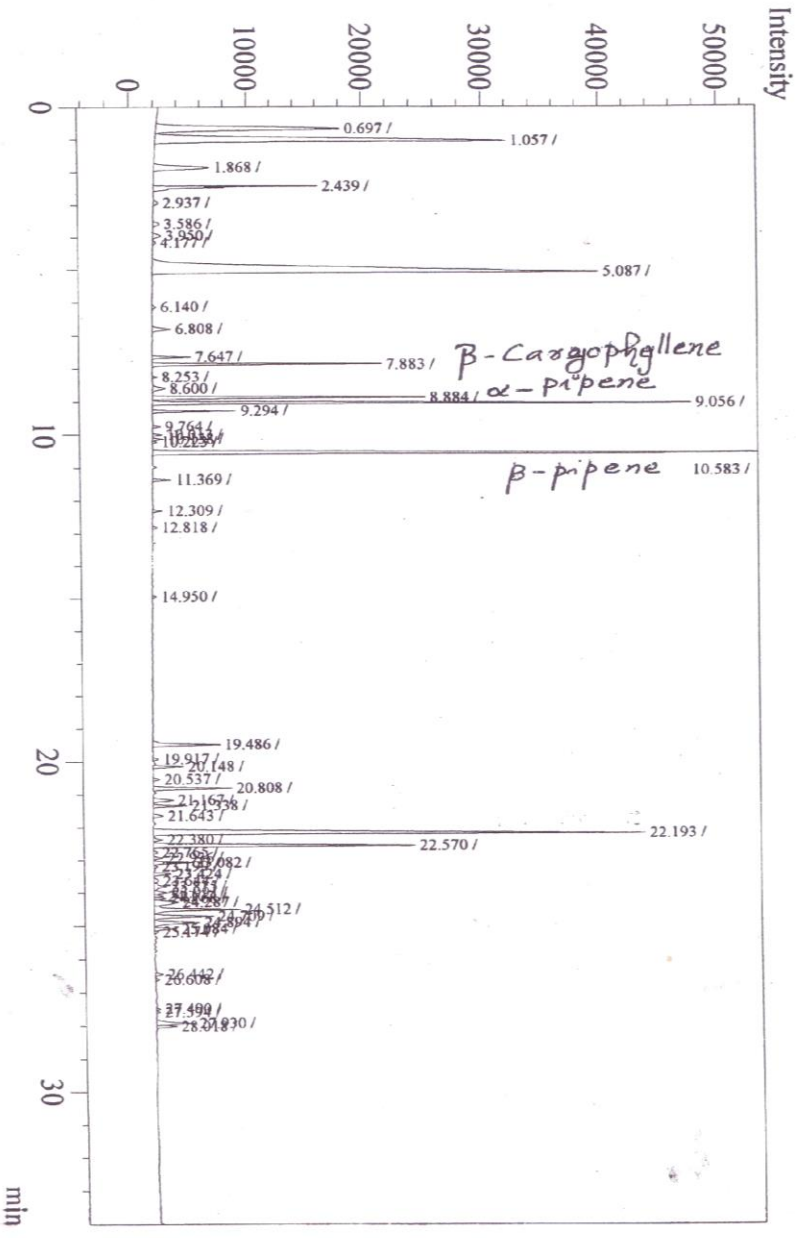


Fig. 4.15 Gas chromatogram of Green pepper oil (Hot air dried sample)

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Spices have been mainly used as seasonings to make processed foods more delicious. Apart from their flavouring properties, spices have been accepted as potent natural antimicrobial in food preservation for extending shelf life for longer periods. The use of spices in food may also be vindicated from their medicinal and anti-microbial properties.

Green pepper is an important value-added product prepared from unripe but fully matured pepper berries. India offers green pepper in several processed forms such as frozen, dehydrated, freeze-dried and packed in brine. Most of the green pepper products are used by the catering sector to be served with meat dishes and by the food manufacturing industries for a variety of food products. It enhances the aroma and pungency of the food products. Annually, the availability of tender green pepper is only for a period of two to three months. To assure round the year availability, green pepper could be better dehydrated and stored for a year or more and can be used at will by simple reconstitution.

Experiments were conducted to gather the first hand information for the production of osmotically dehydrated green pepper. Several trials were conducted for different concentrations of NaCl (20% to40%), time periods (1hr to 4hr) at different temperature (30 to 50 ^{0}C) and sample to solution ratios (1: 2 to 1: 6). The effect of process temperature, time, sample to solution ratio and concentration of the osmotic agent were studied. The best combination was 30% NaCl , 3 hr at 40 ^{0}C and 1:4 sample to solution ratio.

The experiment was conducted as a four factor experiment in Completely Randomized Design (CRD).The results obtained for water loss in panniyur and karimunda were statistically analysed. It was inferred that the water loss was significantly influenced by concentration of the solute, osmosis time, temperature and sample to solution ratio. The interaction effect of ratio, time and concentration had also favoured water loss. The time also had a highly significant effect on water loss compared to sample to solution ratio and concentration. The studies explained that solid gain increased with increase in concentration of osmotic solution for both blanched and unblanched samples. It was also found that weight reduction increased with increase in concentration of the osmotic solution at all temperatures.

In addition, the effect of osmotic dehydration on secondary stage of drying using tray drier and freeze drier were studied. The moisture content of tray dried osmosed samples at 40, 50 and 60 ^{0}C were reached a constant moisture content after a time period of 8, 6 and 5 hr respectively. In the case of non osmosed samples the moisture content was constant at 40 ^{0}C after10 hr. The moisture content of the freeze dried osmosed samples at 40, 50 and 60 ^{0}C were reached a constant moisture content during different time period of 12hr, 10hr and 8hr respectively. At the same temperatures, for non osmosed samples, the moisture content were constant for 12hr, 10 hr and 10hr respectively. The non osmosed samples achieve the desired moisture content with more time period than osmosed samples.

The maximum volatile oil content was observed for non osmosed samples for both drying. In the case of osmosed samples, apart from blanching another heat treat treatment took place during osmosis which may effect the volatile oil percentage.

The colour of dried product was recorded using Hunter lab colour flex meter and values were represented as colour difference from that of the fresh samples. The lower value of ΔE was observed for osmosed freeze dried and tray dried samples at 50 ^{0}C. It may be due to the combined effect of blanching and osmosis, which inactivate the enzymes. The lower value of ΔE indicates a good quality product. Friedman's test for colour reveals that maximum colour is for the osmosed samples treated at 50 ^{0} C for both hot air drying and freeze drying.

In a nutshell, the optimum condition for osmosis is 30%, 3 hr at 40 ^{0}C and 1 : 4 sample to solution ratio. For the secondary drying the best conditions are 50 ^{0}Cand 6 hour for hot air drying and 50 ^{0} C and 10 hr for freeze drier to get a good quality pepper.

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APPENDICES

Table A.1 Water loss (%) of blanched and unblanched samples of Panniyur

Ratio	Concentration (% NaCl)	Temp (^{0}C)	Blanched water loss				Un blanched water loss			
			Time (hr)							
			1	2	3	4	1	2	3	4
1: 2	20	30	9.69	12.13	14.13	15.96	6.83	7.63	10.06	12.21
		40	18.24	21.98	22.42	23.43	10.12	12.58	15.23	17.43
		50	20.51	24.36	24.81	25.27	12.5	16.18	18.34	18.95
	30	30	10.32	12.81	14.72	16.82	8.82	9.57	10.28	11.04
		40	22.14	26.95	28.89	29.04	15.13	16.97	17.32	17.54
		50	23.86	28.18	29.34	29.92	16.98	19.19	19.21	19.34
	40	30	14.81	16.36	17.42	17.96	9.62	10.89	12.78	14.57
		40	25.13	27.97	28.63	29.05	16.32	16.88	17.32	17.58
		50	30.12	30.68	31.46	31.94	16.88	17.16	20.58	20.98
1: 4	20	30	10.82	12.47	14.53	16.11	7.28	9.62	11.06	13.81
		40	19.62	23.41	23.62	24.81	11.12	15.23	18.82	18.97
		50	21.2	24.83	25.03	26.87	12.52	16.48	20.92	21.23
		30	12.12	14.63	16.51	17.12	8.68	9.73	11.1	11.89
	30	40	23.67	27.57	30.14	30.46	16.26	18.14	18.73	18.97
		50	25.25	29.97	30.32	31.14	18.74	19.26	19.32	19.51
		30	14.85	16.16	18.58	19.71	10.82	12.36	14.91	15.02
	40	40	26.88	27.98	30.48	30.63	17.53	17.88	18.62	18.91
		50	30.35	31.28	31.37	31.44	17.96	18.52	19.33	19.51
1: 6	20	30	11.84	12.52	15.61	17.34	7.36	10.12	10.93	12.81
		40	19.86	23.71	23.91	24.86	12.53	16.89	19.01	19.89
		50	22.1	24.99	25.68	26.9	12.52	16.48	20.92	21.23
	30	30	13.23	15.8	17.62	18.95	8.68	9.73	11.15	11.89
		40	23.98	27.81	30.34	30.53	16.88	18.97	19.03	19.11
		50	26.11	30.05	30.56	31.26	18.96	19.38	19.45	19.62
	40	30	15.39	17.15	18.65	20.95	11.12	12.96	15.04	15.23
		40	27.13	28.95	30.53	31.46	17.92	18.08	18.83	19.04
		50	30.68	31.34	31.48	31.53	18.26	18.86	19.78	19.92

Table A.2 WL (%) of blanched and unblanched samples of Karimunda

Ratio	Concentration (% NaCl)	Temp (^{0}C)	Blanched				Un blanched			
			Time (hr)							
			1	2	3	4	1	2	3	4
1: 2	20	30	8.86	11.92	13.18	14.08	6.81	7.56	10.04	12.21
		40	16.88	19..21	20.46	20..93	10.1	12.55	15.19	17.41
		50	19.03	21.69	22.26	23.16	12.47	16.15	20..56	20.94
	30	30	9.63	10.28	13.14	15.21	8.81	9.54	9.26	11.01
		40	21.06	24.99	27.16	27.92	15.11	16.94	17..3	17..51
		50	22.86	25.18	28.03	28.68	16.97	19.14	19.18	19.3
	40	30	13.68	15.12	16.08	16.53	9.59	10.86	12.75	14.55
		40	23.11	25.59	27.88	28.41	16.31	16.84	17.3	17.55
		50	28.42	29.18	29.82	30.03	16.86	17.14	18.32	18.93
1: 4	20	30	9.58	12.31	14.13	15.08	7.26	9.6	10.97	13.76
		40	17.98	20.29	21.18	21.98	12.51	16.84	18.96	19.74
		50	20.13	22.96	23.62	24.48	13.33	17.42	21.1	21.36
		30	10.11	11.76	13.16	14.82	9.61	10.68	10..36	12.49
	30	40	20.98	24.18	27..54	28.13	16.21	18.11	18.69	18.94
		50	22.21	25.32	28.73	28.39	18.71	19.22	19.29	19.5
		30	14.92	16.63	17.24	17.69	10.81	12.34	14.91	15.02
	40	40	24.82	26.98	27.42	28.1	17.51	17.87	18.58	18.87
		50	29.21	30.01	30..34	30.46	17.94	18.51	19.29	19.48
1: 6	20	30	10.84	11.52	14.03	15.93	7.32	10.1	10.96	12.78
		40	18.68	22.59	23.18	24.06	11.1	15.19	18.78	18.94
		50	21.16	23.69	24.16	25.04	12.51	16.46	20.9	21.21
	30	30	12.32	14.81	16.82	17.89	8.66	9.71	10..87	11.86
		40	22.86	26.93	28.64	29.12	16.86	18.94	19	19.1
		50	25.93	28.36		30.48	18.94	19.34	19.43	19.59
	40	30	14.83	15.98	18.43	19.12	11.09	12.94	15.01	15.21
		40	26.96	27.53	29.79	30.92	17.88	18.04	18.81	19.01
		50	29.32	30.08	30.41	30..5	18.24	18.85	19.76	19.89

Table A.3 Solid gain (%) for blanched and unblanched samples of panniyur variety

Ratio	concentration (% NaCl)	Temp (^{0}C)	Solid gain (%) (blanched)				Solid gain (%) (un blanched)			
			Time (hr)							
			1	2	3	4	1	2	3	4
1: 2	20	30	1.36	1.38	1.42	1.47	1.21	1.25	1.36	1.4
		40	1.6	1.75	1.82	1.92	1.26	1.31	1.4	1.42
		50	1.87	1.98	2.1	2.18	1.32	1.44	1.51	1.58
	30	30	1.91	1.94	2.48	2.65	1.31	1.36	1.38	1.4
		40	2.36	3.03	3.98	4.12	1.38	1.41	1.58	1.6
		50	2.68	3.28	4.13	4.36	1.48	1.56	1.66	1.83
	40	30	2.2	2.31	2.85	3.62	1.61	1.73	1.82	1.98
		40	3.14	3.32	3.99	4.12	1.64	1.69	1.72	1.89
		50	3.25	3.89	4.45	4.53	1.68	1.75	1.89	2.14
1: 4	20	30	1.38	1.45	1.47	1.5	1.21	1.38	1.41	1.42
		40	1.62	1.75	1.86	1.97	1.28	1.38	1.45	1.46
		50	1.93	2.02	2.1	2.22	1.36	1.51	1.58	1.6
		30	1.94	2.07	2.69	2.77	1.35	1.38	1.41	1.42
	30	40	2.38	3.24	4.14	4.28	1.43	1.52	1.59	1.63
		50	2.73	3.41	4.35	4.57	1.57	1.63	1.67	1.68
		30	2.2	2.43	3.18	3.54	1.65	1.81	1.94	2.11
	40	40	3.32	3.43	4.25	4.36	1.68	1.73	1.88	1.97
		50	3.46	4.28	4.52	4.66	1.75	1.83	2.12	2.22
1: 6	20	30	1.38	1.47	1.47	1.5	1.2	1.36	1.39	1.41
		40	1.64	1.75	1.86	1.98	1.26	1.37	1.43	1.45
		50	1.95	2.1	2.1	2.34	1.37	1.48	1.56	1.58
	30	30	2.1	2.23	2.71	2.82	1.41	1.42	1.43	1.44
		40	2.42	3.48	4.22	4.39	1.44	1.52	1.60	1.65
		50	3.1	3.67	4.44	4.73	1.59	1.65	1.68	1.72
	40	30	2.6	2.92	3.68	4.23	1.68	1.89	2.1	2.15
		40	3.42	3.61	4.47	4.51	1.72	1.76	1.93	2.1
		50	3.52	4.49	4.61	4.72	1.78	1.85	2.16	2.25

Table A.4 Solid gain (%) of blanched and unblanched samples of Karimunda variety

Ratio	concentration	Temp	(SG blanched)					(SG un blanched)		
	(% NaCl)	(^0C)	Time (hr)							
			1	12	3	4	1	2	3	4
1: 2	20	30	1.32	1.34	1.36	1.42	1.11	1.23	1.33	1.39
		40	1.53	1.62	1.83	1.97	1.24	1.28	1.4	1.45
		50	1.88	1.92	2.02	2.14	1.29	1.41	1.49	1.54
	30	30	1.82	1.92	1.98	2.46	1.29	1.32	1.36	1.39
		40	2.12	2.82	3.06	3.49	1.36	1.4	1.53	1.58
		50	2.56	3.07	3.34	4.12	1.46	1.52	1.64	1.81
	40	30	2.03	2.12	2.46	2.85	1.58	1.68	1.79	1.91
		40	2.93	3.12	3.52	3.95	1.62	1.67	1.7	1.85
		50	3.12	3.63	4.02	4.28	1.66	1.72	1.86	2.12
1: 4	20	30	1.4	1.46	1.48	1.53	1.2	1.35	1.38	1.41
		40	1.62	1.72	1.88	2.03	1.26	1.35	1.43	1.44
		50	1.95	2.32	2.41	2.46	1.34	1.5	1.56	1.58
	30	30	1.88	1.91	2.23	2.34	1.32	1.34	1.38	1.4
		40	2.12	2.82	3.08	3.12	1.41	1.49	1.56	1.61
		50	2.59	2.86	3.85	3.68	1.55	1.59	1.65	1.68
	40	30	2.1	2.32	2.82	3.48	1.62	1.78	1.96	2.27
		40	3.12	3.25	3.68	4.12	1.66	1.69	1.86	1.95
		50	3.25	3.86	4.12	4.34	1.73	1.79	2.11	2.22
1: 6	20	30	1.36	1.42	1.47	1.51	1.18	1.31	1.34	1.4
		40	1.63	1.71	1.83	1.92	1.24	1.36	1.41	1.44
		50	1.9	1.98	2.1	2.31	1.35	1.46	1.55	1.57
	30	30	1.98	2.46	2.68	2.77	1.38	1.41	1.42	1.44
		40	2.83	3.34	4.18	4.29	1.41	1.5	1.58	1.62
		50	3.08	3.58	4.28	4.67	1.56	1.62	1.65	1.68
	40	30	2.5	2.89	3.61	4.18	1.66	1.84	2.08	2.13
		40	3.41	3.58	4.45	4.5	1.69	1.74	1.89	1.98
		50	3.51	4.46	4.55	4.68	1.73	1.81	2.13	2.21

Table A.5 Weight reduction (%) of blanched and unblanched samples of Panniyur variety

			Blanched W R				Unblanched WR			
Ratio	concentration	Temp	Time (hr)							
	(% NaCl)	$^{(0}$C)	1	2	3	4	1	2	3	4
1: 2	20	30	8.33	10.75	12.71	14.49	4.9	6.38	8.7	10.81
		40	16.64	20.23	20.6	21.51	8.86	11.27	13.83	16.01
		50	18.64	22.38	22.71	23.09	11.18	14.74	19.07	19.4
	30	30	8.41	10.87	12.24	14.17	7.51	8.21	8.9	9.64
		40	19.78	23.92	24.91	24.92	13.75	15.56	15.74	15.94
		50	21.18	24.9	25.21	25.56	15.5	17.63	17..55	17.51
	40	30	12.61	14.05	14.57	14.34	8.01	9.16	10.96	12.59
		40	21.99	24.65	24.64	24.93	14.68	15.19	15.6	15.69
		50	26.87	26.79	27.01	27.41	15.2	15.41	16.45	16.81
1: 4	20	30	9.44	11.02	13.06	14.61	6.07	8.24	9.65	12.39
		40	18.06	21.66	21.76	22.84	11.25	15.51	17.56	18.43
		50	19.27	22.81	22.93	24.65	11.99	15.95	19.55	19.75
	30	30	10.18	12.56	13.82	14.35	8.27	9.35	9.69	11.11
		40	21.29	24.33	26	26.18	14.83	16.62	17.14	17.34
		50	22.52	26.56	25.97	26.57	17.17	17.63	17.65	17.83
	40	30	12.25	14.72	15.4	16.17	9.17	10.55	12.94	12.91
		40	23.56	24.37	26.06	27.27	15.85	16.16	16.74	16.94
		50	26.89	27	27.5	27.77	16.21	16.69	17.21	17.29
1: 6	20	30	10.48	11.05	14.14	15.84	6.16	8.76	9.59	11.4
		40	18.22	22.15	21.85	22.88	9.86	13.86	17.37	17.52
		50	20.15	22.89	23.58	24.56	11.15	15	19.36	19.65
	30	30	12.03	13.57	14.91	16.23	7.27	8.31	9.72	10.45
		40	21.56	24.33	26.12	26.14	15.44	17.45	17.43	17.46
		50	23.01	26.38	26.12	26.53	17.37	17.73	17.77	17.9
	40	30	13.19	13.24	14.97	16.72	9.44	11.07	12.94	13.08
		40	23.71	25.52	26.53	27.33	16.2	16.32	16.9	16.94
		50	27.16	26.85	27.57	27.76	16.48	17.01	17.62	17.67

Table A.6 Weight reduction (%) of blanched and unblanched samples of Karimunda variety

		Blanched W R					Unblanched W R			
Ratio	concentration	Temp	Time (hr)							
	(% NaCl)	$^{(0}$C)	1	2	3	4	1	2	3	4
1: 2	20	30	7.54	10.51	11.72	12.59	4.9	6.33	8.71	10.82
		40	15.35	17.59	18.63	18.96	8.86	11.27	13.79	16
		50	17.15	19.59	19.94	20.75	11.18	14.74	14.07	19.4
	30	30	7.81	8.36	11.16	12.75	7.52	8.22	7.9	9.71
		40	18.94	22.17	24.1	24.13	13.75	15.54	15.77	15.93
		50	20.3	22.11	24.69	24.56	15.51	17.62	17..54	17.49
	40	30	11.65	13	13.62	13.68	8.01	9.18	10.96	12.64
		40	20.18	22.47	24.26	24.46	14.69	15.17	15.6	15.7
		50	25.3	25.55	25.8	25.75	15.2	15.42	16.46	16.81
1: 4	20	30	8.81	10.85	12.65	13.55	6.06	8.25	9.59	12.35
		40	16.38	18.57	19.3	19.95	11.25	15.49	17.54	18.03
		50	18.18	20.64	21.21	22.02	11.99	15.92	14.54	19.78
		30	8.23	9.85	10..93	12.48	8.29	9.34	8.98	11.09
	30	40	28.86	21.36	24.75	25.01	14.8	16.62	17.13	17.33
		50	19.62	22.46	24.88	24.71	17.16	17.63	17.64	17.82
		30	12.33	13.09	14.82	14.21	9.19	10.56	12.95	12.93
	40	40	21.7	23.73	23.34	23.98	15.85	16.18	16.72	16.92
		50	25.96	26.16	26.52	26.62	16.21	16.72	17.18	17.26
1: 6	20	30	9.48	10.1	12.56	14.42	6.14	8.79	9.62	11.38
		40	17.05	20.88	21.35	22.14	9.86	13.83	17.37	17.5
		50	19.26	21.71	22.06	22.73	11.16	15	19.35	19.65
	30	30	11.14	12.63	14.14	15.12	7.28	8.3	9.45	10.42
		40	20.14	23.59	24.75	24.83	15.45	17.44	17.42	17.48
		50	22.85	24.78	25.74	25.81	17.38	17.72	17.78	17..91
	40	30	12.82	14.31	14.42	14.94	9.43	11.1	12.93	13.08
		40	23.55	23.95	23.74	26.42	16.19	16.3	16.92	17.03
		50	27.09	26.86	26.76	26.82	16.51	17.04	17.63	17.68

Appendix B

Table B. 1 Waterloss of blanched Panniyur samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	121.977	60.988	152472.2676	0.0000
4	Factor B	2	1739.131	869.565	2173928.9649	0.0000
6	AB	4	6.824	1.706	4264.8496	0.0000
8	Factor C	2	10329.948	5164.974	12912528.2558	0.0000
10	AC	4	9.535	2.384	5959.2585	0.0000
12	BC	4	165.902	41.476	103689.5333	0.0000
14	ABC	8	9.350	1.169	2921.7885	0.0000
16	Factor D	3	1091.174	363.725	909317.9788	0.0000
18	AD	6	2.204	0.367	918.1991	0.0000
20	BD	6	75.774	12.629	31572.8975	0.0000
22	ABD	12	4.824	0.402	1005.0952	0.0000
24	CD	6	49.353	8.226	20564.0232	0.0000
26	ACD	12	4.749	0.396	989.3246	0.0000
28	BCD	12	29.363	2.447	6117.4059	0.0000
30	ABCD	24	11.052	0.461	1151.2939	0.0000
-31	Error	216	0.086	0.000		
	Total	323	13651.246			

Table B. 2 Waterloss of unblanched Panniyur samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	98.944	49.472	123680.2146	0.0000
4	Factor B	2	283.755	141.877	354692.9510	0.0000
6	AB	4	13.118	3.279	8198.6541	0.0000
8	Factor C	2	3401.736	1700.868	4252160.6948	0.0000
10	AC	4	21.461	5.365	13413.1989	0.0000
12	BC	4	98.889	24.722	61805.7949	0.0000
14	ABC	8	13.084	1.635	4088.6903	0.0000
16	Factor D	3	763.542	254.514	636284.0688	0.0000
18	AD	6	3.094	0.516	1289.1378	0.0000
20	BD	6	237.779	39.630	99074.2671	0.0000
22	ABD	12	14.997	1.250	3124.3425	0.0000
24	CD	6	13.362	2.227	5567.5598	0.0000
26	ACD	12	4.620	0.385	962.4276	0.0000
28	BCD	12	67.035	5.586	13965.5003	0.0000
30	ABCD	24	23.808	0.992	2480.0025	0.0000
-31	Error	216	0.086	0.000		
	Total	323	5059.310			

Table B. 3 Water loss of blanched Karimunda samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	265.446	132.723	331806.8302	0.0000
4	Factor B	2	1966.700	983.350	2458372.4012	0.0000
6	AB	4	24.991	6.248	5619.1757	0.0000
8	Factor C	2	9745.655	4872.827	12182054.1575	0.0000
10	AC	4	2.369	0.592	1480.3916	0.0000
12	BC	4	260.893	65.223	163057.7172	0.0000
14	ABC	8	27.062	3.383	8456.8039	0.0000
16	Factor D	3	947.074	315.691	789227.1567	0.0000
18	AD	6	1.085	0.181	451.9718	0.0000
20	BD	6	72.848	12.141	30353.2624	0.0000
22	ABD	12	9.414	0.785	1961.2897	0.0000
24	CD	6	25.516	4.253	10631.7402	0.0000
26	ACD	12	8.445	0.704	1759.2929	0.0000
28	BCD	12	24.256	2.021	5053.3143	0.0000
30	ABCD	24	20.288	0.845	2113.3034	0.0000
-31	Error	216	0.086	0.000		
	Total	323	13402.126			

Table B.4 Waterloss of unblanched Karimunda samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	108.157	54.079	135197.2974	0.0000
4	Factor B	2	219.087	109.544	273860.6602	0.0000
6	AB	4	11.084	2.771	6927.6729	0.0000
8	Factor C	2	3346.945	1673.473	4183705.1425	0.0000
10	AC	4	15.369	3.842	9605.6033	0.0000
12	BC	4	108.458	27.115	67786.7395	0.0000
14	ABC	8	18.157	2.270	5674.2477	0.0000
16	Factor D	3	745.293	248.431	621080.9534	0.0000
18	AD	6	2.603	0.434	1084.5431	0.0000
20	BD	6	267.268	44.545	111362.2747	0.0000
22	ABD	12	7.843	0.654	1634.0396	0.0000
24	CD	6	12.757	2.126	5315.2620	0.0000
26	ACD	12	4.881	0.407	1016.8831	0.0000
28	BCD	12	80.310	6.692	16731.2568	0.0000
30	ABCD	24	9.747	0.406	1015.3346	0.0000
-31	Error	216	0.086	0.000		
	Total	323	4958.046			

Table B. 5 Solid gain of blanched Panniyur samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	3.537	1.768	4420.9239	0.0000
4	Factor B	2	212.914	106.457	266142.9300	0.0000
6	AB	4	1.284	0.321	802.2363	0.0000
8	Factor C	2	68.677	34.338	85845.8821	0.0000
10	AC	4	0.128	0.032	79.8612	0.0000
12	BC	4	7.904	1.976	4940.1127	0.0000
14	ABC	8	0.623	0.078	194.6112	0.0000
16	Factor D	3	48.776	16.259	40646.3339	0.0000
18	AD	6	0.127	0.021	53.0255	0.0000
20	BD	6	14.879	2.480	6199.4090	0.0000
22	ABD	12	0.138	0.011	28.6713	0.0000
24	CD	6	1.915	0.319	797.7408	0.0000
26	ACD	12	0.161	0.013	33.5463	0.0000
28	BCD	12	4.624	0.385	963.2826	0.0000
30	ABCD	24	0.313	0.013	32.6505	0.0000
-31	Error	216	0.086	0.000		
	Total	323	366.084			

Table B. 6 Solid gain of unblanched Panniyur samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	0.351	0.175	438.5831	0.0000
4	Factor B	2	13.364	6.682	16705.0757	0.0000
6	AB	4	0.162	0.040	101.2291	0.0000
8	Factor C	2	1.564	0.782	1954.6868	0.0000
10	AC	4	0.005	0.001	3.3958	0.0102
12	BC	4	0.423	0.106	264.3332	0.0000
14	ABC	8	0.016	0.002	4.8698	0.0000
16	Factor D	3	3.036	1.012	2529.7118	0.0000
18	AD	6	0.030	0.005	12.5463	0.0000
20	BD	6	0.613	0.102	255.3795	0.0000
22	ABD	12	0.108	0.009	22.5255	0.0000
24	CD	6	0.071	0.012	29.4005	0.0000
26	ACD	12	0.040	0.003	8.2338	0.0000
28	BCD	12	0.147	0.012	30.5463	0.0000
30	ABCD	24	0.040	0.002	4.1452	0.0000
-31	Error	216	0.086	0.000		
	Total	323	20.054			

Table B. 7 Solid gain of blanched Karimunda samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	10.953	5.477	13691.4670	0.0000
4	Factor B	2	156.481	78.241	195601.3229	0.0000
6	AB	4	8.308	2.077	5192.5077	0.0000
8	Factor C	2	63.482	31.741	79352.9352	0.0000
10	AC	4	0.322	0.081	201.3506	0.0000
12	BC	4	4.439	1.110	2774.4032	0.0000
14	ABC	8	1.282	0.160	400.5799	0.0000
16	Factor D	3	34.882	11.627	29068.7526	0.0000
18	AD	6	0.515	0.086	214.7060	0.0000
20	BD	6	6.688	1.115	2786.5120	0.0000
22	ABD	12	0.863	0.072	179.8450	0.0000
24	CD	6	1.192	0.199	496.5256	0.0000
26	ACD	12	0.538	0.045	112.0358	0.0000
28	BCD	12	2.597	0.216	541.0603	0.0000
30	ABCD	24	0.777	0.032	80.9456	0.0000
-31	Error	216	0.086	0.000		
	Total	323	293.406			

Table B. 8 Solid gain of unblanched Karimunda samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	0.379	0.190	474.1319	0.0000
4	Factor B	2	13.202	6.601	16502.0229	0.0000
6	AB	4	0.153	0.038	95.5069	0.0000
8	Factor C	2	1.526	0.763	1908.0064	0.0000
10	AC	4	0.018	0.005	11.4236	0.0000
12	BC	4	0.497	0.124	310.7880	0.0000
14	ABC	8	0.035	0.004	11.0799	0.0000
16	Factor D	3	3.318	1.106	2765.2653	0.0000
18	AD	6	0.027	0.005	11.3079	0.0000
20	BD	6	0.630	0.105	262.5648	0.0000
22	ABD	12	0.152	0.013	31.5856	0.0000
24	CD	6	0.062	0.010	26.0162	0.0000
26	ACD	12	0.042	0.004	8.7662	0.0000
28	BCD	12	0.191	0.016	39.7836	0.0000
30	ABCD	24	0.067	0.003	7.0127	0.0000
-31	Error	216	0.086	0.000		
	Total	323	20.388			

Table B. 9 Weight reduction of blanched Panniyur samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	93.529	46.765	116911.1885	0.0000
4	Factor B	2	795.398	397.699	994243.3064	0.0000
6	AB	4	12.823	3.206	8014.3618	0.0000
8	Factor C	2	8804.782	4402.391	11005935.2573	0.0000
10	AC	4	6.999	1.750	4374.5846	0.0000
12	BC	4	110.055	27.514	68784.3617	0.0000
14	ABC	8	14.441	1.805	4512.7341	0.0000
16	Factor D	3	715.974	238.658	596642.8749	0.0000
18	AD	6	6.780	1.130	2824.8696	0.0000
20	BD	6	67.804	11.301	28251.3933	0.0000
22	ABD	12	8.412	0.701	1752.4965	0.0000
24	CD	6	39.057	6.509	16273.5136	0.0000
26	ACD	12	3.795	0.316	790.5693	0.0000
28	BCD	12	28.771	2.398	5993.9024	0.0000
30	ABCD	24	9.302	0.388	968.9353	0.0000
-31	Error	216	0.086	0.000		
	Total	323	10718.007			

Table B. 10 Weight reduction of unblanched Panniyur samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	95.928	47.964	119909.9333	0.0000
4	Factor B	2	133.254	66.627	166567.5701	0.0000
6	AB	4	12.712	3.178	7945.1702	0.0000
8	Factor C	2	3301.825	1650.912	4127282.1374	0.0000
10	AC	4	15.512	3.878	9694.7958	0.0000
12	BC	4	106.137	26.534	66335.4968	0.0000
14	ABC	8	16.306	2.038	5095.7818	0.0000
16	Factor D	3	655.056	218.352	545879.8417	0.0000
18	AD	6	3.072	0.512	1280.1374	0.0000
20	BD	6	288.809	48.135	120337.3305	0.0000
22	ABD	12	7.603	0.634	1584.0605	0.0000
24	CD	6	16.072	2.679	6696.4733	0.0000
26	ACD	12	4.900	0.408	1020.9073	0.0000
28	BCD	12	72.335	6.028	15069.7948	0.0000
30	ABCD	24	14.359	0.598	1495.7172	0.0000
-31	Error	216	0.086	0.000		
	Total	323	4743.967			

Table B. 11 Weight reduction of blanched Karimunda samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	163.883	81.942	204854.9592	0.0000
4	Factor B	2	997.669	498.835	1247091.4430	0.0000
6	AB	4	8.571	2.143	5357.1849	0.0000
8	Factor C	2	8316.878	4158.439	10396140.1008	0.0000
10	AC	4	7.144	1.786	4465.0548	0.0000
12	BC	4	269.197	67.299	168249.0765	0.0000
14	ABC	8	82.150	10.269	25672.0749	0.0000
16	Factor D	3	471.682	157.227	393069.9303	0.0000
18	AD	6	16.836	2.806	7015.1592	0.0000
20	BD	6	58.976	9.829	24573.5577	0.0000
22	ABD	12	31.812	2.651	6627.5286	0.0000
24	CD	6	13.203	2.201	5501.3668	0.0000
26	ACD	12	53.150	4.429	11073.0620	0.0000
28	BCD	12	43.775	3.648	9119.7414	0.0000
30	ABCD	24	82.292	3.429	8572.0878	0.0000
-31	Error	216	0.086	0.000		
	Total	323	10617.306			

Table B. 12 Weight reduction of unblanched Karimunda samples

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	110.228	55.114	137785.2674	0.0000
4	Factor B	2	200.028	100.014	250035.1955	0.0000
6	AB	4	10.195	2.549	6372.0116	0.0000
8	Factor C	2	3080.751	1540.375	3850950.7430	0.0000
10	AC	4	14.719	3.680	9199.5912	0.0000
12	BC	4	81.615	20.404	51009.5591	0.0000
14	ABC	8	16.104	2.013	5032.6616	0.0000
16	Factor D	3	611.467	203.822	509557.2223	0.0000
18	AD	6	8.156	1.359	3398.3238	0.0000
20	BD	6	239.089	39.848	99620.5498	0.0000
22	ABD	12	20.656	1.721	4303.4210	0.0000
24	CD	6	17.143	2.857	7142.9949	0.0000
26	ACD	12	10.955	0.913	2282.2083	0.0000
28	BCD	12	57.218	4.768	11920.4894	0.0000
30	ABCD	24	25.379	1.057	2643.6059	0.0000
-31	Error	216	0.086	0.000		
	Total	323	4503.788			

Appendix C

Table C.1 Friedman Test for volatile oil

Ranks	
	Mean Rank
VAR00001	3.75
VAR00002	5.25
VAR00003	3.50
VAR00004	5.50
VAR00005	1.0
VAR00006	2.0

Table C.2 Friedman Test for colour

Ranks	
	Mean Rank
VAR00001	2.5
VAR00002	4.5
VAR00003	1.5
VAR00004	4.5
VAR00005	2.0
VAR00006	6.0

Table C.3 Drying rate during hot air drying

Hot air drying (Osmotic dehydration)										
Time(hr)	1	2	3	4	5	6	7	8		
Temp(°C)										
40	0.0372	0.0306	0.0271	0.0262	0.0178	0.0142	0.0132			
50	0.0592	0.0508	0.0462	0.0323	0.0318	0.031				
60	0.0951	0.0566	0.0478	0.0331	0.0328					
	Hot air drying(Non osmotic dehydration)									
	Time(hr)									
	1	2	3	4	5	6	7	8	9	10
Temp										
40	0.0313	0.0308	0.0292	0.0283	0.0263	0.0241	0.0238	0.0225	0.0176	0.0123
50	0.0441	0.0421	0.0402	0.0381	0.0351	0.0332	0.0321	0.0218		
60	0.0684	0.0581	0.0568	0.0498	0.0486	0.0453	0.0421	0.0398		

Table C.4 Drying rate during freeze drying

Freeze drying (Osmotic dehydration)								
Time(hr)								
	2	4	6	8	10	12	14	
Temp(°C)								
40	0.0464	0.0397	0.0335	0.02912	0.02832	0.02518		
50	0.054	0.0432	0.0403	0.0343	0.0323			
60	0.0593	0.0512	0.0482	0.0348				
Freeze drying(Non osmotic dehydration)								
Time(hr)	2	4	6	8	10	12	14	
Temp								
40	0.0367	0.0238	0.0198	0.0173	0.0165	0.0153	0.0141	
50	0.0382	0.0243	0.0236	0.0193	0.0182	0.0162		
60	0.0392	0.0293	0.0268	0.0253	0.0241			

ABSTRACT

STUDIES ON OSMOTIC DEHYDRATION OF GREEN PEPPER
(*Piper nigrum* L.)

By

SMITHA.K.E

ABSTRACT OF THE THESIS REPORT

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ABSTRACT

Experiments were conducted using a newly developed osmotic dehydration plant for the production of osmotically dehydrated green pepper. Several trials were done for different concentrations of NaCl (20% to 40%), time periods (1hr to 4hr)at different temperatures (30,40 and 50 ^{0}C) and sample to solution ratios(1:2 to 1:6). Blanched and unblanched samples of panniyur and karimunda varieties were used for the study. The effect of process temperature, time, sample to solution ratio and concentration of the osmotic agent were studied. Optimum condition was selected on the basis of the water loss, solid gain and weight reduction. The results obtained for water loss in panniyur and karimunda were statistically analysed. It was inferred that the water loss was significantly influenced by concentration of the solute, osmosis time and sample to solution ratio. The best result obtained from panniyur blanched samples treated was 30% NaCl, 3 hr and 1:4 sample to solution ratio at 40 ^{0}C and are selected for the secondary stage of drying using tray drier and freeze drier. The colour of dried product was recorded using Hunter lab colour flex meter and values were represented as colour difference from that of the fresh samples. The best colour was achieved at 50 ^{0}C. The optimum conditions for secondary drying were assessed on the basis of volatile oil content, component and colour as 50 ^{0}C and 6 hr for hot air drying and 50 ^{0}C and 10 hr for freeze drier.