STUDIES ON DEVELOPMENT OF COCONUT CHIPS

BY

BHAVYA E.P

GOVIND RAMACHANDRAN NAIR

SOUMYA MOHAN

PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree

BACHELOR OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Post-Harvest Technology and Agricultural Processing

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

KERALA, INDIA

2008

DECLARATION

We hereby declare that this project entitled "**Studies on Development of Coconut Chips"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another university or society.

Place: Tavanur

Date:

Bhavya E. P
(2003-02-10)

Govind Ramachandran Nair
(2003-02-08)

Soumya Mohan
(2003-02-23)

CERTIFICATE

Certified that this project report, entitled, **“Studies on Development of Coconut Chips**” is a record of project work done jointly by **Bhavya E.P**, **Govind Ramachandran Nair**, and **Soumya Mohan** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

Place : Tavanur

Date :

Dr. Santhi Mary Mathew
Associate Professor
Department of Post Harvest
Technology and
Agricultural Processing

ACKNOWLEDGEMENT

With whole heartedness we thank ‘**God the Almighty**’ for his unspeakable help, rendered through various hands, which helped us pursue the endeavour to completion.

None other than our respected guide **Dr. Santhi Mary Mathew**, Associate Professor, Dept. of Post Harvest Engineering and Agrl. Processing, deserves, at the second place our heartfelt thanks for her persistent initiation, efficacious advice and zealous intellectual support at the nick of time.

We are greatly indebted to **Dr. M. Sivaswami**, Dean i/c, KCAET, Tavanur, for his interest and kind support rendered to us.

We would like to express our sincere gratitude to **Dr. Sajeev M.S**, Senior scientist, CTCRI Tiruvananthapuram and **Dr Augustian A**, Professor, Dept. Biotechnology, College of Horticulture, Vellanikkara, for their help rendered to us in successful completion of our work.

Words would not suffice to express our gratitude to all staff members of PHT & AP, especially **Er. Prince M.V, Dr. Sudheer K. P, Er. Rajesh G.K, Miss Deepthi C, Er. Simi V. P, Mrs. Sheena.S, Mr. Ashraf** and **Mr. Manohar** for their sincere help and co-operation during the entire project work.

We exploit this opportunity to thank our **Dr. Binitha N.K, Er. Smitha K.E, Library Staff, our classmates & juniors** for their ardent spirits in aiding us.

We are greatly indebted to **our parents** for their blessings and prayers and support without which we could not have completed this work.

We are thankful to **all those**, who directly or indirectly helped us.

Bhavya E.P. **Govind Ramachanadran Nair** **Soumya Mohan**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS

%	percentage
^{0}B	degree Brix
^{0}C	degree Celsius
µm	micrometer
db	dry basis
et al.	and other people
etc	etcetera
Fig.	figure
HCl	hydrochloric acid
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
Kg	Kilogram
min	minute
ml	millilitre
mm	millimeter
PHT&AP	Post Harvest Technology and Agricultural Processing
wb	wet basis
w/w	weight by weight

CHAPTER 1

INTRODUCTION

Coconut is a crop of great antiquity in India. It has a recorded history of over 3000 years and has always been an object of reverence in the local tradition. It is one of the consistent food suppliers to mankind which no other tree crop could be said to possess. It occupies a prime position in the cultural, social and economic lives of millions of people across the world and in our country. The word 'coco' is derived from the Spanish word 'Macoco' which refers to three holes on coconut that resembles the face of an ape. Coconut Palm (*Cocos nucifera*) is a member of the Family Arecaceae (palm family) and is the only species in the genus Cocos. The term coconut refers to the fruit of the coconut palm. Every part of the tree is useful to human life for some purpose or the other. It is unique, producing a host of products and by products with distinctive application at home and industry. Hence, the coconut palm is endearingly called 'Kalpavriksha' - the tree of heaven, meaning the eternal tree or the tree that provides everything.

It is the only tropical crop commercially cultivated in about 93 countries with Indonesia ranking the first among the major coconut producing countries followed by Philippines and India. Our country accounts for almost 19.88 per cent of world's total coconut production and area wise it accounts for 15.91 per cent of the total global area under coconut. About 91 per cent of our total area and production of the coconuts is concentrated in the four southern states; namely Kerala, Tamilnadu, Karnataka and Andhra Pradesh. The production of coconut had reached 12147.6 million nuts in 2003-04 from the level of 5,940 million nuts in 1980-81 recording a compounded growth rate of 3.16 per cent per annum. According to Asian and Pacific Coconut Community (APCC) statistics, the production of coconut in India was 6337 nuts per hectare in the year 2003, which is 67.70 per cent more than that of Philippines and 79.41 per cent more than that of Indonesia. The progress achieved in enhancing the production of coconut, at least to meet the domestic demands commensurate with the rate of growth in the population is remarkable (Thomas Mathew, 2006).

The coconut palm is found to grow under varying climatic and soil conditions. It is essentially a tropical plant growing mostly between 20ºN 20ºS latitudes. However, a rainfall of about 2000 mm per year, well distributed throughout, is ideal for proper growth and maximum production. Coconut is grown under different soil types such as loamy, laterite, coastal sandy, alluvial, clayey and reclaimed soils of the marshy low lands. The ideal soil conditions for better growth and performance of the palm are proper drainage, good water-holding capacity, and presence of water table within 3m and absence of rock or any hard substratum within 2m of the surface.

Botanically, a coconut is a simple dry fruit known as a fibrous drupe (not a true nut). The husk (mesocarp) is composed of fibers called coir and there is an inner "stone" (the endocarp). This hard endocarp (the outside of the coconut) has three germination pores that are clearly visible on the outside surface once the husk is removed. It is through one of these that the radicle emerges when the embryo germinates. Adhering to the inside wall of the endocarp is the testa, with a thick albuminous endosperm (the coconut "meat"), the white and fleshy edible part of the seed. The endosperm surrounds a hollow interior space, filled with air and often a liquid referred to as coconut water. Coconut water from the unripe coconut, on the other hand, is drunk fresh as a refreshing drink. (http://www.wikipedia.com/coconut)

Coconut kernel, the most commercially exploited part of the coconut is a good nutritive source of various minerals such as calcium, phosphorous, iron, copper and sulphur. It also contains 7-8 per cent dietary fibre. And coconut protein and fibre with proven scientific facts reported to have cholesterol lowering properties.The fresh kernel of ripe coconut constitutes an essential ingredient in the recipes of diverse food preparations in households as well as in food industries of different countries.

Indian coconut sector is driven by global competition and market expansion to come abreast of other leading countries in product diversification and by-product utilization. So value addition of the coconut kernel is gaining prominence, with diversified products succeeding grounds in the market with huge commercial value. Since coconut is not grown in all places it is transported as whole nut or as partially dehusked nut to the uncultivated regions. The transportation of whole is bulky and need more space. Dessication of kernel, germination, damages due to stress crack development and the high cost of transport are the major disadvantages of transporting or storing whole or partially husked coconut. This can be overcome by preparing the dehydrated coconut chips of intermediate moisture coconut kernel. One of the most efficient ways of reducing the initial moisture content is through osmotic dehydration by using suitable hypertonic solution.

Drying of various fruits and vegetables are extensively carried out by the use of conventional tray driers. Even though the products obtained are wholesome, nutritive and palatable, they have not gained popular acceptance, owing to their reduction in flavour, colour and texture of the original material after rehydration. Freeze drying of products results in good quality of dried material with long storage stability but the cost of processing is very high. Hence the new method of drying on the basis of osmosis, in which partial dehydration of fruit either whole or in sliced form is brought about by dipping them in osmotic solution followed by hot air drying.

In osmotic dehydration, the material is dehydrated by dipping or spreading them in aqueous sugar syrup under specific conditions so that water from it migrates to sugar syrup. Osmotic dehydration can remove up to 50% of the water from fresh ripe fruits. The osmotic dehydration techniques not only enables the storage of the fruits for a longer period but also preserves flavour, nutritional characteristics and prevents microbial spoilage. The use of osmotic dehydration also attracts the interesting fact of energy savings that are obtained by eliminating water from the product without evaporation. Overall this makes an effective solution for the dehydration of fruits

Conventionally, sugar syrups were used for osmotic dehydration. But the products obtained are constituted with more glucose which is not advisable to the diabetic patient. Alternative medium of osmotic dehydration can be made use of like jaggery and honey to substitute the sugar syrup. Jaggery is an effective substitute for sugar, which is much less harmful compared to sugar for the diabetics patients and enhances the flavour and colour of the product and honey is said to posses medicinal values. (http://timesofindia.indiatimes.com/articleshow/911384.cms). These can be made use of in the osmotic dehydration of various fruits and vegetables (http://www.drgrotte.com/honey-medicine.shtml).

Osmotic dehydration is followed by secondary drying. It is a mass transfer process resulting in the removal of moisture by evaporation from a solid, semi-solid or liquid to end in a solid state. Drying is used to reduce the water activity of the food products and prevent it from microbial attack .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.

Considering the above cited advantages in view, a study was conducted in Kelappaji College of Agricultural Engineering and Technology, Tavanur which encompasses the following specific objective.

i) Development of coconut chips from coconut kernel

ii) Standardization of hypertonic solution for osmotic dehydration

iii) To study the effects of time and concentration of solution on osmotic dehydration

iv) To study the drying characteristics of osmotically dehydrated products

v) Quality analysis and packaging of coconut chips.

CHAPTER 2

REVIEW OF LITERATURE

This chapter gives general information on coconut kernel, its chemical composition, osmotic dehydration, drying characteristics and its effects on the quality of end products. Research done on these aspects were reviewed and discussed in detail under the following topics.

2.1 Coconut

The coconut palm is the most useful palm in the world. Coconut is one of the high value commercial crops which have an immense scope for product diversification either by technology transfer or development of indigenous technology so that various proposed coconut based products can tap both the export and domestic markets.

It is no wonder then that the palm is looked upon with reverence and affection by the inhabitants of the coconut producing countries and given such eulogistic epithets such as Kalpa Vriksha (Tree of Heaven), the Consols of the East, Mankind's Greatest Provider in the Tropics, Tree of Life, Tree of Abundance, Tree of Plenty, etc.

Each and every part of the coconut palm is useful to man in one way or another. The raw kernel is an important article of food. The oil from the nut is used in cooking and in the manufacture of soap and other toilet requisites. The coconut oil cake is a valuable cattle feed. Fibre from the husk is used in the manufacture of coir ropes, mats and matings. The trunk, otherwise called 'porcupine wood', is used in house construction and furniture making. The leaves after plaiting are used to thatch houses. The juice obtained on tapping the inflorescence is rich in sugar and is converted into jaggery, sugar, vinegar and sweet or fermented toddy. The products of commercial importance are copra, oil, cake, desiccated coconut and fibre.

On account of all these utilitarian and desirable features, it has been rightly called Kalpavriksha, the Tree of Heaven the tree that provides all the necessities of life. The coconut is, therefore, a unique tree among the economic plants of the tropics.

In India, coconut is consumed in the form of tender nuts, raw kernel, copra, coconut oil and desiccated coconut. Since dish made from the coconut furnish fat, protein and some vitamins, they counterbalance some of the deficiencies inherent in the predominantly starchy foods consumed in the countries concerned. Some of countries derive substantial revenue from the coconut industry. In India, coir products exported abroad earn the much needed foreign exchange.

2.1.1 Climate and Soil

The coconut palm is found to grow under varying climatic and soil conditions. It is essentially a tropical plant growing mostly between 20ºN 20ºS latitudes. However, a rainfall of about 2000 mm per year, well distributed throughout, is ideal for proper growth and maximum production.

Coconut is grown under different soil types such as loamy, laterite, coastal sandy, alluvial, clayey and reclaimed soils of the marshy low lands. The ideal soil conditions for better growth and performance of the palm are proper drainage, good water-holding capacity, and presence of water table within 3m and absence of rock or any hard substratum within 2m of the surface.

2.1.2 Varieties

There are only two distinct varieties of coconut, the tall and the dwarf. The tall cultivars that are extensively grown are the West Coast Tall and East Coast Tall. The dwarf variety is shorter in stature and its life span is short as compared to the tall. Tall x Dwarf (TxD), Dwarf x Tall (DxT) are the two important hybrids.

2.2 Coconut Kernel

Dehusked coconut yields three distinct but valuable raw materials (50% kernel, 17% water and 33% shell) for further processing. The coconut kernel is the white and fleshy edible part of the seed. Kernel may be processed to obtain many value added products. Coconut kernel contains on average 40 per cent oil. Protein in fresh coconut kernel is the highest in the eighth month old nuts. Coconut kernel is consumed as a culinary ingredient throughout the country even though its regular use is restricted to the traditional growing tracts in the country.

The coconut meat in the fruit begins to form after about 160 days, when it is at its full size. The shell begins to harden after 220 days and the meat gets fully formed after 300 days. However, for full maturity 360 days are required.

2.2.1 Chemical composition

The composition of fresh coconut kernel (in percentage) as reported by the Central Food Technological Research Institute (CFTRI), Mysore, India.

Moisture	45
Protein	4.0
Fat	37.0
Minerals	4.0
Carbohydrates	10.0

Table 2.1 Chemical composition of fresh coconut kernel

2.2.2 Coconut kernel based products

In the recent years, there have been attempts to develop value added products. As a result, products such as dessicated coconut, coconut cream, dehydrated coconut milk, Virgin oil etc. were developed to cater the export market.

1. Dessicated coconut

Dessicated coconut is the white kernel of the fruit comminuted and dessicated to a moisture content of less than 3%. It is white in colour. It is very important commercial product havindg demand all over the world in the confectionary and in other food industries, as one of the main subsidiary ingredients of fillings for chocolate, candies etc.

2. Coconut cream

Coconut cream is a white, smooth, liquid cream with excellent coconut flavour and 20-30% fat, aseptically packed. The product is easily pourable and ready for direct serving or to be used in other food preparation.

3. Dehydrated coconut milk

This is produced on a commercial scale in the, Malaysia and India. In the Philippines, the fresh coconut milk is blended with small amounts of additives such as maltodextrin or casein and is spray dried. The powder is easily dissolved in water to form a milky white liquid with the flavour and texture of coconut milk.

4. Virgin oil

Virgin oil is a high quality product from coconut kernel with the following added values viz., coconut flavour, low free fatty acid, maximum natural vitamin E content. In this process, coconut milk is filtered and concentrated and then cream is separated by centrifugation. The cream is stirred vigorously to get the virgin coconut oil. The oil thus obtained is very clear, nutritious and has got longer shelf life.

5. Edible coconut flour

After expelling the milk, the protein rich residue is dried and powdered to obtain a product called coconut flour. The flour so obtained typically contains 7-8% protein, 3-5% moisture and 17% oil. It can be used as an ingredient in weight control foods because of its high fibre content.

2.3 Osmotic Dehydration

Osmotic dehydration is the process of water removal by immersion of water containing cellular solid in a concentrated aqueous solution. The driving force for water removal is the concentration gradient between the solution and the intercellular fluid. It improves the quality of the product in terms of colour, flavor, aroma and texture, and is less energy intensive process than air or vacuum drying process. Osmotic dehydration got its attention due to its great importance in processing industry. This simple pretreatment prior to drying was governed by various factors such as type, concentration and time. Osmotic dehydration is mostly used as an initial processing prior to convection or vacuum drying, freeze drying, freezing or pasteurization (Lenart *et al*. 1987)

2.3.1 Osmotic dehydration of fruits

Souryl *et al*. (1981) made an evaluation of osmotic concentration of apple rings using corn syrup solid solution. It was found that weight loss in apple was promoted by increased corn syrup solids concentration, increased immersion time, increased temperature and decreased thickness.

Bongirwar and Sreenivasan (1977) described partial dehydration of banana by osmosis in 70% sugar syrup. The fruit was reduced to about 50% of its original weight by the process of osmosis. Flavour, colour, appearance and texture attributes were maximally retained in osmotically dried products.

Torregiani *et al*.(1987) found that good quality and shelf stable cherries were obtained by osmotic dehydration for two hours.

Angela *et al.* (1987) made a combination process of osmotic dehydration and freeze drying to produce a raisin type blueberry product. The product was made by using berry; sugar ratio of 3:1 or 4:1 for osmotic dehydration followed by freeze drying. The final product has a good texture, flavor, acceptability and predicted shelf life of 16 and 64 months at 25^0 C and 50^0C respectively.

Vyas and Sharma (1989) applied osmotic technique in plum wine fermentation. Compared to untreated fruits, wines of acceptable acidity were produced from most of the preheated fruits. Water blanching of plum followed by osmotic treatment improved the sensory qualities of plum wine by reducing excessive acidity and astringency.

Bolin and Huxsoll (1993) observed weight loss of about 50% by immersing pear in sucrose of 60^0Brix at 60^0C.

Chaudhary *et al*. (1993) stated that during osmosis when the time of treatment increases the weight loss of the product increases.

Parjoko *et al.* (1996) made a study on the influence of syrup concentration in osmotic dehydration. Pineapple wedges were used for the study. It was found that at constant temperature the rate constants for both water and solids increased with increase with increase syrup concentration which was due to the increase of driving force for both water and solids.

Das *et al.* (1997) found out the influence of concentration on osmotic dehydration of banana. The sugar concentration of 45^0, 50^0 and 60^0 Brix were selected for the study. The maximum water loss and solid gain was found to occur in slices treated with 60^0 Brix.

Jean *et al.* (1998) studied osmotic dehydration of jackfruit. Different osmotic solutions at different temperatures as well as different concentrations were tested. Several parameters were investigated such as the effect of salt, blanching, agitation and size on the water loss and sugar gain. Volume changes during the process were also investigated. The change in colour during osmotic dehydration was studied as well as the texture. The results obtained from this study showed that sucrose gave the highest reduction in moisture and was found to have acceptable quality while glucose gave the lowest reduction in moisture. A mixture of sucrose and glucose 1/1 yielded an acceptable behavior in both water loss and sugar gain. Salt was found to have a positive effect on osmotic dehydration by increasing the solute gain and decreasing the shrinkage. Blanching increased the water loss and sugar gain.

Machado *et al.* (2003) evaluated the parameters of the osmotic dehydration process of banana and the influence of concentration of the osmotic solution over the chemical and physical-chemical characteristics of the fruit after osmosis and drying. The fruits were submitted to an osmotic pre-treatment into 45º, 55º and 65ºBrix sucrose syrups and 1:2 fruit: syrup ratio at 65ºC during 2 hours. After osmosis, drying was carried out in oven with air circulation at 65ºC until water activity lower than 0.8 was achieved. At the beginning and the end of osmosis, as well as during the drying, the values of total soluble solids (ºBrix), water activity, moisture content, color and texture were evaluated. It was concluded that it is possible to obtain banana by osmotic dehydration, where the chemical and physical chemical characteristics are influenced by the concentration of the solute used as osmotic agent, mainly color and texture, after osmosis and drying, decreasing time of drying with the concentration increase.

Edson *et al*. (2006) found that loss of fruit ranges from 10% to 40% and could be reduced if papayas were dried. So he studied the process of osmotic dehydration followed by air-drying and modelled for papaya preservation, so it could be optimized. The developed model has been validated with experimental data and simulations have shown how the operating conditions affect the process. An optimization was done using the model in order to search for the best operation condition that would reduce the total processing time.

2.3.2 Osmotic dehydration of Vegetables

Baroni *et al.* (1999) in this work, small squares of onion (*Allium cepa L.,* var. Baia Piriforme) were submitted to dehydration by an immersion process in salt solutions. Different concentrations of sodium chloride (5, 10 and 15% w/w) and temperatures (22, 30 and 40°C) were tested to evaluate the kinetics, and the profiles of moisture content and salt penetration were constructed. After 1 hour 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 40ºC, with a solid uptake of 9%. It was also observed that the concentration of the salt solution was more important than the temperature in the process mass transfers.

Danila *et al.* (2001) suggested osmotic dehydration as a pre-step to further processing. The distinctive aspect of this process, when compared with other dehydration methods, is the direct formulation achievable through the selective incorporation of solutes, without modifying the food integrity. By balancing the two main osmotic effects, water loss and solid uptake, the functional properties of the fruit could be adapted to many different food systems. The role of an osmotic step mainly related to improvement of processed fruit quality characteristics, such as texture, and pigment, vitamin and aroma content, is analysed.

Hanna *et al.* (2001) studied mass transfer during osmotic dehydration of plant tissues of apple, pumpkin and carrot. Osmotic dehydration was carried out in 61.5% solution of sugar. Temperature of dewatering was constant at 30°C. Time of dehydration was varied from 0 to 180 min. Osmotic dehydration in sugar solution at 30°C depends on the kind of plant tissue. The most significant changes of water content, water loss and solids gain took place during the first 30 min of dewatering. During that time the water content in apples was reduced by some 48%, whereas further dehydration from 60 to 180 min resulted in water content reduction by next 30%. Further dewatering of pumpkin and carrot proceeded much slower than that at the beginning of the process. Rate of water loss was 5–10 times higher than the rate of solids gain and depended on the advancement of the dewatering process.

Sagar *et al*. (2001) made a study on preparation of onion powder by means of osmotic dehydration and its packing and storage. The rate of water removal and salt uptake were maximum at the beginning of osmotic dehydration.

Burhan *et al.* (2004) investigated quantitatively water and sucrose transfer during osmotic dehydration of carrot slices using response surface methodology with the sucrose concentration (40–60%, w/w), temperature of sucrose solution (40–60 °C) and immersion time (0.5–6.0 h) being the independent process variables. It was found that immersion time and concentration of sucrose solution were the most significant factors affecting the water loss during osmotic dehydration of carrots followed by temperature. Effect of temperature and time were more pronounced for solid gain than the concentration of sucrose solution.

Aleksandar *et al.* (2005) used response surface methodology for quantitative investigation of water and solids transfer during osmotic dehydration of sugar beet cossettes in combined aqueous solutions of sucrose and sodium chloride. Effects of immersion time (30–240 min), sucrose concentration (30–70%, w/w), sodium chloride concentration (0–8%, w/w), and temperature of the osmotic solution (30–50 °C) were estimated. It was found that effects of immersion time and sucrose concentrations were more significant on the water loss than the effects of sodium chloride concentration and temperature. As for solids gain immersion time and sodium chloride concentration were the most significant factors.

Corzo *et al*. (2005) optimized the osmotic dehydration of the cantaloupe using the desired function methodology. Cantaloupe cylinders were cut and weighted, initial humidity and °Brix were measured, then four cylinders were osmo-dehydrated in solutions of sucrose of give concentration and temperature by a stipulated time. The conditions of dehydration were established by means of a central rotable composite design for temperatures, concentrations and times between 40–50 °C, 45–55 °Brix and 60–120 min, respectively. Weight, humidity and °Brix were determined in each cylinder after each dehydration in order to calculate the mass loss, water loss and °Brix increase. Applying the method of the desired function, the dehydration was optimized in 37.95 °C, 41.6 °Brix and 132.30 min in order to obtain weight loss equal to 0.11 g/g, water loss equal to 0.33 g/g and °Brix increase equal to 12.3 °Brix/g.

2.3.3 Osmotic dehydration of coconuts

Rastogi *et al*. (1994) used osmotic dehydration as one of the upstream processing steps (separation of kernel from shell) during wet processing of coconut. Water loss from the coconut increased with the increase in temperature and concentration of the osmotic solution. A correlation has been proposed for the reduced weight based on Fickian diffusion as a function of temperature, concentration and immersion time. High correlation was observed between experimental and predicted values.

Rastogi *et al*. (1995) determined osmotic dehydration rates for coconut over a range of osmotic solution concentration (40–70°B) and temperature (25–45C). A semi-empirical relation for kinetics of osmotic dehydration has been proposed, which indicates the moisture diffusion as a function of concentration of osmotic solution and its temperature. Good agreement was observed between the observed and predicted values. The effective diffusion coefficients of water in coconut during osmotic dehydration were estimated and also the activation energy of the osmotic dehydration process of coconut was found as 1.75 × 104 J/kg-mole.

Vennila et al. (1998) conducted a study on the feasiblity of using sugar as an osmotic agent for the dehydration of coconut.osmotic dehydration was done at 30 ^{0}Brix for 48 hours subsequently followed by drying at a temperature of 60 ^{0}C . The study showed that lower incidence of microbial population in the sugar syrup treated sample is considered to be by far the best and also indicated its suitability for consumption. The colour appearance, flavour, texture and taste were found to be highly acceptable for all the prepared products.

2.4 Effect of osmosis on subsequent drying

Ponting *et al.* (1966) reported that fruits which have been osmotically dehydrated to about 50% weight reduction could be air dried to low moisture content in a short time.

Nanjundaswamy *et al.* (1978) found that substantial decrease in moisture pineapple, pappaya and apple by initial osmosis quickened further air drying process.

Levi *et al*. (1983) studied the air drying behavior of fruits and vegetables. The increase in added sugar content in papaya significantly affected the rate of water evaporation during the drying process. During the first stage of direct drying, (3h at 75^{0}C) the drying rate was 22 percent/hr. The rate slowed down during the second stage (65^{0}C) to 9.1 percent of water removed/hr.

Kim and Toledo (1987) found out the effect of high temperature fluidized bed drying and osmotic dehydration on the properties of blueberries. High temperature fluidized bed drying reduced dehydration time compared to conventional dehydration. The dried product had less bulk density large diameter faster rehydration time higher rehydration ratio. High temperature fluidized bed increased drying rate and thereby facilitating final drying of osmotically dehydrated blueberries.

Rahman and Lamb (1990) studied air drying behavior of fresh and osmotically dehydrated pineapple. The drying rates of osmosed pineapple significantly decreased due to the presence of infused solute. The effective diffusion coefficient decreased with the increasing solid gain during osmosis.

Shahabuddin *et al.* (1990) investigated the drying behaviour of osmosed and fresh pineapple and the development of pineapple powder for use as dry food ingredient. It was found that by osmotic dehydration alone 30 to 40 percent of the water content of pineapple could be removed in a day.

Colignan *et al*. (1992) studied about the drying of fresh and solute impregnated fruit to determine whether pretreatment by dehydration, impregnation, soaking operation on a sucrose solution is advantageous. Drying performances of the fruits was assessed according to the kinetics and energy consumption. No significant difference was noticed between drying of fresh and solute impregnated fruit in terms of drying period and energy consumption per unit of evaporated water. When energy consumption is considered in terms of output weight more energy is required for drying fresh fruit than for solute impregnated fruit. The later was also of higher quality.

Grabowski *et al.* (1992) conducted a study on production of kiwi chips by solar assisted osmotic dehydration. He found that after osmotic treatment the fruit retained its natural colour and high quality product was obtained.

Lewicki *et al*. (1992) conducted a study on energy consumption during osmo-convection drying of fruits and vegetables. He concluded that combining osmotic dewatering with convection drying, a substantial reduction of energy consumption can be foreseen.

Grabowski *et al.* (1994) showed that a reduction in drying time by a factor of 1.5 times was achieved by simultaneous osmotic and convection drying of grapes immersed in fluidized bed of sugar.

Ertekin and Cakalosz (1996) revealed that initial osmotic step shortened the drying air time for peas.

Cohen *et al*. (2000) demonstrated the feasibility of osmotic drying of various foods, pitted cherries, whole blueberries and cubed carrots. The feasibility of applying the osmotically-induced migration of compounds through the membrane of food samples was also examined. The osmotic solutions included sucrose, dextrose, maltose, honey, maltodextrin and salt. Drying was accomplished at atmospheric pressure at room and boiling temperatures and under vacuum at room temperature. In some experiments, final drying was achieved in a forced air dryer.

Torringa *et al.* (2000) revealed osmotic dehydration as a pretreatment before combined microwave hot air drying of mushrooms. He found osmotic dehydration as an effective method to remove water from vegetable tissues while simultaneously introducing solutes in the products. The residues of the solutes inside the products not only influence the taste and flavour of the product but as well as the dielectric properties.

Betsy Holman (2001) dried the toasted coconut by removing white meat from coconut shell and grating coarsely. Place grated coconut were the placed in roasted pan and baked at 200 ^{0}F for 2 hours, tossing frequently, until coconut is golden brown and dry. It was recorded to be stored for several months in an air tight container.

Floreslopez *et al.* (2001) reported osmotic dehydration as a pretreatment capable of improving the sensory quality of dried food stuffs. He evaluated the effect of temperatures used for osmotic treatment and air drying, on the sensory preference based on colour and flavor of shredded coconut. Osmotic dehydration treatment of 3h with 65^0 Brix sucrose syrup was applied and the strips were air dried until 5% moisture content was reached. The osmotic treatment temperatures were 30, 40, or 50 ^{0} C and drying air temperatures were 50, 60 or 70 ^{0}C. It was found that treatments including osmotic dehydration at 40^0C and drying temperatures of 50 or 60 ^{0}C had highest score. The osmotic dehydration treatment of wet coconut pulp before air drying improved colour and flavor of finished product.

Abraham *et al.* (2004) dehydrated jackfruit with 40 °Brix, 50 °Brix and 60 °Brix sucrose solutions at 30°C, for three hours. Kinetics of drying was conducted using a convective tray drier treatment. Osmotic treatment decreased water contents. Water activity decreased with the increase concentration of sucrose solutions. The data also showed that drying time decreased with the increased of the concentration of osmotic solutions.

Bosco and Vidhan Singh (2005) developed sweet coconut chips from tender coconut by osmotic dehydration and subsequent drying of slices in forced hot air electrical dryer. The osmosis time and the drying time were 1 hour and 6 hours respectively. Packaging was done in LDPE film pouches and flavour, crispiness upto 6 months period was retained without affecting its microbial and biochemical qualities.

Bruce *et al.* (2005) made dehydrated coconut flakes that have been lightly sweetened with evaporated cane juice.

Naka *et al.* (2006) made coconut chips from coconut meat by mixing coconut slices in a mixture of 12 percent sugar and 1 percent salt by keeping it in refrigerator for 12 hours. The water was drained and dried the chip in indirect dryer at 70^0C for 15-18 hours.

A research was conducted in Philippines to produce salted coconut chips from organic Philippine coconuts. The coconut slices were preheated in the oven to a temperature of 350^{0}F and salt was sprinkled on the slices. Storage life of salted coconut chips were upto a week.

2.5 Quality of the osmotically dehydrated product

2.5.1 Texture

Texture includes those qualities that can feel with the fingers, tongue, the palate or the teeth. It is an important attribute that affects consumer attitude toward preferences for different foods. Textural characteristics of food have both positive and negative cannotations for the consumer. Those textures that are universally liked are crisp, crunchy, tender, juicy and firm. .The subjective method of analysing the texture of the food materials is by using a texture analyser.

Segini *et al*. (1999) compared the relationship between instrumental and sensory analysis of texture and colour of potato chips. The instrumental measurement of puncture test with an Intron Universal testing machine and the parameters fracture force, deformation and stiffness were considered. The instrumental colour quantification was done by computerized video image analysis technique and the colour was expressed as L*a*b* values. Sensory evaluation of texture and colour was performed by a sensory panel especially trained in evaluating potato chips.Discriminant analysis showed that tenderness and crunchiness could predict correctly 90% of the data while fracture force correlated well with all sensory attributes.

Segini *et al.* (1999) developed an Instron punch test with a three point support of a potata chip and the factors affecting the results were evaluated. The moisture content and their texture of fried potato chips were determined at oil temperatures of 140 ^{0}C and 180^{0}C. He found out that the maximum force of break was in the 2-4% moisture region.

Wellington and Badri (2003) conducted a study on the quality characteristics of osmo-dehydrated Christophene in syrups. Christophene cubes immersed in 50% sucrose/50% blend of glucose and 100% fructose syrup were more preferred to those in 100%sucrose.Variations in blends of sucrose with glucose/fructose produced changes in colour (‘L’), texture total soluble solids and overall acceptability.

Pedreschi *et al. (*2004) evaluated the texture of fried potatoes. The texture of potatoes with different shapes was evaluated after frying and in some cases after baking. He also conducted a study on blanched and unblanched potato slices at the four oil temperatures: 160,170,180 and 190 ^{0}C until reaching a moisture content of 1.7%.The texture was evaluated using a bending test with two support points.The maximum force of deformation and maximum deformation were extracted from the force versus distance curves. It was found that the unblanched potato slices are crisper than blanched chips for moisture content lower than 4%.

Flade and Aworh (2005) reported the study of sensory evaluation and consumer acceptance of osmosed and oven dried African star apple and African mango. It was found that there are no significant differences in all the sensory attributes of oven dried African star apple slices preosmosed in the sucrose solutions. However unosmosed and dried samples received consistent poor scores for all the sensory attributes. There was no significant differences in the quality attributes of preosmosed oven dried African mango except the taste. Consumer's acceptance showed no significant differences in all the sensory attributes of preosmosed African star apples and African mango slices.

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials used and methods followed for the development of coconut chips. The various pretreatments and dehydration methods involved during the processing are listed below:

3.1 Test Sample

Coconut of 8-10 months old was procured from the instructional farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur was used for the study. The critical moisture content, fat and carbohydrates were determined as per the standard procedure.

3.1.1 Dehusking and Deshelling

The fresh matured coconuts are de-husked and de-shelled. Dehusking was done by using “Keramithra”. Deshelling was done by using a hammer without breaking the coconut kernel, which helps in the easy removal of the testa and the scooping was carried out using a curved knife. The shell can also be removed after breaking the coconut into halves and then scooping out the kernel pieces by the knife. The testa of the coconut kernel was removed by using an ordinary knife.

3.1.2. Cutting and slicing

The white kernel was cut into pieces of triangular shape of about three inch size so that the pieces can be held in the hand for easy slicing of the kernel. It was sliced transversely to a uniform thickness of about one mm using a vegetable slicer. Slicing was done in such a way that the slices fall directly into the water.

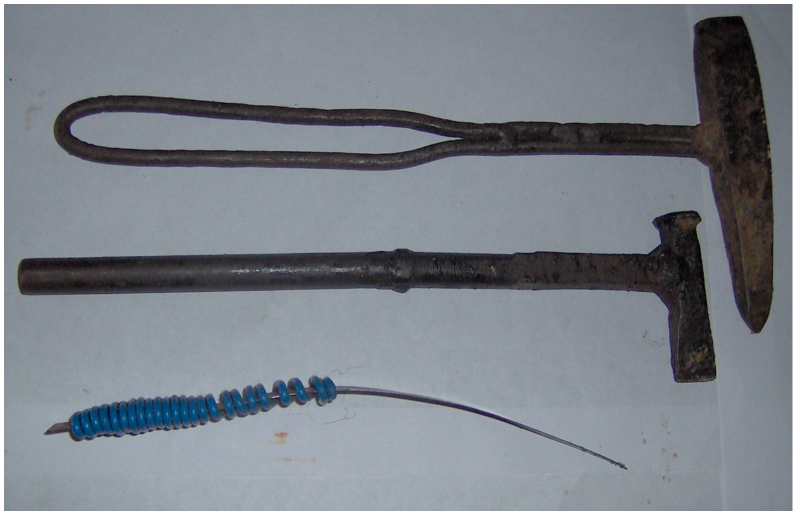

Plate 1. Tools used for deshelling

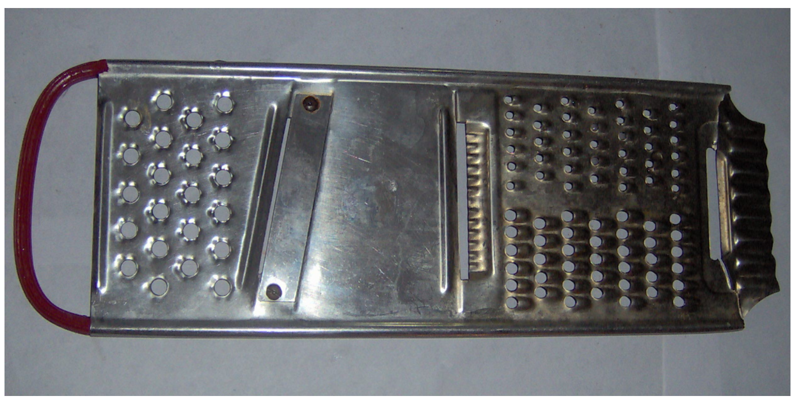

Plate 2. Vegetable Slicer

3.2 Pre-treatments

The different treatments used for the study includes:

1. Control sample

The fresh coconut slices of uniform size and of thickness one mm size were directly taken for osmotic dehydration

2. Blanched sample

The coconut slices of same size were blanched by immersing in boiling water at 100^{o} C for 4 minutes.

3. Chemically treated sample

The coconut slices were treated with 0.05% of potassium metabisulphate for about five minutes.

3.3 Osmotic dehydration

3.3.1 Preparation of syrup

The study was conducted using different hypertonic solutions such as sugar, jaggery and honey. Fruit to solution ratio was taken as 1:4. The osmotic solution of required concentration of 50 ^{0}B, 53 ^{0}B, 56 ^{0}B was prepared, filtered and was checked using a hand refractometer (ERMA, Japan) (Plate 3).

Plate 3. Hand Refractometer

3.3.2 Optimisation of concentration of solution

A preliminary study was undertaken to determine the optimum concentrations of hypertonic solutions required for osmotic dehydration. Fresh coconut slices was washed and immersed in the solutions of 50 ^{0}B, 53 ^{0}B, and 56 ^{0}B concentration at normal atmospheric conditions. The optimisation of the concentration was done based on water loss and solid gain.

3.3.3 Optimisation of osmosis time of osmotic dehydration

The optimisation study for osmosis time was conducted by dipping coconut slices in osmotic media for 30 min, 60 min and 90 min of optimised concentration. The optimum time was determined by calculating water loss and solid gain and also by physicochemical analysis.

3.3.4 Determination of solid gain and water loss

In osmotic dehydration there is a simultaneous counter current mass transfer of water from the sample to the concentrated solution and of water from the sample to the concentrated solution and of solute from concentrated solution into the sample.

Hence in order to analyse the data, the three parameters namely, water loss and solid gain were calculated for each sample using the formulae (Mujumdar and Grabowski, 1991).

Water Loss (WL): It is defined as the net water loss of the sample on initial mass basis.

$$WL = \frac{\text{Initial Moisture} - \text{Final Moisture}}{\text{Initial gross weight}} \times 100$$

Solid Gain (SG): It is the net solid transported into the sample on initial mass basis.

$$SG = \frac{\text{Total solids} - \text{Initial solids}}{\text{Initial gross weight}} \times 100$$

3.4 Secondary drying of coconut slices

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. After osmotic dehydration of the slices, the osmotic medium was drained off and then drying was carried out in tray dryer.

3.4.1 Tray Drying

After osmotic dehydration, optimized samples were further dried in the tray drier of commercially available model as shown in Plate 4. The aluminium trays were cleaned by wiping with a clean cotton cloth. The osmosed samples were then spread uniformly over the tray. Before keeping the tray inside the chamber, the unit was run for one hour in order to stabilise the heat inside the chamber. The trays were then placed on the tray stand in position. By using the thermostat, temperature of 60 ± 1^0C was chosen from the earlier studies. The drying conditions were kept constant for all the experiments. Drying was terminated until the moisture content of the samples become constant. The samples were weighted at regular intervals of 30 minutes by using an electronic balance.

Plate 4. Tray Drier

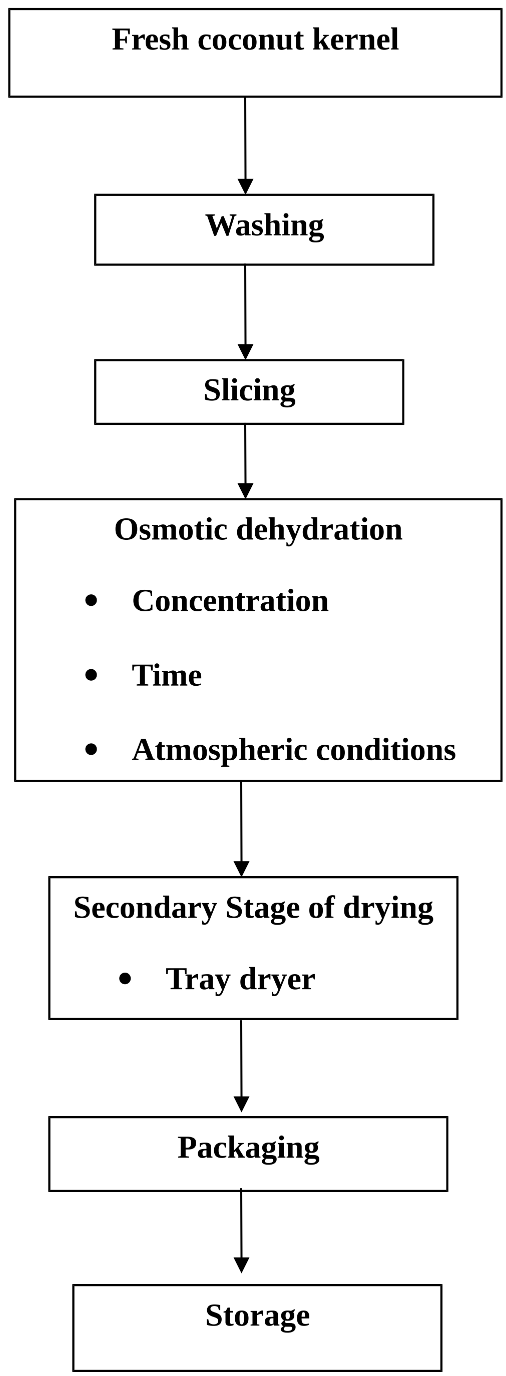

Fig. 3.1 Flow Diagram for the development of Coconut Chips

3.5 Quality assessment of the tray dried product

3.5.1 Moisture content

Moisture content of the coconut sample was determined by drying a known weight of the sample in a hot air oven at 105 ^{0}C to a constant weight. The observations were recorded and the moisture content was calculated using the equation

$$\text{Moisture (\% wb)} = \frac{Ww}{W} \times 100$$

Where, Ww = Weight of water, g

W = Total weight of the sample, g

3.5.2 Rehydration Ratio

Rehydration characteristics of dehydrated food products are of great importance. About 5 g of osmo-air dried samples were taken and immersed in distilled water at room temperature. The rehydration ratio was computed as the ratio of the weight of rehydrated sample to that of dehydration sample.

$$\text{Rehydration Ratio} = \frac{W_2}{W_1}$$

where, W_2 = Weight of the rehydrated sample, g

W_1 = Weight of the dehydrated sample, g

3.5.3 Fat content

Fat is usually extracted from the coconut kernel with n-hexane by using a solvent extraction method with the help Soxhlet extraction apparatus. Although extraction with solvent constitutes the most efficient method for the recovery of oil from any oil bearing material, it is relatively the most advantageous in the processing of seeds or other material low in oil.

The coconut kernel was cut into small pieces and about 20 gram of it was packed in a thimble, in the extraction tube of the Soxhlet apparatus. About 75 ml of n-hexane was taken in the Soxhlet flask and attached to the extraction tube along with a condenser. The extraction was continued for four hours (six cycles) on water bath. At the end of the extraction period, the packet was removed from the apparatus and distilled further for the removal of the solvent.

$$\text{Fat, \%} = \frac{\text{Weight of extracted material}}{\text{Weight of sample}} \times 100$$

3.5.4 Estimation of carbohydrates

Carbohydrates are the most important components of storage and structural material in the plants. They exist as free sugars and polysaccharides. The basic units of carbohydrates are the monosaccharides which cannot be split by hydrolysis into more simple sugars. The carbohydrate content can be measured by hydrolysing the polysaccharides into simple sugars by acid hydrolysis and estimating the resultant monosaccharides.

Hence the total carbohydrate in the sample was estimated by Anthrone method (Sadasivam and Manickam, 1992). A 100 mg of sample was put into a boiling tube and the sample was hydrolysed by keeping it in the boiling water bath for three hours with 5ml of 2.5 N HCl and the whole content were cooled to room temperature. It was neutralised with sodium carbonate until the effervescence ceased. Then the volume was made into 100 ml with distilled water and the supernatant was collected after centrifuging. The 0.5 and 1ml aliquots were taken for analysis.

The standards were prepared by taking 0, 0.2, 0.4, 0.6, 0.8 and 1 ml of the working standard. Then the volume was made up to 1ml in all the test tubes including samples by adding distilled water. Then 4 ml of anthrone reagent was added to all the test tubes and were heated for 8 minutes in boiling water bath. The tubes were then cooled rapidly and the green to dark green colour was read at 630 nanometer. The standard graph was drawn by plotting concentrations of the standard on the X- axis verses absorbance on the Y- axis. From the graph the amount of carbohydrate present was calculated using the formula.

$$\text{Amount of carbohydrate present in 100 mg of sample} = \frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100$$

3.5.5 Texture

Texture of the product was analysed by texture analyzer (Plate 5). Different kinds of probes are used for the texture analyser. Here the crisp fracture support rig is used to measure the fracturability of the coconut chips, by means of a penetration test. It allows accurate location and quick alignment of the sample and is used with the heavy duty platform. P/0.25s ball probe was used with ¼ inches in diameter and spherical in shape made of stainless steel.

3.6 Sensory evaluation of Coconut chips

The sensory evaluation of coconut chips was carried out by a panel of 10 panel judges. Different attributes that is colour, texture in terms of hardness, crispness and tenderness, taste and overall acceptability were observed by a 9 point Hedonic rating scale.

The 9-point Hedonic rating scale was used for the purpose.

9- Like extremely

8- Like very much

7- Like moderately

6- Like slightly

5- Neither like nor dislike

4- Dislike slightly

3- Dislike moderately

2- Dislike very much

1- Dislike extremely

The samples were arranged in tables with specific codes. The scale was easily understood by each of the panelist and their response was converted to numerical values for computation purposes. Final results were obtained by calculating average all marks given by panelist.

3.7 Packaging studies

The samples after the optimization study was packed in 0.5mm Aluminum coated plastic film. The samples were stored in ambient condition (Temp 29-35 ^{0} C with 40-80% RH) for seven days and the quality was evaluated in terms of hardness and toughness using texture analyser.

CHAPTER 4

RESULTS AND DISCUSSION

Results and discussions of the experiments carried out during the development of coconut chips are presented in this chapter. The results obtained are discussed under the following headings.

4.1 Test sample

The coconut of 8-10 months maturity procured from the instructional farm of Kelappaji College of Agricultural Engineering and Technology, Tavanur was used for the experiments. The initial moisture content, fat and carbohydrates of the fresh coconut were estimated by the standard methods explained in chapter 3 and the results are tabulated in the Table 4.1.

4.1.1 Composition of fresh coconut kernel

Brix (^{0}B)	12
Moisture content (% wb)	49
Fat (%)	11
Carbohydrates (%)	6.5

Table 4.1. Composition of fresh coconut kernel

4.2 Osmotic dehydration of coconut

4.2.1 Optimisation of concentration of solution

The coconut slices of uniform thickness of one mm was either pretreated by blanching or chemical treatment or kept untreated. Then the samples were osmotically dehydrated in different hypertonic solutions. The hypertonic solutions include sugar, jaggery and honey syrups of different solute concentrations of 50^0B, 53^0B, 56 ^{0}B for various contact times of 30, 60 and 90 minutes.

The effects on solid gain and water loss in sugar syrup concentration of osmotically dehydrated samples were tabulated in Table 4.2 and represented in Fig 4.1 respectively. It was found that the coconut samples which were not treated or blanched showed maximum water loss and minimum solid gain. Therefore, the pretreatments have no significant effect on the water loss and solid gain. The same trend of water loss and solid gain was also reported in a study conducted on carrots (Falade and Aworh, 2005).

Osmosis time	30 min			60 min			90 min		
Sample	C	B	T	C	B	T	C	B	T
50^0B	0.003	0.005	0.004	0.008	0.009	0.016	0.009	0.010	0.008
53^0B	0.003	0.007	0.008	0.005	0.012	0.017	0.015	0.023	0.021
56^0B	0.057	0.063	0.060	0.900	0.121	0.128	0.288	0.291	0.305

* C – Control *B – Blanched * T – Treated

Table 4.2 Effect of hypertonic sugar solution on solid gain of osmotically dehydrated coconut slices.

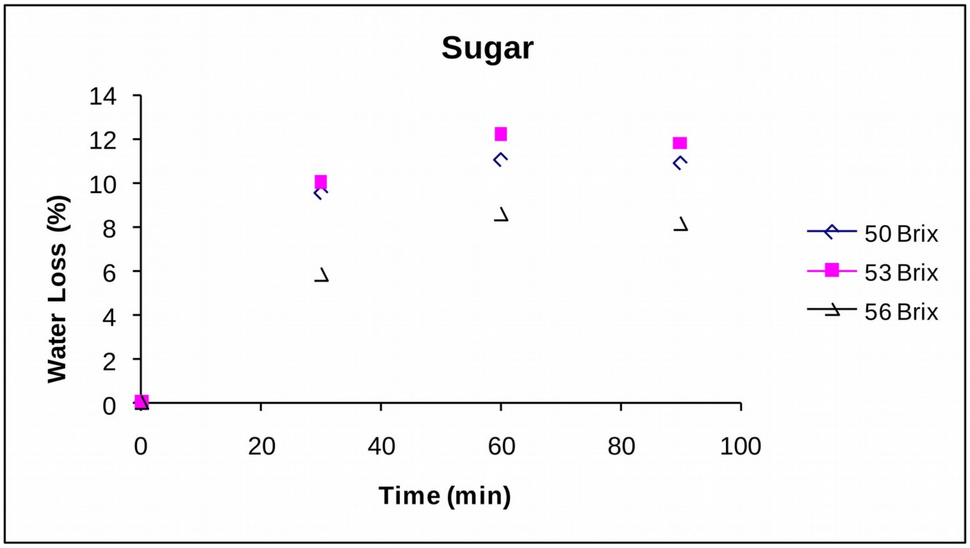

Fig 4.1. Effect of concentration (sugar syrup) on water loss of osmotically dehydrated coconut slices

The effect on solid gain and water loss in jaggery syrup concentration of osmotically dehydrated samples were tabulated in Table 4.3 and represented in Fig. 4.2 respectively. From the table it was observed that in the case of 50 ^{0}B and 56 ^{0}B, the solid gain increases with osmosis time. The concentration of the osmotic solution increases the water loss and solid gain increases and reaches equilibrium towards the termination of the process. The same trend of water loss and solid gain was also reported in a study conducted on carrots (Falade and Aworh, 2005).

Osmosis time	30 min			60 min			90 min		
Sample	C	B	T	C	B	T	C	B	T
50^{0}B	0.008	0.009	0.010	0.007	0.011	0.009	0.008	0.009	0.009
53^{0}B	0.054	0.065	0.067	0.070	0.087	0.080	0.065	0.083	0.071
56^{0}B	0.059	0.076	0.073	0.075	0.091	0.092	0.108	0.020	0.121

* C – Control *B – Blanched * T - Treated

Table 4.3. Effect of hypertonic jaggery solution on solid gain of osmotically dehydrated coconut slices.

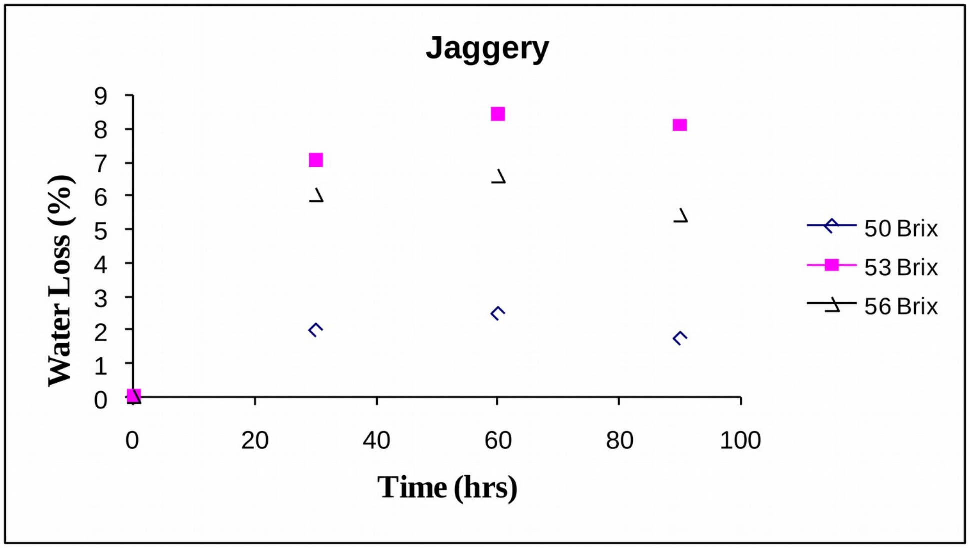

Fig 4.2. Effect of concentration (Jaggery syrup) on water loss of osmotically dehydrated coconut slices

The effect on solid gain and water loss in honey of osmotically dehydrated samples were tabulated in Table 4.5 and represented in Fig. 4.4 respectively. It was observed from the graph that the water loss of honey as hypertonic solution was poor at higher concentration at higher and lower concentration and it was found to be optimum at 53 ^{0}B.

Osmosis time	30 min			60 min			90 min		
Sample	C	B	T	C	B	T	C	B	T
50^{0}B	0.005	0.007	0.006	0.069	0.073	0.071	0.048	0.051	0.05
53^{0}B	0.008	0.010	0.009	0.001	0.077	0.009	0.003	0.007	0.069
56^{0}B	0.006	0.011	0.015	0.49	0.078	0.064	0.006	0.054	0.077

* C – Control *B – Blanched * T - Treated

Table 4.4. Effect of honey on solid gain of osmotically dehydrated coconut slices.

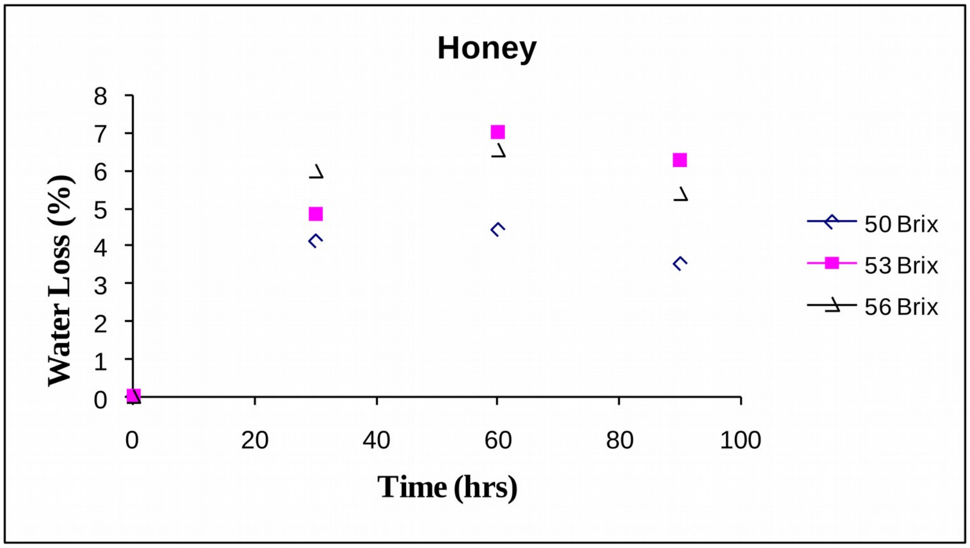

Fig 4.3. Effect of concentration (honey) on water loss of osmotically dehydrated coconut slices

The optimum results of water loss and solid gain are obtained in the concentration of 53 0B when compared with 50 0B and 56 0B for the fresh samples of coconut when compared to the blanched or chemically treated one.

4.2.2 Optimisation of osmosis time of osmotic dehydration

The optimum time is selected in such a way that the amount of water removal is maximum with no appreciable uptake of solids. From the Fig 4.1, 4.2 and 4.3, it is clear that the water loss increases with increase osmosis time and reaches the maximum value at 60 minutes and later the rate of water loss decreases. The solid gain is also optimum for the 60 minutes duration for each of the samples. Therefore for the completion of osmosis at the normal atmospheric conditions, the time required was one hour.

4.2.3 Optimisation of hypertonic solution

The different hypertonic solutions sugar, jaggery and honey were evaluated for optimisation of hypertonic solution. The Fig.4 shows the effect of hypertonic solutions on water loss of osmotically dehydrated coconut slices.

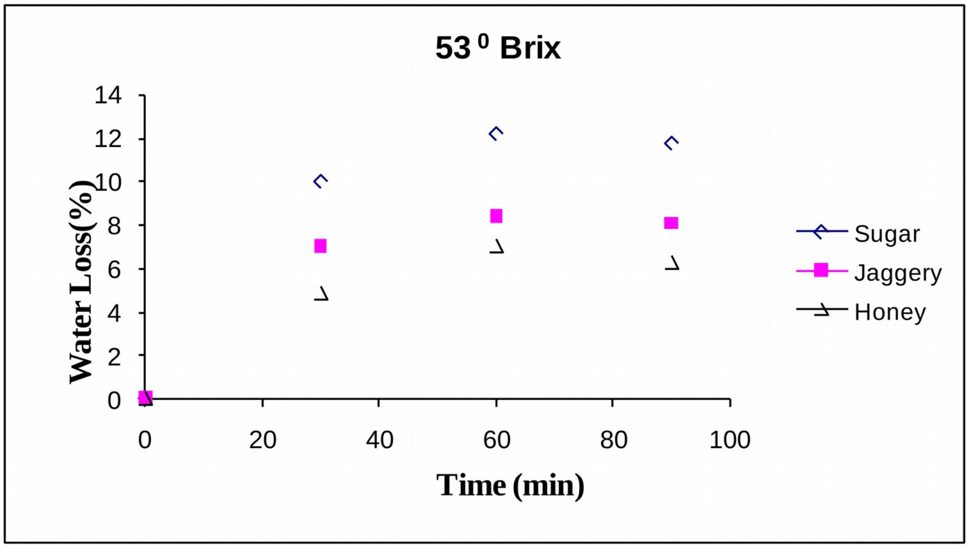

Fig 4.4 Effect of hypertonic solution on water loss of osmotically dehydrated coconut slices

From the graph, the maximum water loss was observed in sugar syrup concentration followed by jaggery. Honey showed minimum water loss with osmosis time compared to sugar and jaggery. It may be due to the low viscous nature of the honey. Therefore, jaggery can be used as an alternative hypertonic solution over conventional sugar syrup as it causes much less harmful effects to diabetics patients when compared to the purified sugar. It has an added advantage of being economically cheaper than sugar.

4.2.4 Effect of pretreatments on secondary drying

The sample which was osmotically dehydrated in 53 ^{0}B with osmosis time of 1 hour was taken for secondary drying in tray drier at a temperature of 60 $\pm$ 1^{0}C. The effect of different pretreatments of test samples in sugar syrup, jaggery syrup, and honey were shown in Fig. 4.5, 4.6 and 4.7 respectively. It was found that as drying time increases the moisture content decreases and reaches almost constant value after 6 hours. It was also revealed that the blanching and chemical pretreatments have little effect on drying rate. Blanching as a pretreatment in potato showed reduction in water loss during osmosis (Islam and Flink, 1982).

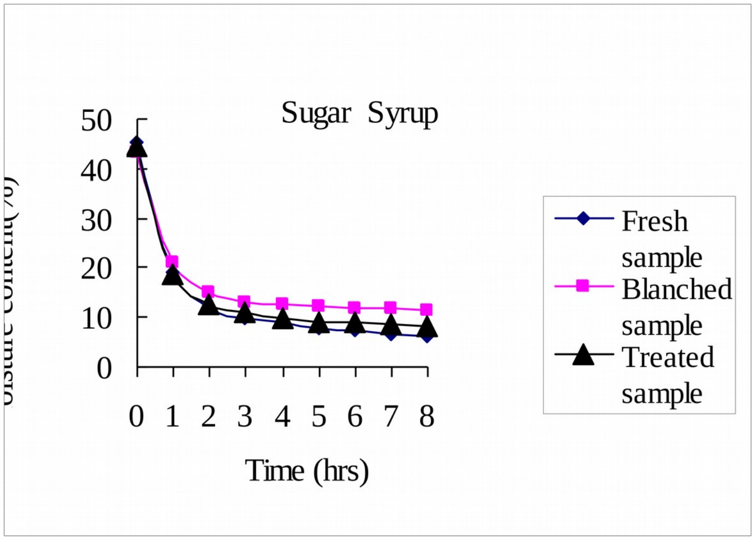

Fig. 4.5 Effect of sugar syrup concentration on secondary drying

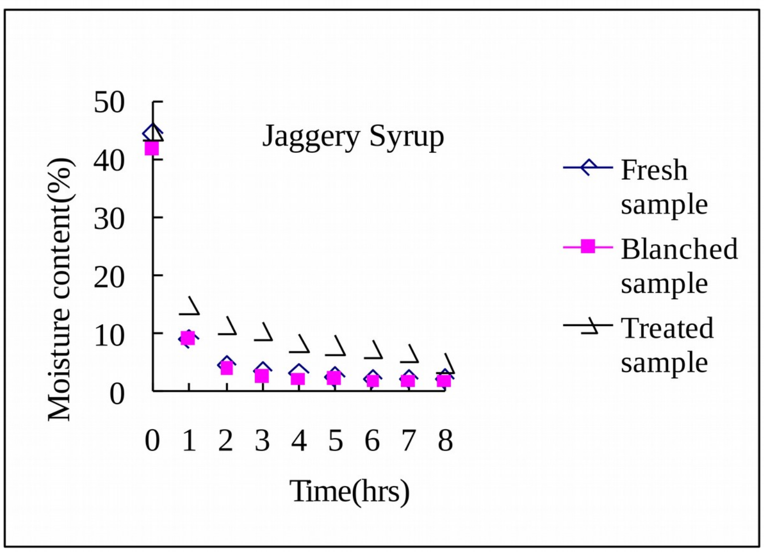

Fig. 4.6 Effect of jaggery syrup concentration on secondary drying

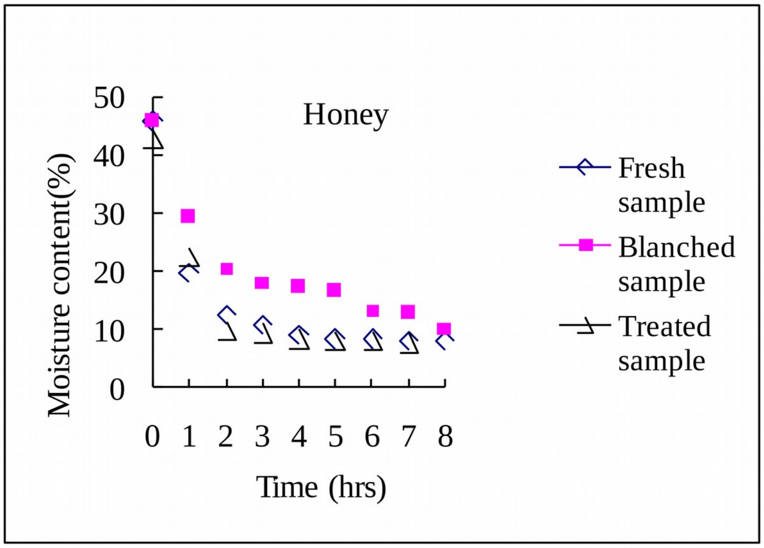

Fig. 4.7 Effect of honey on secondary drying

It can be confirmed from the above figures that maximum water loss is obtained in the case of fresh coconut when compared to blanched and chemically treated coconut samples.

In the light of all above observations it can be confirmed the fresh sample at concentration of 53 ^{0}B kept for 60 minutes duration shows better results of osmotic dehydration and drying for 6 hours in tray drier is optimum. Honey even though superior over jaggery and sugar when the medicinal properties are taken into consideration, shows poor results in the moisture removal and solid gain, so it can be discarded as hypertonic solution used for preparing the coconut chips. It can also be confirmed that, the jaggery can be used as an alternative hypertonic solution over sugar as convectional osmotic media.

Plate 6. Control sample + sugar syrup

Plate 7. Blanched + sugar syrup

Plate 8. Treated + sugar syrup

Plate 9. Control sample + Jaggery syrup

Plate 10. Blanched + Jaggery syrup

Plate 11. Treated + Jaggery Syrup

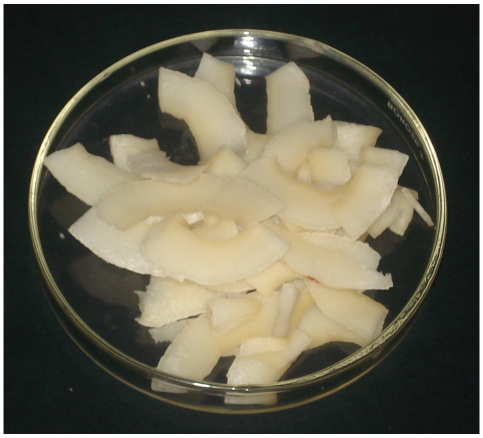

Plate 12. Control sample + Honey

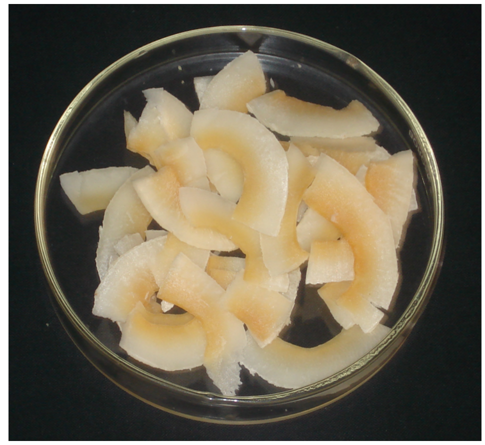

Plate 13. Blanched + Honey

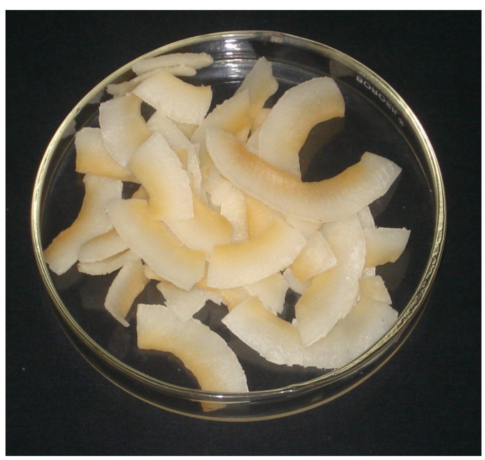

Plate 14. Treated + Honey

4.3 Quality analysis of coconut chips

4.3.1 Fat content

The fat content of the optimised sample was found out and it was observed that there was no significant change before and after drying.

4.3.2 Carbohydrates

The amount of carbohydrates in different test samples was found out and tabulated in Table 5. It was observed that there is no significant decrease in the percentage of carbohydrates compared to the fresh sample. The carbohydrates of the blanched asmple in jaggery syrup increased to about 1.05 times that of the fresh sample.

Test sample	Carbohydrates (%)
Control sample + sugar syrup	7.5
Blanched sample + sugar syrup	6.5
Treated sample + sugar syrup	6.4
Control sample + Jaggery syrup	6.8
Blanched sample + Jaggery syrup	6.6
Treated sample + Jaggery syrup	6.3

Table 4.5. Percentage of carbohydrates in different test samples

4.3.3 Rehydration ratio

The rehydration ratio of the test samples were tabulated in the Table 6. The rehydration ratio of control sample in jaggery syrup was found to be higher than other test samples. So, osmotic dehydration combined with subsequent drying has an advantage that the dried sample resembles the fresh sample.

Test sample	Rehydration ratio
Control sample + sugar syrup	2.58
Blanched sample + sugar syrup	2.62
Treated sample + sugar syrup	2.52
Control sample + Jaggery syrup	2.69
Blanched sample + Jaggery syrup	2.58
Treated sample + Jaggery syrup	2.59
Control sample + Honey	2.61
Blanched sample + Honey	2.60
Treated sample + Honey	2.60

Table 4.6 Rehydration ratio of different test samples

4.4 Quality characterstics of coconut chips

4.4.1 Texture analysis

The texture of the different samples of coconut chips were analysed for seven days and the parameters like toughness and hardness of the samples were recorded. The toughness and hardness found to be lower in samples dipped in hypertonic solution of jaggery when compared to that of sugar and honey. Since low toughness and hardness will result in crispy and crunchy chips, samples in jaggery syrup showed better results (Fig 4.8, Fig. 4.9 and Fig. 4.10).

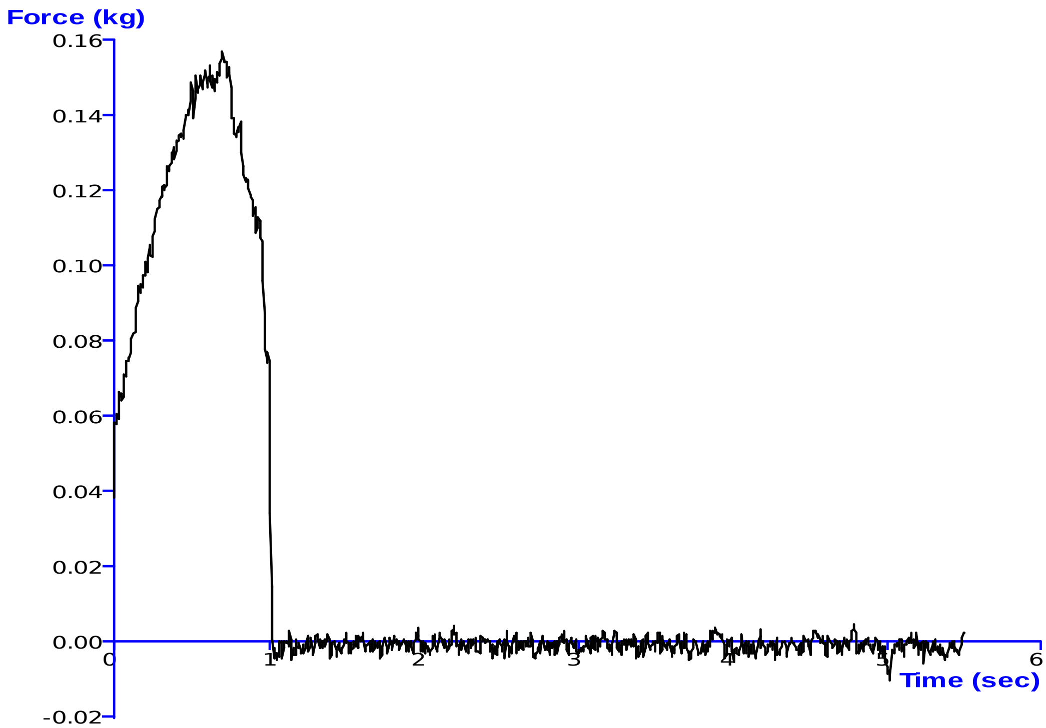

Fig. 4.8 Force- time curve for control sample in sugar syrup from texture analyzer

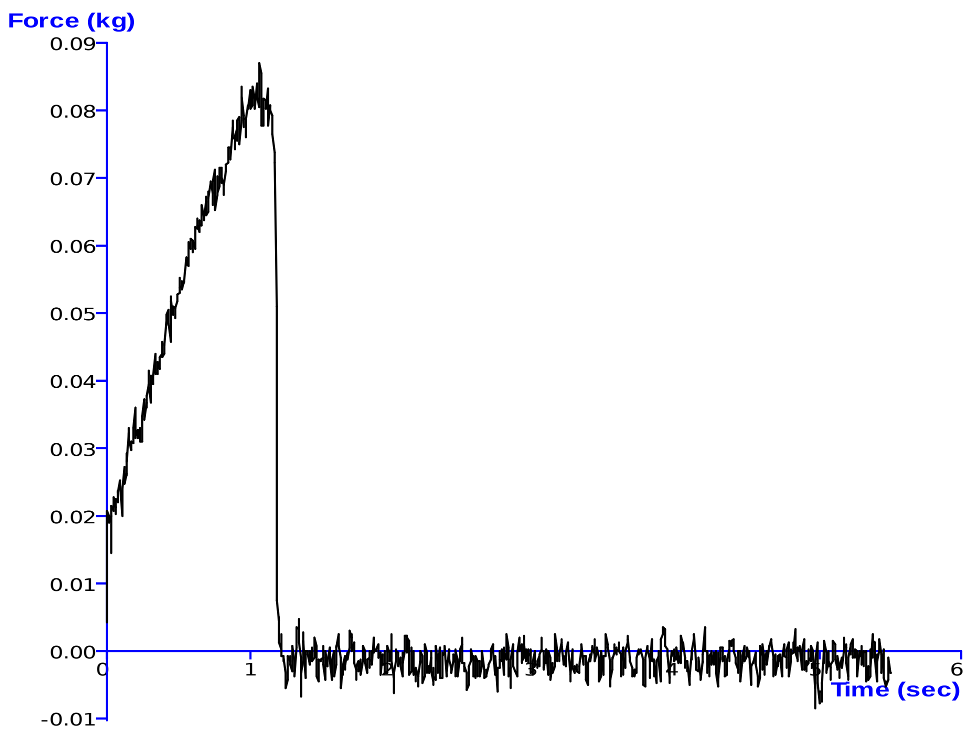

Fig. 4.9 Force- time curve for control sample in jaggery syrup from texture analyser

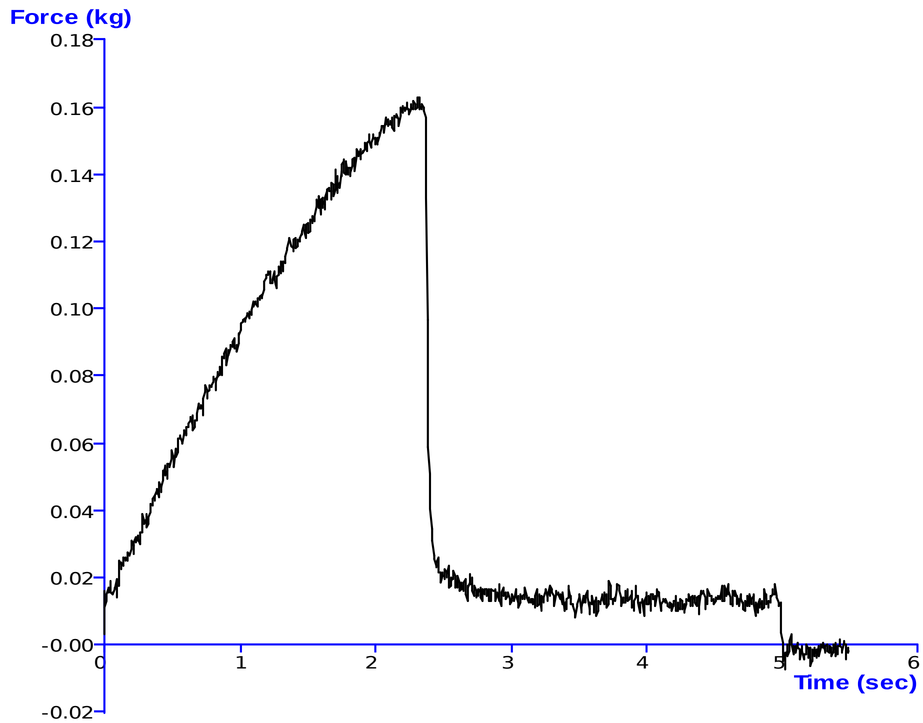

Fig. 4.10 Force- time curve for control sample in honey from texture analyzer

4.4.2 Sensory Analysis

Sensory quality greatly influences the market performance of product. Sensory analysis preference test was carried out in sensory analysis Lab. Ten panelists were assigned to asses the difference in the coconut chips using a 9-point Hedonic scale test. The panelist evaluated parameters such as taste, crispiness, tenderness and general acceptability. These Panelists assessed the difference in pretreatments and acceptability of hypertonic solution used in the study.

Test sample	Taste	Crispiness	Tenderness	General Acceptability
Treated + sugar syrup	7	7	6	6
Treated jaggery	7	7	6	7
Control + honey	6	6	6	6
Blanched+ honey	7	6	6	6
Blanched + jaggery syrup	7	7	6	7
Blanched + sugar syrup	7	7	6	7

Control+ jaggery syrup	8	7	6	8
Control + Sugar syrup	7	7	6	7
Treated+ honey	6	6	5	6

Table 4.7 Sensory evaluation result

From the above table, Control sample in jaggery syrup gave maximum taste and general acceptability. The samples treated with sugar were found to have intermediate result. The test samples in honey showed less crispiness, tenderness and general acceptability was found to be poor.

4.5 Packaging studies

The samples were packed in commercially available packaging materials for seven days and the texture of the samples were analysed. The toughness and hardness of the coconut chips were the two important characteristics that were objectively quantified by the textural analyzer.

As observed from the Table 4.8, we can observe the trend of increasing toughness and hardness of the coconut chips. The toughness indicates the brittleness of the chips. The hardness is inversely proportional to the crispness, as the hardness increases the crispness decreases. Thus the chips should have low hardness and low toughness.

It can be inferred from the Table 4.8, for a particular day the hardness of coconut chips osmotically dehydrated in jaggery syrup is much less than that of chips in sugar and honey. So it can be quantified objectively that chips obtained from jaggery are of much superior quality than honey and comparable to that of chips obtained from sugar.

	Days										
	1		2		3		4		5		
	Toughness	Hardness	Toughness	Hardness	Toughness	Hardness	Toughness	Hardness	Toughness	Hardness	Toug nes
	N Sec	kg	N Sec	kg	N Sec	kg	N Sec	kg	N Sec	kg	N Se
I	1.509	0.087	1.974	0.1626	2.455	0.223	2.556	0.242	2.58	0.245	2.6
II	1.423	0.122	2.057	0.124	2.105	0.191	2.171	0.222	2.457	0.258	2.70
III	1.131	0.132	2.011	0.228	2.218	0.274	2.375	0.278	2.966	0.279	3.47
IV	1.114	0.098	1.502	0.103	2.123	0.128	2.171	0.132	2.213	0.141	2.86
V	1.426	0.074	1.723	0.075	1.733	0.122	1.852	0.123	2.123	0.152	2.16
VI	2.083	0.097	2.116	0.142	2.26	0.163	2.328	0.187	2.695	0.212	2.91
VII	2.580	0.151	3.204	0.201	3.441	0.206	3.444	0.223	3.674	0.224	3.71
VIII	2.395	0.131	2.975	0.201	3.632	0.210	4.155	0.211	4.382	0.215	4.85
IX	2.243	0.169	3.033	0.185	4.226	0.198	4.429	0.215	5.515	0.224	5.39

I-Control + sugar syrup **II**-Blanched + sugar syrup **III**-Treated + sugar syrup **IV**-Control + jaggery **V**-Blanched + jaggery **VI**-Treated + jaggery **VII**-Control + honey VIII Blanched + Honey **IX**-Treated + Honey

Table 4.8 Textural analysis of different test samples

CHAPTER 5

SUMMARY AND CONCLUSION

Coconut (*Cocos nucifera*) is a versatile and important commercial palm in the tropics of the world. Each and every part of coconut is used in India in one way or the other. Hence it has ben rightly called as Kalpa Vriksha- The all giving tree.

Global competition and market expansion to come abreast of other leading countries in product diversification and by-product utilization has driven the Indian coconut sector. So value addition of the coconut kernel is gaining prominence, with diversified products succeeding grounds in the market with huge commercial value. There are various products of coconut gaining momentum in the export market.

The Central Plantation Crops Research Institute has developed Coconut chips as a value added product of coconut. But the major drawback is that the chips made were from the sugar syrup and had high glucose content which are not advisable for the diabetic's patients.

Hence a need was felt to develop coconut chips from alternative osmotic media without compromising the quality and taste of the chips, which can be consumed by the diabetic's patients, as the cases of diabetics are reported more frequently in our country. The development of coconut chips was done after a thorough study of various value added of coconut. The main objectives of the project to develop of coconut chips from the coconut kernel, standardization of the hypertonic solution for osmotic dehydration, studying the effect of time and concentration of the solution on osmotic dehydration, the drying characteristics of osmotically dehydrated products and the quality analysis and packaging of the coconut chips.

The coconut chips were made from freshly harvested 6-8 months old coconut, the kernel of coconut was removed first by a chipping tool and a specialized flexible knife. The kernel is sliced into pieces with the aid of a slicer then the slices are dehydrated first by osmosis at 53º Brix for 1 hour in jaggery solution, which was found to be superior alternative for sugar as osmotic media when compared with honey. After osmotic dehydration the slices are arranged in trays of the conventional dryers and dried at the temperature of 60º Celsius for 8 hours. After drying we obtain chips that are ready to be served. The storage life of the coconut chips can be increased by packaging it in aluminium coated plastic foils.

The quality analysis of the coconut chips was done by using Sensory evaluation and Textural analyser to quantify subjectively and objectively respectively the quality of the coconut chips

Suggestions for future work:

1. A suitable mechanism can be developed for removing the coconut kernel from the coconut husk without spilling out the coconut water, so that it can be stored for a long period of time without any spoilage and can be sliced when required.
2. Different flavour enhancing volatile oils can be added to coconut chips and the taste can be improved. The chips can also be made in spicy osmotic medium
3. Suitable Modified Atmospheric Packaging systems can be developed for prolonging the shelf life of the chips.

REFERENCES

Abraham D., Giraldo-Zuniga., Aroldo, A., Rosimeire M., Carla S. S and Amanda C, 2004. The air drying behavior of osmotically dehydrated for jackfruit slices. Drying 2004 –Proceedings of the 14th International Drying Symposium (IDS 2004). Vol. C: 2120-2126.

Ahmed, J and Shivhare, U.S, 2001. Effect of pretreatment on drying characteristics and colour of dehydrated green chillies. J.Food Sci. Technol., 38(5) : 504-506.

Aleksandar Jokie, A , Julianna Gyuraa, Ljubinko Levica and Zoltan Zavargoa, 2007. Osmotic dehydration of sugar beet in combined aqueous solutions of sucrose and sodium chloride. Journal of Food Engineering, Vol 78(1): 47-51

Bolin, H .R., C.C. Huxsoll, R. Jackson and K.C. NG, 1983. Effect of osmotic agents and concentration on fruit quality. J. Food Sci., 48(1): 202-205.

Bongirwar, D.R. and A. Sreenivasan, 1977. Studies on osmotic dehydration of banana. J. Food Sci Technol., 14(3): 104-112.

Burhan Uddina M., Paul Ainsworthb and Enol banolu, 2004. Evaluation of mass exchange during osmotic dehydration of carrots using response surface methodology. Journal of Food Engineering. Vol. 65 (4): 473-477.

Chaudhari, A.P., B.K. Kumbhar, B.P.N. Singh and Maharaj Narain, 1993. Osmotic dehydration of fruits and vegetables. A Review. Indian Food Industry, 12(1): 20-27.

Collignani, A., A.L. Raoult Wack and A. Themelin, 1992. Energy study of food processing by osmotic dehydration and air drying. Agrl. Engg. J., 1 (3) : 125-135.

Danila Torreggiani, and Gianni Bertolo, 2001. Osmotic pre-treatments in fruit processing: chemical, physical and structural effects. Journal of Food Engineering. Vol. 49(3): 247-253.

Ertekin, F. K. and T. Cakaloz, 1996. Osmotic dehydration of peas: I. Influence of process variables on mass transfer. J. Food Processing and Preservation, 20: 87-104.

Fabiano A.N. Fernandes, Sueli Rodrigues and Edson L. Oliveira, 2006. Optimization of osmotic dehydration of papaya followed by air-drying : Food Research International. Vol. 39(4): 492-498.

Fabiano A.N. Fernandes, Sueli Rodriguesb, Odisséia C.P. Gasparetoc and Edson L. Oliveira, 2006. Optimization of osmotic dehydration of bananas followed by air-drying. Journal of Food Engineering . Vol. 77(1) : 188-193.

Falade, K.O and Aworh, O.C, 2005. Sensory evaluation and consumer acceptance of osmosed and oven dried African star apple and African mango. J. Food, Agrl and Environment, 3(1): 91-96.

Grabowski, S., A.S. Mujumdar, H.S. Ramaswamy and C. Strumillo, 1994. Osmo-convective drying of grapes in the fluidised bed of sugar ans semolina. In drying''94. Proceedings of 9th International Drying Symposium, Gold Coast, Australia. August 1-4. Vol 13 : 921-928.

Hanna Kowalska and Andrzej Lenart, 2001. Mass exchange during osmotic pretreatment of vegetables: Journal of Food Engineering. Vol. 49 (3): 137-140.

http://timesofindia.indiatimes.com/articleshow/911384.cms

http://www.drgrotte.com/honey-medicine.shtml.

Levi, A., S. Gagel and B. Juven. 1983. Intermediate moisture tropical fruit products for developing countries I. technological data on pappaya. J. Fd. Technol., 18: 667-685.

Marion Bannion and Barbara Scheule. Introductory foods. 11th ed. Prentice Hall, Upper Saddle River, New Jersy.

Mata-Montes De Oca1, M., M. K. Flores-Lopez, B. Tovar-Gomez, and H. S. Garcia, 2001. Effect of osmotic treatment and air drying temperatures on the sensory preference of dried, shredded coconut. Session 88E, Fruit & Vegetable Products: Processing, IFT Annual Meeting - New Orleans, Louisiana.

Nanjundaswamy, A.M., G.Radhakrishaiah Setty, C. Balachandran, S. Saroja nad K.B.S. Murthy Reddy, 1978. Studies on development of new catogaries of dehydrated product from indegenous fruits.Indian Food Packer, 32(1): 91-98.

Pedreschi, F., Segini, S and Dejmek, P, 2004. Evaluation of the texture of fried potatoes. Journal of Texture studies, 35(3): 277-291.

Phanindra Kumar, H.S., Nagaraju, P.K., Radhakrishna, K and Bawa, A.S, 2004. Effect of dehydration techniques on the quality of onion slices. J. Food Sci. Technol., 41(4): 397-400.

Rahman, M. S. and J. Lamb, 1990. Osmotic dehydration of Pineapple. J . Fd. Sci. Technol., 27(3): 150-151.

Ranganna, S. 1995. Handbook of analysis and quality control for fruit and vegetable products. 2nd ed. Tata McGraw-Hill Publishing Co. Ltd. , New Delhi.

Sadashivam, S. and A. Manickam, 1992. Biochemical methods for agricultural sciences. Wiley Eastern Ltd ., New Delhi.

Segini, S.,Dejmek, P and Oste, R, 1999. Reproducible textrure analysis of potato chips. J. Food Sci.., 64(2): 309-312.

Segini, S.,Dejmek, P and Oste, R, 1999.Relationship between instrumental and sensory analysis of texture and colour of potato chips. Journal of Texture studies, 30(6):677-690.

Torregiani, 1993. Applied technology. Osmotic dehydration in fruits and vegetable processing. Food Research International, 26 : 59-68.

Torringa, E., Esveld, E., Scheewe, I., Berg, R and Bartels, P, 2000. Osmotic dehydration as a pretreatment before combined microwave hot air drying of mushrooms. J. Fd. Engg., 49:185-191.

Vennila,P, 1998. Microbial properties of the osmotically dehydrated coconut. Processed Food Industry, Vol. 6(4): 21-22.

Vyas, K. K., R. C. Sharma and V. K. Joshi, 1989. Application of osmotic technique in plum vine fermentation: Effect on Physiochemical and Sensory qualities. J. Fd. Sci. Technol., 26: 126-128.

Wellington, M.C and Badrie, N, 2003. Quality characterstics of osmo dehydrated christopene in syrups. J. Food Sci. Technol., 40(5): 465-467.

APPENDIX I

Water loss of control sample in jaggery solution (56 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	25	-
30	23.5	6
60	23.36	6.56
90	23.65	5.4

Water loss of control sample in sugar solution (56 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	25	-
30	23.54	5.84
60	22.85	8.6
90	22.96	8.16

Water loss of control sample in honey (56 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	25	-
30	24.87	0.52
60	24.54	1.84
90	24.63	1.48

Water loss of blanched sample in jaggery solution(50 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	20	-
30	19.6	2
60	19.5	2.5
90	19.65	1.75

Water loss of blanched sample in sugar solution(50 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	20	-
30	18.1	9.5
60	17.8	11
90	17.83	10.85

Water loss of blanched sample in honey (50 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	20	-
30	19.18	4.1
60	19.12	4.4
90	19.3	3.5

Water loss of treated sample in jaggery solution(53 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	50	-
30	47.89	7.033333
60	45.8	8.4
90	45.97	8.06

Water loss of treated sample in sugar solution(53 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	50	-
30	47	10
60	43.9	12.2
90	44.12	11.7

Water loss of treated sample in honey (53 ^{0}B)

Time (min)	Weight (g)	Water Loss (%)
Initial	50	-
30	48.5	4.8
60	46.5	7.0
90	46.8	6.2

APPENDIX II

Drying data on osmotic dehydration of coconut slices with sugar syrup at 53 ^{0} Brix with osmosis time of 60 minutes

Drying data of control sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture Content (%db)
Initial	50.00	49.00	96.078
After osmosis	46.37	45.02911	81.91448
1	31.47	19.00222	23.46018
2	28.93	11.89077	13.49549
3	28.27	9.833746	10.90624
4	27.98	8.899214	9.768537
5	27.58	7.577955	8.199294
6	27.45	7.140255	7.68929
7	27.2	6.286765	6.708513
8	27.18	6.217807	6.630051

Drying data of blanched sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture Content (%db)
Initial	50.00	49.00	96.078
After osmosis	44.69	42.96263	75.32366
1	32.25	20.96124	26.5202
2	29.96	14.91989	17.53629
3	29.33	13.0924	15.06473
4	29.14	12.52574	14.31934
5	28.95	11.95164	13.57395
6	28.9	11.79931	13.3778
7	28.88	11.73823	13.29933
8	28.7	11.18467	12.59317

Drying data of treated sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture Content (%db)
Initial	50.00	49.00	96.078
After osmosis	45.75	44.28415	79.48215
1	31.26	18.45809	22.63633
2	29.13	12.49571	14.28011
3	28.56	10.7493	12.04394
4	28.2	9.609929	10.63162
5	28.01	8.996787	9.88623
6	27.95	8.801431	9.650843
7	27.8	8.309353	9.062377
8	27.78	8.243341	8.983915

Drying data on osmotic dehydration of coconut slices with Jaggery syrup of concentration 53 ^{0}Brix with osmosis time of 60 minute

Drying data of control sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture Content (%db)
Initial	50	49.00	96.078
After osmosis	45.8	44.34498	79.67831
1	28.07	9.191307	10.12162
2	26.75	4.71028	4.943115
3	26.45	3.62949	3.766183
4	26.33	3.190277	3.29541
5	26.12	2.411945	2.471557
6	26.1	2.337165	2.393095
7	26.08	2.26227	2.314633
8	26.04	2.112135	2.157709

Drying data of blanched sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture Content (%db)
Initial	50.00	49.00	96.078
After osmosis	43.72	41.69716	71.51824
1	28	8.964286	9.846999
2	26.5	3.811321	3.962338
3	26.13	2.449292	2.510789
4	26.08	2.26227	2.314633
5	26.02	2.036895	2.079247
6	26	1.961538	2.000785
7	25.99	1.923817	1.961554
8	25.99	1.923817	1.961554

Drying data of treated sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture content (%db)
Initial	50.00	49.00	96.078
After osmosis	46.25	44.88649	81.4437
1	30.01	15.06165	17.73244
2	28.84	11.61581	13.14241
3	28.5	10.5614	11.80855
4	27.87	8.539648	9.336995
5	27.7	7.978339	8.670067
6	27.5	7.309091	7.885445
7	27.3	6.630037	7.100824
8	26.8	4.88806	5.13927

Drying data on osmotic dehydration of coconut slices with honey of concentration 53 ^{0} Brix with osmosis time of 60 minutes

Drying data of control sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture content (%db)
Initial	50.00	49.00	96.078
After osmosis	46.92	45.67349	84.07219
1	31.77	19.76708	24.63711
2	29.16	12.58573	14.3978
3	28.62	10.93641	12.27933
4	28.04	9.094151	10.00392
5	27.8	8.309353	9.062377
6	27.79	8.276358	9.023146
7	27.77	8.210299	8.944684
8	27.77	8.210299	8.944684

Drying data of blanched sample

Time (hrs)	Weight (g)	Moisture Content (%wb)	Moisture Content (%db)
Initial	50.00	49.00	96.078
After osmosis	47.03	45.80055	84.50373
1	36.02	29.23376	41.31032
2	32.08	20.54239	25.85328
3	31.13	18.11757	22.12632
4	30.82	17.29396	20.91016
5	30.53	16.50835	19.77246
6	29.4	13.29932	15.33935
7	29.25	12.8547	14.75088
8	28.4	10.24648	11.41624

Drying data of treated sample

Time (hrs)	Weight (g)	Moisture content (%wb)	Moisture content (%db)
Initial	50.00	49.00	96.078
After osmosis	44.54	42.77054	74.73519
1	32.9	22.5228	29.07022
2	27.32	6.698389	7.179286
3	28.23	9.705987	10.74931
4	28.12	9.352774	10.31777
5	27.79	8.276358	9.023146
6	27.75	8.144144	8.866222
7	27.73	8.077894	8.78776
8	27.59	7.611453	8.238525

STUDIES ON DEVELOPMENT OF COCONUT CHIPS

BY

BHAVYA E.P

GOVIND RAMACHANDRAN NAIR

SOUMYA MOHAN

ABSTRACT OF THE PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree

BACHELOR OF TECHNOLOGY

IN

AGRICULTURAL ENGINEERING

Faculty of Agricultural Engineering and Technology

Kerala Agricultural University

Department of Post-Harvest Technology and Agricultural Processing

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR - 679 573, MALAPPURAM

KERALA, INDIA

2008

ABSTRACT

A study on development and packaging of coconut chips was conducted in Kelappaji College of Agricultural Engineering and Technology for developing value added product of coconut for prolonging their shelf life and increasing its market value. The study consisted of development of coconut chips from the coconut kernel, standardization of the hypertonic solution for osmotic dehydration, studying the effect of time and concentration of the solution on osmotic dehydration, the drying characteristics of osmotically dehydrated products and the quality analysis and packaging of the coconut chips were done. The coconut chips can be made by osmotically dehydrating the kernel slices of 1mm thickness in a media of 53º Brix for 1 hour and then drying it for six hours in a tray dryer at a temperature of 60º Celsius. Jaggery, was selected as hypertonic solutions on the basis that, the jaggery syrup is much less harmful than the conventional osmotic media sugar syrups for consumption of diabetic patients The quality was quantified objectively and subjectively by sensory evaluation and textural analyser to analyse the colour and textural characteristics respectively of the coconut chips. The coconut chips were packed in aluminium coated plastic foils. The product obtained from jaggery was of superior quality and jaggery solution can be substituted for sugar as hypertonic solution.