# STUDIES ON VACUUM DRYING OF COCONUT

**By**

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## DECLARATION

We hereby declare that this project report entitled "**STUDIES ON VACUUM DRYING OF COCONUT**" is a bonafide record of project done by us during the course of study and that the report has not previously formed the basis for award of any degree, diploma, associate ship, fellowship or other similar title of any other University or Society.

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# CERTIFICATE

Certified that this project report, entitled, "**STUDIES ON VACUUM DRYING OF COCONUT"** is a record of project work done jointly by Anjali.V and Hafisa Hameed under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship, associateship or other similar title of any other University or Society.

**Place: Tavanur**

**Date: 23/1/2014**

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**Hafisa Hameed**

**DEDICATED TO OUR PROFESSION**

## CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF PLATES

## SYMBOLS AND ABBREVIATIONS

| | |
|---|---|
| & | and |
| $^0C$ | degree Celsius |
| % | percentage |
| AOAC | Association of official Analytical chemists |
| cm | centimeter |
| et al. | And other people |
| etc. | Etcetera |
| Fig. | Figure |
| g | gram |
| KCAET | Kelappaji College of Agricultural Engineering and Technology |
| M.C | Moisture content |
| mg | milligram |
| ml | milliitre |
| No. | number |
| Viz | namely |
| wb | Wet basis |
| db | Dry basis |
| $^0N$ | degree north |
| $^0S$ | degree south |
| kg | kilogram |

| | |
|---|---|
| meq | milliequivalent |
| mm | millimetre |
| Hg | Mercury |
| TSS | Total soluble solid |
| N | normal |

# INTRODUCTION

# CHAPTER 1

# INTRODUCTION

Coconut (*Cocos nucifera*) has been part of peoples' diet and livelihoods in the tropical countries of Asia, the Pacific, South and Central America and Africa for thousands of years. In these areas, native meals are cooked with either coconut milk or coconut oil. In the Cook Islands in the South Pacific, particularly Rarotonga Island, slices of fresh, mature coconut kernel are served with fruits after every meal. In India, the use of coconut for food and its applications in the Ayurvedic medicine were documented in Sanskrit 4000 years ago. Records show that in the United States, coconut oil was one of the major sources of dietary fats, aside from dairy and animal fats, prior to the advent of the American edible oil (soybean and corn) industry in the mid-1940s (Dayrit, 2005).

The long history of usage and the diverse studies carried out to characterize and define the composition of the various components of the coconut tree, its fruit and the related products derived from it, established the coconut's uniqueness and superiority among agricultural crops. Every part of the coconut tree and its fruit can be either consumed by humans or animals or converted into other valuable products. If properly utilized, the coconut has the highest economic value among the palm family. This is why the coconut is normally referred to as the Tree of Life, Man's Most Useful Tree, King of the Tropical Flora, Tree of Abundance.

Coconut production in Kerala plays an important role in the state economy and culture of Kerala in southwestern India. Kerala is actually named after the coconut tree with "Kera" meaning coconut tree and "Alam" meaning land so means "Land of Coconut trees'. Various terms like copra and coir are derived from the native Malayalam language. In Kerala, the coconut tree is called as "Kalpa vriksham" which essentially means all parts of a coconut tree are useful some way or other. *Cocos nucifera* dominate the landscape in many parts, rising up to a height of 25 m, and bearing over 50 fruits on average in a year. The trees have many uses; their leaves are used to make sheds, baskets, and doormats, the husk for making coir, the shell for making ladles and spoons, and fruits used for making hair oil or for eating. Coconut is a staple ingredient in many Kerala dishes and coconut oil is widely consumed and used to make drinks such as coconut toddy and dishes such as appam.

Desiccated coconut, coconut milk/cream in liquid and powder form, and coconut oil are the most popular edible commercial products derived from fresh coconut meat (kernel). The meat is very nutritious as it contains dietary fat, dietary fibre, protein, carbohydrates, micro minerals such as potassium and phosphorus, and vitamins such as niacin and riboflavin. Coconut water, which is the liquid inside the coconut fruit, has also been shown to contain micro minerals and nutrients which are essential to human health.

The degree of saturation and length of the carbon chain of the fatty acids comprising a particular fat or oil determines its properties, corresponding uses and its effects on human health. The more saturated the fat and the longer the chain, the harder the fat and the higher the melting point (Fife, 2001). Coconut oil is unique amid fats and oils, as it contains the highest percentage of medium-chain fatty acids (MCFA) with a carbon-chain length of 8 to 12 carbon atoms. MCFA in coconut oil is about 64%, with lauric fatty acid (C12) as the highest ranging from 47 to 53% depending on the coconut variety. The most significant physical property of coconut oil is that unlike most fats, it does not exhibit gradual softening with increasing temperature, but passes rather abruptly from a brittle solid to a liquid within a narrow temperature range. In this respect, it resembles cocoa butter. Coconut oil is liquid at about 27°C or higher and solidifies at about 22°C when it has the consistency of butter in temperate countries. Copra-derived coconut oil has been produced and used commercially for almost a century. As such, its use for edible and inedible applications has already been well established. For edible purposes, coconut oil is generally used as frying and cooking oil because of its excellent resistance to rancidity development. It is also used as a substitute for expensive butterfat in filled milk, filled cheese and ice cream making these products cheaper without changing their palatability. When hydrogenated, coconut oil is used as margarine, shortening and baking fat. Besides other edible application of coconut oil may be summarized as:

• as a source of fat in infant formulas and baby foods because of its easy digestibility and absorbability;

• as a spray oil for crackers, cookies and cereals to enhance flavour, increase shelf-life and impart a glossy appearance;

• as an ingredient in confectionaries such as candy bars, toffee, caramels, etc.

The major inedible use of coconut oil is as a raw material in the manufacture of laundry and bath soaps; as coconut chemicals for production of biodegradable detergents, shampoos, shower gels and other cleaning agents; for cosmetics and toiletries; for foam boosting of non-coconut oil based soaps; for the production of synthetic resins and plasticizers for plastic etc. With the advent of energy crisis in the 1970s, the use of coconut oil and coconut oil-derived coco methyl ester have been successfully used as a diesel fuel substitute.

The common methods involved in the extraction of coconut oil are dry process, solvent extraction process, and wet process.

In dry process, oil is extracted by drying the coconut. A number of drying techniques have been developed over the years. The most commonly used method is sun drying. It has its own seasonal limitations along with low quality oil production. The drying method should be consistent with the characteristics of the products and socio-economic considerations.

During wet season the industries use fossil fuels for drying which produces low quality coconut oil. To reduce the use of fossil fuel, electrical energy is an alternate source of energy for drying applications especially where electricity is generated by a renewable source such as hydro or wind power.

Drying of coconut greatly affects the quality of oil produced. Researches are to be carried out to explore the possibility of employing drying techniques for easy, economic and efficient processing to minimize the nutrient and the flavor losses, thus yielding high quality oil. Based on the above facts, an investigation was undertaken with the following objectives:

1. To conduct studies on vacuum drying of fresh grated coconut kernel.
2. To study the quality of the vacuum dried coconut kernel.

# REVIEW OF LITERATURE

# CHAPTER 2
# REVIEW OF LITERATURE

This chapter outlines a brief review on the origin, composition of coconut, oil characteristics and drying methods.

## 2.1 Coconut.

### *2.1.1 Origin.*

The Coconut Palm is one of man's most useful plants. The heavy crown of long flowing fronds and gently curved trunks lend a tropical effect to any landscape setting in which they can grow. A beautiful street tree, Coconut Palm is also ideal as a background tree, framing tree, or as a striking freestanding specimen (Gilman *et al*., 1993). The coconut palm was first grown as a plantation crop in the 1840's (Child, 1974).

South East Asian region, comprising of Malayan peninsulas, Java, Sumatra, Borneo, Philippines and Papua New Guinea are believed to be the origin of coconut. Ninety percent of worlds acreage lies in the zone $20^o$ N and $20^o$ S Latitude, where the six primary areas Philippines, India, Indonesia, Ceylon, South Sea Islands and Malaysia are situated. They are grown within a few degrees of equator within 600 feet of mean sea level, on the loose sandy soil, with higher mean temperature and relative humidity (Bawalan, 2006).

### *2.1.2 General Information.*

**Plate No. 2.1 Coconut tree**

Gilman *et al*. (1993) reported the following descriptions about coconut tree.

Scientific name: *Cocos nucifera*

Common name(s): Coconut Palm

Family: *Arecaceae*

Height: 50 to 60 feet

Spread: 15 to 25 feet

Fruit shape: oval; round

Fruit length: 6 to 12 inches

Fruit covering: dry or hard

Fruit color: brown; green; yellow

Fruit characteristics: does not attract wildlife; suited for human consumption; fruit, twigs, or foliage cause significant litter; persistent on the tree; showy.

### *2.1.3 Production.*

*Indonesia* and the *Philippines* are the first and the second largest coconut producing country in the world. India is the third largest coconut producing country having an area of about 1.78 million hectares under the crop. Annual production is about 7562 million nuts with an average of 5295 nuts per hectare (Perera, 2012).

The major coconut growing states in India are Kerala, Tamilnadu, Karnataka, West Bengal, Maharashtra, Orissa, Assam, Goa, Daman and Diu, Lakshadeep, Gujarat. Kerala tops in production accounting 39 percent of total production in the country (Gopala Krishna, 2010).India ranks third largest coconut producing country (area, 15.5%; coconut production, 21%) in the world. It annually produces 14.81 billion nuts from an area of 1.93 million ha (Ayyappan *et al.*, 2010).

***2.1.4 Uses.***

Coconut is a product having multifarious utility. It is noticeable that almost all the parts of freshly grown coconut, eatable coconut or dried are used in some or the other manner. Gopala Krishna (2010) reported the following uses of coconut.

1) Coconut water or milk is an excellent natural soft drink for all. It is useful for diabetics and heart patients. It is very useful to people suffering from diarrhea and vomiting. It helps in increasing blood circulation in the kidneys.

2) Oil is extracted from dry copra. Copra contains about 65 to 75 percent oil. Copra is also used in the preparation and decoration of cakes. Sweets such as Ladoo, Barfi etc are prepared from it.

3) The unopened spathe is tapped for toddy. This toddy can be converted into jaggery, vinegar and sugar.

4) Kernel (wet meat) is mainly used in making curries, chutney, toffee, sweet and for other cooking purposes.

5) Coir, the fibrous husk of the coconut, is used in a surprisingly large number of ways. Ropes and yarns, aquarium filters, car seat covers, flower pots, soundproofing, mulch for plant growing, heat insulation, brushes, bristles, mattresses, door mats and matting, rugs, carpets etc.

6) Leaves are used for making thatch, jhaps and for other purposes while leaflets are collected and composted.

7) Coir pith (or) coir dust is used as a soil conditioner (manure).

8) Midribs and leaf petioles are used for making brooms.

9) Inflorescence bunk stalk, stipules and dried spathe are used for warming water or for cooking purpose.

10) Coconut shell is used for making fancy items, households utensils etc.

11) Decoction obtained from roots is used as mouthwash and gargle.

12) Coconut oil is one of the most important edible oil for domestic use. It has also some medicinal value (as it prevents skin diseases like Eczema).

**2.2 Copra.**

Copra, the dried kernel is the chief commercial product from coconut, which is mainly used for oil extraction. Copra normally has an oil content varying from 65 to 72 per cent. Two types of copra namely milling and edible are made in India. Milling copra is used to extract oil while edible grade of copra is consumed as a dry fruit and used for religious purposes. Milling copra is generally manufactured by adopting sun drying and artificial means. Substantial quantity of milling copra is manufactured using modern hot air driers resulting in the availability of superior quality copra, which is required for the manufacture of best grade coconut oil. A good number of farmers′ co-operative societies are also involved in the manufacture and marketing of milling copra. Milling copra is available in different grades. Edible copra is made in the form of balls and cups. Different grades of edible copra are available in the market according to the size, colour etc ( Gopala Krishna, 2010).

**Plate No. 2.2 Copra**

**2.3 Coconut oil.**

Coconut oil is produced by crushing copra, the dried kernel, which contains about 60-65% of the oil. The oil has the natural sweet taste of coconut and contains 92% of saturated fatty acids (in the form of triglycerides), most of them (about 70%) are lower chain saturated fatty acids known as medium chain fatty acids (MCFAs). MCFAs are not common to different vegetable oils with lauric acid at 45- 56%. Various fractions of coconut oil have medium chain triglycerides and are excellent solvent for flavours, essences, emulsifiers etc. These fatty acids are used in the preparation of emulsifiers, as drugs and also in cosmetics (Bhatnagar *et al*.,2010).

Arumugham *et al.* (1984) discussed the commercial and economic importance of coconut. They have envisaged developing process know-how for the products like coconut milk, coconut milk powder, coconut gratings, etc. The extraction of coconut milk has been standardized. From 500g nut 250 g of kernel can be recovered. From this 250g of kernel 150g of milk and 60g of oil can be recovered. The extraction of coconut milk has been standardized and a material balance for domestic processing of coconut has been worked out.

Rossell *et al.* (1985) stressed the need for maintaining the purity of palm oil and other vegetable oils in the international trade. The characteristic fatty acid content for palm and coconut oil was separated out. From the various samples of palm oil and coconut oil tested the palmitic acid content was very high in Malaysian palm oils in the range of 43.1 per cent to 45.3 per cent and it was reported that the level of palmitic acid varies with the geographical origin. The lauric acid was in the range of 45.9 to 50.3 per cent for coconut oils when all origins are considered.

Knaut *et al.* (1985) have made an attempt to determine the importance of palm and lauric oil in the coming decades. The products obtained from such oils like the soaps and other oleo chemicals and their value have been discussed.

### *2.3.1 Composition.*

Coconut oil contains a high proportion of glycerides of lower chain fatty acids. The oil is highly stable towards atmospheric oxidation. The oil is characterized by a low iodine value, high saponification value, and high saturated fatty acids content and is a liquid at room temperature of 27°C (Dayrit, C.S, 2003). The composition of coconut oil is given in table 2.1.

**Table 2.1 Composition of coconut oil**

| | Virgin coconut oil from wet coconut | Unrefined coconut oil from copra | Refined coconut oil |
|---|---|---|---|
| Appearance | Colourless | Slight brownish | Colourless |
| Odour | Coconut smell | Coconut smell | Odourless |
| Melting point $^{0}$C | 24 | 24 | 24 |
| Moisture (%) | <0.1 | <0.1 | <0.1 |
| Iodine value (cg12/g) | 12-15 | 12-15 | 10-12 |
| Peroxide value | 0-1 | 0-1 | 0-1 |
| Saponification value (mg KOH/g) | 245-255 | 245-255 | 250-255 |
| Phospholipids (%) | 0.1 | 0.1 | 0.0 |
| Unsaponifiable matter (%) | _ | 0.42% | 0.19% |
| Tocopherols mg/kg | 150-200 | 150-200 | 4-100 |
| Phytosterols mg/kg | | 400-1200 | |
| Total phenolics mg/kg | 640 | 618 | 20 |
| Saturates | 92.0 | 92.0 | 92.0 |
| Monounsaturates | 6.0 | 6.0 | 6.0 |

| | | | |
|---|---|---|---|
| Poly unsaturates | 2.0 | 2.0 | 2.0 |

(Source : Dayrit, C.S, 2003)

### *2.3.2 Coconut oil health properties.*

Bruce Fit (2000) reported that coconut oil melts at 24°C (76°F), so a jar may be liquid or solid depending on the room temperature. It is heat stable, making it suitable for cooking at high temperatures, slow to oxidise and has a shelf life of several years. It is antimicrobial. Destroys bacteria, fungi and protozoa. It Works as a powerful antibiotic and anti-fungal and antiviral. There are no pharmaceutical medications that can effectively kill viruses. Some viral infections can linger on in the body indefinitely. For example, an infection with herpes or hepatitis C is with you for life. MCFAs offer a natural, harmless method controlling these troublemakers and letting you live a normal life. Because MCTs are so easily digested, they help with the absorption of other nutrients as well. Studies show that MCTs enhance the absorption of minerals (particularly calcium and magnesium), B vitamins, the fat-soluble vitamins (A, D, E, K, and beta-carotene), and other nutrients. Coconut is a good antioxidant. Coconut oil provides a small reduction of about 20% of ultraviolet exposure. It provides a precursor for creation of vitamin D, which is made from the action of sunlight on cholesterol in the skin. Another reason why it may be a good sunscreen.

### *2.3.3 Digestive benefits.*

Verghese (1952) quotes that “Any fat that melts at the temperature of the digestive tract is easily absorbed and digested by the digestive system”. So coconut oil which melts about 23 to 26$^{o}$C (i.e. less than the body temperature) is readily digested.

Thampan (1993) gave the following values for the percentage of digestibility of coconut oil compared to other fats:

**Table 2.2 Percentage digestibility of different oils**

| Type oil | Digestibility |
|---|---|
| Coconut oil | 99.3 |
| Seasame oil | 95.8 |
| Mustard oil | 94.1 |

Banzon and Resurreccian (1974) has compared the properties of coconut oil compared to other oils such as soybean oil. The important properties and unique features of coconut oil and the health benefits obtained by the consumption of coconut oil were justified. It was reported that the people who consume coconut oil was very healthier than those who consume soybean oil because the coconut oil contains the right amount of PUFA and the excess PUFA present in the soybean oil will be excreted with other impurities.

## 2.4 Common Methods of Extraction of oil.

The methods by which a particular oil seeds are extracted depend on the type of seed, the seed characteristics and oil content of the seed (FAO 1992; Lawson 1999; Iwe 2003). Some of the common methods involved in the extraction of coconut oil are as follows

1. Dry process
    - Expeller method
    - Screw press method
    - Ghani method
    - Solvent extraction method
2. Wet process
    - Dessicated coconut method
    - Grated coconut method
    - Low pressure oil extraction method or intermediate moisture content method
    - Traditional wet process
    - Fermentation method
    - Bawalan – Masa method
    - CFTRI method/Krauss Maffei method
    - Texas A and M University Process
    - TPI process
    - Modified solvol process

### *2.4.1 Dry Processing of Coconut.*

Verghese *et al.* (1955) studied the quantity and the quality of ball copra obtained in relation to the age, size and shape of the nuts. All the nuts were examined for weight, water content, condition of the husk and the presence and absence of perianth lobes. The observations were carried out for 36 weeks. From the observations made he has concluded that small sized round nuts 11 to 14 months old are preferable for making ball copra. It was reported that the volume to be 279 to 382 cc, weight to be 191 g, height to be 8.68 to be 11.67 cm, diameter to be 7.57 cm and thickness to be 0.87 cm of the ball copra respectively.

Rajasekharan *et al.* (1961) has conducted some preliminary studies on the mechanical drying of coconuts. They have plotted the drying rate with the moisture ratio and the relative humidity with that of the per cent moisture, and drying time with moisture ratio and optimized the drying conditions for proper drying of the coconuts. He has shown the drying of coconuts at four different temperatures 70, 65, 60, $55^0$C and found that the quality of copra was good at $55^0$C dried for 21.5 hours and the free fatty acid was in the range of 0.14 per cent. He has plotted the relationships between various parameters.

Baltasar (1992) has discussed the extraction of oil from copra by means of mechanical screw press or the combination of expeller and solvent processes. One phase was concerned with the mechanics of oil extraction, while the other concerns the chemistry of oil extraction. The various steps in the extraction of coconut oil by expeller process were discussed. The processes include feeding the material to the mill at a uniform rate, cleaning thoroughly, weighing, magnetic separation, crushing, grinding, cracking, handling and filtering of crude oil, cooling the oil.

Gopalakrishnan *et al.* (1987) has analyzed the coconut cake obtained from expeller after extraction. They have examined the primary extracted coconut oils with their respective cake oils and the fatty acid composition of both the oils were studied and compared.

#### *2.4.1.1 Expeller method.*

During the process of mechanical expression the oil seeds are compressed in various types of compression devices/equipments. There are two steps involved in the expulsion of oil through the expeller.

a) Disintegration

b) Pressing

Under disintegration process, the oil globules are separated. The tough membrane surrounding the oil droplets exposed and burst under pressure enabling the oil to ooze out (Sahay and Singh, 1994).

The procees of mechanical expulsion of coconut oil includes cracking of coconut shells, separation of coconut meat and producing desired sized flakes. The thin flakes of coconut meat are cooked by heating them at an elevated temperature for 90 minutes. Then the oil is expelled whose free fatty acid value ranging from 0.3 to 0.4 (Chakraverty, 1995)

#### *2.4.1.2 Solvent extraction.*

Cancel *et al.* (1976) has standardized conditions for coconut oil extraction from coconut milk press-cake. Gonzalez *et al.* (1973) studied the solvent extraction of residual oil from wet coconut meal using isopropanol. Bernardini (1970) has described a new single solvent direct extraction process (by CMB, Pomezia) which obviates the need for pressing. Aliwalas and Buccat (1970) studied the filtration-extraction of granulated coconut on a bench scale. Claudio *et al.* (1968) carried out laboratory scale studies on the preparation of highly nutritious coconut flour from granulated coconut. Preliminary feeding experiment indicate a PER comparable with casein. Prepared foods (cakes, doughnuts, cookies, pastries) with 20-30% wheat flour replaced by coconut flour obtained high taste rating.

Ghosh (1953) has explained the solvent extraction of oils and the unit operations involved in such extraction processes. He has given the mathematical equation that governs the extraction process using solvents.

Murti (1965) has described the extraction of fats with solvents, the most efficient method of obtaining oils and fats from the oil-bearing materials. The complete process of solvent extraction involves the study of the unit operations namely, material handling, size reduction, size separation, drying, flow of fluids, heat transfer, extraction, evaporation, stripping, filtration and sometimes absorption, which has been explained by the author.

The advantages of solvent extraction over other methods of oil expression include higher oil yield, larger processing capacity, solvent extraction also gave oil that may considered to be of superior bleaching quality, lower refining losses, reduced susceptibility to rancidity and better retention of fat-soluble vitamins (Robbellen *et al*, 1989; Goss,2004).

## 2.5 Drying.

Drying is one of the man's oldest methods of food preservation and is the most widely used technique. During drying, two processes take place simultaneously such as heat transfer to the product from the heating source and mass transfer of moisture from the interior of the product to its surface and from the surface to the surrounding air. The basic essence of drying is to reduce the moisture content of the product to a level that prevents deterioration within a certain period of time, normally regarded as "the safe storage period" as reported by Woodruff and Luh (1986). Although the origin of dehydration goes back to antiquity there is continuous interest in technological improvements in this process. Of many methods of dehydration, freeze drying, vacuum drying and microwave drying are considered to give better quality products than the other methods of dehydration like sun drying or hot air drying. Among these methods, microwave drying and freeze drying are not commonly used due to the fact that the equipments are very expensive and should be custom designed for specific food applications (Rao, 1995; Tulasidas and Raghavan, 1995). Whereas vacuum drying could be used for most of the food drying operations where high quality is desired (Singh and Heldman, 2009).

Sahay and Singh (1994) reported that when drying foods, the key is to remove moisture as quickly as possible at a temperature that does not seriously affect the flavour, texture and colour of the food. If the temperature is too low in the beginning, microorganism may survive and even grow before the food is adequately dried.

### *2.5.1 Solar drying of coconut.*

There are several methods and practices in drying the coconut kernel or in making copra. The methods vary from that which is considered primitive and traditional to one that adheres to certain scientific principles of drying. The three common methods of drying are sun drying or solar drying, kiln drying which is either direct or semi-direct drying and indirect drying using hot-air dryers (Sukanya, *et al.,* 1995).

Various investigations have shown that solar drying can be an effective means of food preservation since the product is completely protected during drying against rain, dust, insects and animals (Vega-Mercado,2001). But still some obstacles have to be overcome that solar drying will become a technology with a broad dissemination. Although a lot of research work has been conducted during the last decades, only a small number of appropriate solar dryers which can be used by farmers or small scale industries in developing countries are commercially available. Furthermore, there is still a lack of knowledge on how to process fruits, vegetable, fish, etc. in a proper way to ensure a high quality product and to minimize post-harvest losses (Maskan M, 2001).

In direct radiation drying, part of the solar radiation may penetrate the material and be absorbed within the product itself, thereby generating heat in the interior of the product as well as at its surface, and thereby enhancing heat transfer (Hall, 1980). During drying, there is a tendency of the food to form dry surface layers which are impervious to subsequent moisture transfer, if the drying rate is very rapid. To avoid this effect, the heat transfer and evaporation rates must be closely controlled to guarantee optimum drying rates (Nair, 1994).

During monsoon, drying by artificial method is the only solution for copra making. The direct-type kiln dryers are not desirable, as the copra becomes inferior in quality due to the smoking and improper drying. The production of copra using the solar tunnel dryer is an improved and effective method, which addresses the drawbacks associated with open sun drying and kiln-drying (Ayyappan *et al.,* 2010).

### *2.5.2 Vacuum drying.*

The main aim of creating vacuum during drying is to enable the removal of moisture at lower temperature than the boiling point under ambient condition. Water boils at 100ºC under standard atmospheric pressure (1.013 bar), but if the pressure is reduced or the vacuum is created to 40 mbar, the boiling temperature will be reduced to 29ºC (Moran and Shapiro, 1996).

The important feature of vacuum drying is the exclusion of air during drying, which makes this process more attractive for drying food materials that may deteriorate or chemically modified due to air or exposure to high temperature. The lower pressure (vacuum) in the system allows the use of lower drying temperature in order to achieve similar moisture content of the end product with other drying methods. The drying system that has vacuum application consists of four main components such as vacuum chamber, vacuum pump, heat supply and a device to collect condensed water vapour. Vacuum treatment is useful in combination with other processes to get a good final end product. Obvious advantages of combining vacuum with other drying processes have guided many scientists to work on food drying experiments. Since, the product temperature is lower compared to other drying methods; drying time will be reduced as a result the final quality of the product will be better (Long Wu *et al.*, 2007).

Many scientists have contributed in the vacuum application to food drying and combining with other systems like microwave and freeze drying. Among them, Fernando and Thangavel (1987) reported that the quality of vacuum dried coconut was superior to the conventionally dried products. Similarly, the vacuum dried celery was better in quality compared to hot air dried ones (Madamba *et al.*, 2001).

Combination of microwave heating and vacuum drying resulted in the accelerated drying rate of model fruit gels (Drouzas *et al.*, 1999). Further, they reported that the experimental pectin gel with 38.4% moisture content was dried to less than 3% moisture in four minutes and the colour of the dried gel was better compared to air drying. Similar combination method was used by Mousa and Farid (2002) for drying banana slices with microwave under vacuum. They concluded that thermal and drying efficiencies were almost 100% at the beginning of the drying process, but decreased with reduction in the moisture content and the effect of vacuum was particularly important to attain low moisture values in food products. Also Sunjka and Geyer (2003) reported that the combination method could increase the drying rate of cranberries and guava fruit, respectively.

Kumar *et al.* (2011) reported that vacuum dried curry leaves exhibit higher quality and longer shelf life. Curry leaves took 2.5 to 3 hours to attain final moisture content of 4%, at a vacuum of 600 mm of Hg (gauge). Blanched curry leaves dried at 600 mm of Hg, $36^0$C retained more colour, texture and flavour than the unblanched ones.

# MATERIALS AND METHODS

# CHAPTER 3

## MATERIALS AND METHODS

This chapter deals with the materials used and the methods adopted for the various drying methods, packaging, oil extraction and qualitative analysis of oil extracted.

### 3.1 Grating of coconut.

The coconuts were brought from the local market of Tavanur, Malappuram district. They were dehusked, splitted and were manually grated with help of domestic grater.

### 3.2 Drying.

In this study in order to assess the drying quality of conventional and vacuum drying, methods such as sun drying and vacuum drying of grated coconut were carried out for comparison.

#### 3.2.1 *Sun drying.*

Grated coconuts were spread uniformly over a tray with a minimum thickness of 0.5 cm. The trays were then kept on clean concreted yard with full sunshine throughout the day. Sun drying was carried out as a control.

#### *3.2.2 Vacuum drying.*

A vacuum tray drier with digital display cum controller was used for the study. The grated coconuts were spread on stainless steel tray and were kept inside the vacuum drier for various time, temperature and vacuum. Commercial type of tray dryer essentially consist of a drying chamber fitted with stainless steel hollow flat trays, vacuum system consisting of water ring vacuum pump and hot water system to provide heating medium which circulates through the hollow trays inside the drying chamber.

Degree of vacuum in the drying chamber was adjusted by varying the flow of water through vacuum pump. The chamber temperature was controlled by temperature of heating medium flowing through the hollow trays. The desired temperature of hot water was set by switching on the required number of electrical heaters. The samples were allowed to dry on the hollow trays inside the vacuum chamber at predetermined vacuum and temperature levels.

Drying trials were conducted at three levels of vacuum of 510, 600 and 640 mm of Hg (gauge).Two levels of chamber temperatures such as were 40 and 50 °C were used. Three replications were done for these vacuum-temperature combinations. Practical limitations in the equipment restricted to these temperature limits for functioning and operation of the system. Fresh grated coconut samples of known weight were spread on the trays of vacuum tray dryer for drying studies.

The drying trials were conducted till the samples attained the desired final moisture level of 5-7%. At the end of each trial, the vacuum was broken and allowed to stand and stabilize for 10 minutes. The dried samples were then taken out and transferred to desiccators for stabilization. The final weight of dried sample was recorded. The final moisture content was then determined using standard techniques and was expressed as moisture on wet basis (AOAC,2002).The dried sample were then used for oil extraction.

**Plate No.3.1 Grated coconut**

**Plate No.3.2 Sun dried coconut kernel grates**


**Plate No.3.3 Vacuum dryer**

### 3.3 Oil extraction.

Oil from the dried coconut was extracted using solvent extraction method. Normal hexane was the solvent used in soxhlet apparatus for oil extraction. Fifty gram sample were taken in the soxhlet apparatus and the extraction was carried out for three hours.

**Plate No.3.4 Soxhlet apparatus**

### 3.4 Qualitative analysis of oil extracted from sun dried and vacuum dried coconut.

Oil content of the dried coconut kernel, acid value, Iodine value, rancidity and peroxide value of oil extracted were estimated as per the procedure mentioned by Sadasivam *et al.*, (1996).

#### *3.4.1 Moisture content.*

Moisture content of the coconut kernels were determined by oven drying as per AOAC (1984) method. The samples were kept in the oven at 130±2 $^{o}$C for 1 hour. Weight of samples before (w1) and after (w2) drying was noted.

Moisture (% db) = $\frac{(w1-w2)}{w2}$×100

where,

w1=weight of sample before drying

w2=weight of sample after drying

***3.4.2 Oil content.***

Oil content of both sun dried and vacuum dried coconut were determined by extracting the oil by soxhlet apparatus.

Fifty gram dried grated coconut were placed in the filter paper, sealed and placed in the butt tubes of the soxhlet apparatus. Extraction was carried out using n-hexane as solvent for 3 hours without interruption by gentle heating. After cooling, the flask was dismantled and hexane was evaporated until no odour of hexane remained. The oil was cooled and washed. The oil obtained from dried grated coconut is obtained as,

Oil in dried sample % $= \frac{\text{Weight of oil (g)}}{\text{Weight of sample(g)}} \times 100$

***3.4.3 Acid value.***

A small quantity of free fatty acids is usually present in oils along with the tryglycerides. The free fatty acid content is known as acid number/acid value. It increases during storage. The keeping quality of oil therefore relies upon the free fatty acid content.

The neutral solvent was prepared by mixing 25 ml ether, 25 ml 95% ethanol and 1 ml of 1% phenolphthalein solution and neutralized with N/10 alkali. Five gram of oil was dissolved in 50ml of neutral solvent in a 250ml conical flask. A few drops of phenolphthalein are added. After titrating the contents against 0.1N potassium hydroxide, it was shaken constantly until a pink colour which persists for fifteen seconds is obtained.

Calculation

Acid value (mg KOH/g) $= \frac{\text{Titre value} \times \text{Normality of KOH} \times 56.1}{\text{Weight of the sample(g)}}$

***3.4.4 Iodine value.***

The iodine value is a measure of the degree of unsaturation in an oil. It is constant for particular oil or fat. Iodine value is a useful parameter in studying oxidative rancidity of oils since higher the unsaturation the greater the possibility of the oils to go rancid.

Five gram of oil was dissolved in 10 ml of chloroform in conical flask. Twenty five milliliters of Hanus iodine solution was added and mixed well and allowed to stand in dark for exactly 30 minutes with occasional shaking. Then 10 ml of 15% KI was added and shook thoroughly and 100 ml of freshly boiled and cooled water was added to wash down any free iodine on the stopper. The sample was titrated against 0.1N sodium thiosulphate until yellow solution turned almost colourless. A few drops of starch indicator was added and titrated until the blue colour completely disappeared. A blank was run without the sample.

Calculation

$$\text{Iodine No.} = \frac{\text{equivalent weight of iodine} \times \text{vol. of } Na2S2O3 \text{ used} \times \text{N of } Na2S2O3 \times 100}{\text{Weight of sample (g)} \times 1000}$$

Where,

Equivalent weight of iodine=127

Normality of sodium thiosulphate=0.1

Volume of sodium thiosulphate used= [blank-test], ml.

***3.4.5 Rancidity.***

Kreis Kerr test was used to find the presence of aldehydes and ketones in fats and oils created by its rancidity. The term rancidity is used to describe the development of bad flavours and odours in fats and oils. It may result either from hydrolysis of the triacyl glycerol present in fats and oils or from oxidation of the unsaturated fatty acids present in triacyl glycerols.The former cause may be detected by an increase in the acid value of the sample. Auto oxidation of fatty acid double bonds occurs by reaction with molecular oxygen present in the atmosphere, causing the formation of labette peroxides.

The peroxides formed during auto oxidation are unstable and decompose in to free radicals. These initiate the chain reactions which lead eventually to decomposition of fatty acids in to various low molecular weight aldehydes and ketones.

Aldehydes and ketones react with Floroglucinol developing a red colour. Concentrated HCl was added to 1 ml of sample. Two milliliters of Floroglucinol was then added to it. A red colour will develop if the oil is rancid.

***3.4.6 Peroxide test.***

Peroxide value is a measure of peroxides contained in the oil. The peroxides present were determined by titration against thiosulphate in the presence of KI. Starch was used as indicator.

One gram of powdered potassium iodide and 20 ml of solvent mixture (2 volumes of glacial acetic acid with 1 volume of chloroform) were added to one gram of oil in a clean dry boiling tube. The tube was placed in boiling water for 30 seconds. The contents were transferred quickly to a conical flask containing 20 ml of 5% KI solution. The tube was washed twice with 25 ml of water each time and was collected into a conical flask. Then it was titrated against N/500 sodium thiosulphate solution until yellow colour disappeared. 0.5 ml of starch was added and thoroughly mixed. Again it was titrated carefully till the blue colour just disappeared.

Calculation

Peroxide value (meq peroxide/kg sample) $= \frac{S \times N \times 1000}{\text{g sample}}$

Where,

S=ml $Na_2S_2O_3$.

N= Normailty of $Na_2S_2O_3$.

# RESULTS AND DISCUSSION

# CHAPTER 4

# RESULTS AND DISCUSSION

In this chapter results of the studies on vacuum drying of coconut are discussed. The results of the quality of the dried kernel and extracted oil from the vacuum dried coconut are also presented.

### 4.1 Drying studies of coconut.

Drying studies were conducted at designated levels of vacuum and drying chamber temperature. As indicated earlier, studies were conducted at temperatures of 40°C and 50°C and three levels of vacuum of 510, 600 and 640 mm of Hg (gauge). The drying time required to reach a final moisture content of 5-7 % (db) are presented in table 4.1.

**Table 4.1 Drying time at different pressure and temperature levels.**

| Sample | Pressure (mm Hg) | Temperature (°C) | Time (min) |
|---|---|---|---|
| A1 | 640 | 50 | 150 |
| A2 | 640 | 40 | 180 |
| B1 | 600 | 50 | 180 |
| B2 | 600 | 40 | 210 |
| C1 | 510 | 50 | 210 |
| C2 | 510 | 40 | 240 |
| Sun dried | - | - | 540 |

The drying behavior of grated coconut was then plotted (Fig.4.1). Weight loss at an interval of 30 minutes was recorded and corresponding moisture content during the regime is shown.

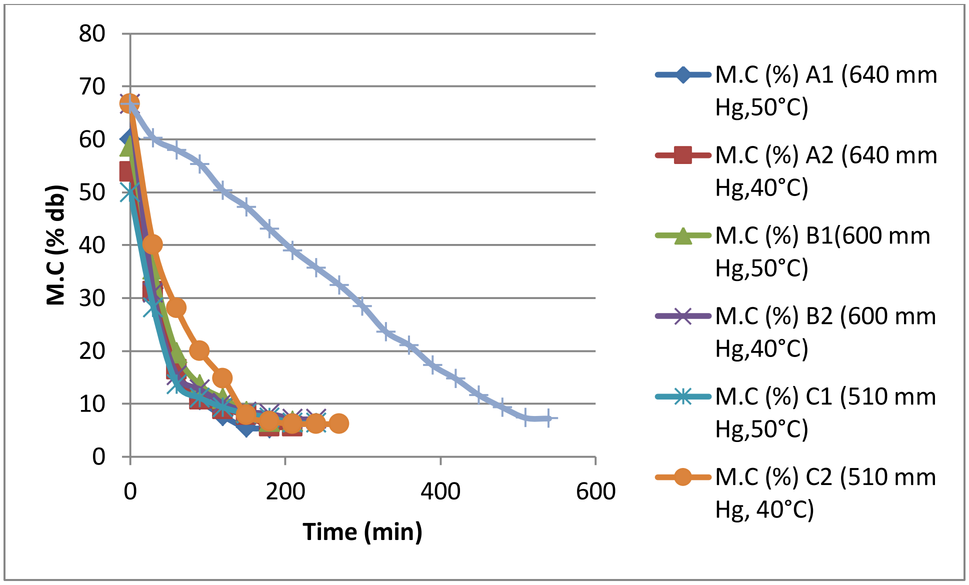


**Figure 4.1 Drying curve for vacuum drying of coconut**

It may be observed from the Fig. that except the sample treated at 510 mm Hg (gauge) and $40^0$ C temperature, all the other curves shows similar drying behavior whereas the sample C2 shows slow drying rate and it took 240 minutes to reach a moisture content of 5-7 % (db). All other samples in general took 100-150 minutes only to reach the same level and the drying rate was faster. With increase in vacuum level and temperature, the drying time to reach predetermined moisture content was found to decrease. With reduction in pressure, the vaporization temperature of water is reduced and with increase in temperature, the vaporization at that particular pressure level is increased; which could be the reason for the decrease in drying time. As may be seen from the table 4.1, the minimum drying time was obtained for samples with maximum vacuum level and highest temperature among the variables chosen, which was found to be150 minutes. The data obtained for sun drying of the kernel were also plotted and it may be observed from the Fig. that the drying rate was slower than all the vacuum drying trials and the drying time to reach the predetermined level of 5-7 % (db) was 540 minutes.

**4.2 Oil extraction.**

Oil from the dried coconut was extracted using solvent extraction method using soxhlet apparatus as described in chapter 3.

### *4.2.1 Oil content.*

It was found that the oil vacuum dried samples were higher than in sun dried sample. The results were presented in table 4.2.

**Table 4.2 Oil content of vacuum dried coconut kernel**

| Sample | Oil content (%) |
|---|---|
| A1 | 64 |
| A2 | 63 |
| B1 | 62 |
| B2 | 61.5 |
| C1 | 61 |
| C2 | 60.5 |
| Sun dried | 60 |

It may revealed from the table that samples dried at highest vacuum level of 640 mm Hg (gauge) and temperature of $50^0$C was found to possess maximum oil content of 64%.With decrease in vacuum level and decrease in temperature, the oil content was found to decrease. It may also be pointed out that the oil content in sun drying method was minimum of all the other treatments i.e. 60%. With increase in vacuum levels, the moisture gets evaporated from the cellular and intercellular spaces which open up the existing capillary pathways or form new capillary pathways through which oil can flow out easily. This phenomenon may not occur in sun drying since it is a non-uniform drying.

Also higher the temperature, lower the viscosity of the oil and therefore the oil could easily flow out through the capillary pores already formed during the vacuum drying process.

### 4.3 Quality characteristics of oil extracted from sun dried and vacuum dried coconut.

Quantitative analysis of quality characteristics of dried coconut and the extracted coconut oil were carried out as described in chapter 3.


**Plate No. 4.1 Extracted oil**

### *4.3.1 Acid value.*

Acid values of vacuum dried and sun dried samples were determined as described in chapter 3 and the results are presented in table 4.3.

**Table 4.3 Acid value of the oil extracted from vacuum dried coconut kernel**

| Sample | Acid value |
|---|---|
| A1 | 0.34 |
| A2 | 0.34 |
| B1 | 0.45 |
| B2 | 0.56 |
| C1 | 0.561 |
| C2 | 0.67 |
| Sun dried | 1.12 |

The acid value of the oil extracted from vacuum dried samples ranged between 0.34 to 0.67 and that of sun dried kernel oil was 1.12. In general, the acid values increased with decrease in vacuum levels and decrease in temperature. The minimum acid value of 0.34 was observed for samples treated at a vacuum level of 640 mm of Hg and chamber temperature of $50^0$C.

The presence of more free fatty acids along with the triglycerides indicate the low keeping quality of oil, therefore acid value is a good judgment factor in determining the quality of oil. In this study, the acid value of vacuum treated sample at 640 mm of Hg (gauge) and $50^0$C shows minimum acid value indicating the higher quality factor. This implies that the storage life would be maximum for this sample if other parameters are maintained.

### *4.3.2 Iodine value.*

The table 4.4 gives the results for iodine test conducted for the oil extracted from vacuum dried and sun dried samples.

**Table 4.4 Iodine value of oil extracted from vacuum dried coconut kernel**

| Sample | Iodine value |
|---|---|
| A1 | 7.52 |
| A2 | 7.62 |
| B1 | 7.62 |
| B2 | 7.88 |
| C1 | 8.13 |
| C2 | 8.23 |
| Sun dried | 8.64 |

It may be revealed from the table that the iodine value of oil extracted from vacuum dried sample ranged between 7.52 to 8.23 and that of sun dried kernel oil was 8.64. In general, the iodine values increased with decrease in vacuum level and decrease in temperature. The minimum iodine value of 7.52 was observed for samples treated at higher vacuum level of 640 mm of Hg (gauge).

High degree of unsaturation indicates that the oil has undergone oxidative rancidity which imparts off-flavour and odour. Therefore the iodine value is a good judgment factor in determining the quality of the oil. In this study, the iodine value of vacuum treated samples at 510 mm of Hg (gauge) has greater possibility to go rancid than those samples treated at 640 mm of Hg (gauge).

### *4.3.3 Rancidity.*

Kreis Kerr test gave negative results indicating the absence of aldehydes and ketones, which are created by rancidity. Rancidity may be resulted either from hydrolysis of the triacylglycerols present in fats and oils or from oxidation of the unsaturated fatty acids present in triacylglycerols. Since the samples tested were freshly prepared, decomposition of fatty acids into various low molecular weight aldehydes and ketones were less.

### *4.3.4 Peroxide test.*

Since the oil samples were not rancid, degree of peroxide formation was nil. It indicates that proper storage prevented the action of air or microorganisms (ketonic rancidity) in oil.

## 4.4 Optimisation of the process parameters.

From the studies it may be concluded that a vacuum level of 640 mm of Hg (gauge) and a chamber temperature of 50°C may be chosen as optimum operating conditions for the vacuum drying of grated coconut.

# SUMMARY AND CONCLUSION

# CHAPTER 5

## SUMMARY AND CONCLUSION

The coconut oil is widely used all over the world for different purposes. They impart health benefit by providing much needed dietary essential minerals and vitamins to human diet. Drying is the major process which determines the quality of the oil. The challenge of drying is to reduce the moisture content to a certain level where microbiological growth will not occur while maintaining the quality of the product. The traditional method uses sun drying which is having seasonal limitations. It is a common practice to use smoke drying during cloudy climate which yields a poor quality and off-flavoured oil. Based on the above facts, an investigation was undertaken to study the effect of vacuum drying of coconut and also to study the quality of the dried kernel. These results were compared with that of sun dried kernel.

The grated coconuts were spread on stainless steel tray of vacuum drier and drying trials were conducted at three levels of vacuum of 510,600,640 mm of Hg (gauge). Two levels of chamber temperatures such as 40 and 50°C were used.

- The drying curve were plotted and it may be revealed from the curve that sample dried at highest vacuum level of 640 mm of Hg (gauge) and at temperature of 50°C showed faster drying rate. As the vacuum decreases and temperature decreases, drying rate will be slow.
- The drying curve of sun dried sample showed that the drying rate is far lower than that of vacuum dried samples.
- The oil content of the sample dried at highest vacuum of 640 mm of Hg (gauge) and at temperature of 50°C was found to possess maximum oil content of 64%.
- It may also be pointed out that the oil content in sun dried sample was minimum.
- Lower acid value of 0.34 for vacuum dried sample at 640 mm of Hg (gauge) and 50°C indicates higher keeping quality.
- The iodine value of sun dried sample is 8.64 and those of vacuum dried samples ranged between 7.52 to 8.23, indicating the lower oxidative rancidity.

- Among the vacuum dried samples, those dried at higher vacuum level and temperatures possess more quality.
- The standardized operation parameters for vacuum drying of coconut were found to be 640 mm Hg (gauge) vacuum and 50°C chamber temperature.

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# REFERENCES


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## ABSTRACT

The coconut (*cocos nucifera)* has multifarious uses. The coconut oil is a good source of MCFA and has higher degree of digestibility. It is mostly included in diets all over the world. Traditional method of oil extraction has many limitations which results in low quality oil. An investigation was undertaken to study the effect of vacuum drying of coconut and also to study the quality of the dried kernel. Grated coconuts were dehydrated under three vacuum levels and two temperatures in a vacuum drier to optimize drying process. Vacuum levels used were 640, 600 and 510 mm of Hg vacuum (gauge). Sun dried samples were taken as control. Drying characteristics were studied by plotting drying curve. Oil was extracted by solvent extraction method and different quality tests were done. The oil extracted from samples dried at 640 mm Hg vacuum (gauge) and 50 ˚C resulted in an excellent quality product with faster drying rate and other quality attributes such as high oil content, low acid and iodine values and no rancidity. Therefore a vacuum level of 640 mm Hg (gauge) and a chamber temperature of 50°C may be chosen as optimum operating parameters for vacuum drying of coconut.

# APPENDIX

| Time (min) | M.C (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | A1 (640 mm Hg,50°C) | A2 (640 mm Hg,40°C) | B1(600 mm Hg,50°C) | B2 (600 mm Hg,40°C) | C1 (510 mm Hg,50°C) | C2 (510 mm Hg, 40°C) | Sun dried |
| 0 | 60 | 53.85 | 58.63 | 66.67 | 50 | 66.67 | 66.66 |
| 30 | 31.8 | 31.2 | 35.4 | 31 | 28.2 | 40 | 60.25 |
| 60 | 15.4 | 16.45 | 19.6 | 15.4 | 13.7 | 28 | 58 |
| 90 | 10.7 | 10.8 | 13.54 | 12.7 | 11.1 | 20 | 55.32 |
| 120 | 7.67 | 8.97 | 11 | 10.08 | 9.3 | 14.7 | 50.27 |
| 150 | 5.48 | 7.86 | 8.4 | 8.5 | 8.12 | 7.87 | 47.2 |
| 180 | 5.45 | 5.71 | 6.62 | 8.1 | 7.4 | 6.68 | 43 |
| 210 | | 5.69 | 6.61 | 7.15 | 6.38 | 6.19 | 39 |
| 240 | | | | 7.07 | 6.36 | 6.17 | 35.7 |
| 270 | | | | | | 6.11 | 32.4 |
| 300 | | | | | | | 28.4 |
| 330 | | | | | | | 23.56 |
| 360 | | | | | | | 21.02 |
| 390 | | | | | | | 17.23 |
| 420 | | | | | | | 14.69 |
| 450 | | | | | | | 11.58 |
| 480 | | | | | | | 9.28 |
| 510 | | | | | | | 7.31 |
| 540 | | | | | | | 7.2 |