PROPERTIES OF VIRGIN COCONUT OIL FROM WEST COAST TALL COCONUT PROCESSED BY DIFFERENT METHODS

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Affiliated to

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In partial fulfilment of requirement for the

AWARD OF THE DEGREE OF MASTER OF SCIENCE IN HOME SCIENCE (BRANCH C) FOOD SCIENCE AND NUTRITION

By

MEGHASREE P.

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'Certified as bonafide research work'

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Place: Ernakulam **MEGHASREE P.**

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ABSTRACT

Virgin coconut oil is extracted from fresh coconut kernels without chemical processing has high nutritional quality. The extracted oil did not pass through chemical refining, bleaching, or deodorizing which does not lead to the alteration of the nature of the oil. So Virgin coconut oil doesn't need to be processed further and it is suitable for human consumption. It containsa lot of lauric acid, which is good for health and gives more energy and quicker recovery from illness. The study entitled "*Properties of Virgin Coconut Oil from West Coast Tall Coconut Processed by Different Methods"* focused on the yield, physicochemical properties, lauric acid content, vitamin E content, and stability during storage of Virgin coconut oil fromWest Coast Tall coconut processed by different methods such as hot process, fermentation process, and centrifugation process. Coconuts that are mature enough as indicated by yellow-brownish colour approximately one year old and sloshing when shaken were taken as samples. The procedure of the hot process and centrifugation process was obtained from ICAR – CPCRI, Kasaragod (2016). The centrifugation process was done as per Aashaan & Co, Calicut and this procedure was provided by the Coconut Development Board. The yield,physicochemical properties, lauric acid content, vitamin E content, and stability during storage of Virgin coconut oil were determined. The highest oil recovery was found in the hot process followed by the centrifugation process and low oil recovery was obtained in the fermentation method. The virgin coconut oil extracted by the hot process was found to be more acceptable and fermentation method was found to be less acceptable. The virgin coconut oil obtained by the hot process was coloured, which shows a pale-yellow colour andVCO by fermentation method and centrifugation method were colourless and similar to water. The moisture level of virgin coconut oil obtained by the hot process was less, followedby centrifugation process and it is higher in fermentation process. The higher acid value is present in the fermentation process, and lowest in the hot and centrifugation process. The higher iodine value is found in the fermentation process, followed by the hot process. The lowest iodine value is present in the centrifugation process. Higher concentrations of Lauricacid are found in virgin coconut oil that is extracted using a fermentation process, followed by a hot process and centrifugation process. Higher vitamin E concentrations are found in virgin coconut oil that is extracted using a fermentation process. Lower vitamin E concentrations

are found in virgin coconut oil extracted using a hot process. After storing for one month, it was noted that the oil produced through the centrifugation process had absorbed the least amount of moisture. The acid value of the three samples of virgin coconut oils after one month of storage is found to be under the permitted level. In terms of yield, the hot process is best, followed by the centrifugation process. Nutritional properties like lauric acid and vitamin E content were higher in the virgin coconut oil obtained by the Fermentation method. The centrifugation process has a higher nutritional content than the hot process. However, In the case of physicochemical properties, the hot process and centrifugation process gave the best results. In terms of time required to complete the process, the hot process required less time but manpower was high. The fermentation process and centrifugation process required more time than the hot process, and themanpower was less than that of the hot process. In terms of energy, all processes use either electrical energy, heat energy, or both to complete the process.

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INTRODUCTION

CHAPTER 1

INTRODUCTION

The coconut tree is a member of the palm family, Arecaceae, and the only living species ofthe genus Cocos. *Cocos nucifera* is the scientific name of the coconut tree. The coconut is amonocot tree with more than 50 years of economic life span. The coconut is known as the "Tree of Life" because of the economic benefits of the coconut. All parts of the coconut tree have benefits (M. DebMandal, S. Mandal, 2011). Among its various applications, the coconut tree produces food, fuel, cosmetics, traditional medicine, and building materials. They are a cultural symbol of the tropics and are common in coastal tropical regions. The coconut is technically a drupe rather than a nut.

According to IBEF (2024), India is the world's greatest producer of coconuts, with 19,247 million nuts produced in 2021–2022, contributing roughly 31.45% of the global total. In 2022–2023 the crop adds approximately Rs. 30,795.6 crore (or US$ 3.72 billion) to the GDPof the nation. In India, the coconut palm gives around 12 million people access to food security and means of living. Additionally, it provides fiber to over 15,000 coir-based enterprises, supporting almost 6 lakh people's jobs. In 2022–2023 (till February 2023) the country's coconut productivity was 9,346 nuts per hectare, ranking among the highest globally. The nation's traditional coconut-based industries include the production of coir, the processing of copra, and the extraction of coconut oil. With 89.13% of the country's coconut land and 90.77% of its production in 2021–2022, Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh account for the majority of India's coconut production. States that also produce coconuts in the nation include West Bengal, Orissa, Maharashtra, Gujarat, Bihar, and Assam.

The important coconut variety along India’s west coast was West Coast Tall (WCT). Undergood management conditions, it gave a high yield. Due to its ability to grow in a variety of soil types and agroclimatic conditions, WCT has been widely cultivated. The plant typicallygrows to a height of 7.5 meters and produces 36 leaves on average. The fruits range in colorfrom green to greenish-yellow to brown. The shape of the coconut was round or oval in shape. This cultivar starts to produce after planting in favorable conditions in roughly 6 to 8years. A usual year produces ninety-six nuts on average. This species helps

make products for the home, like coir, coconut oil, and copra (Thomas et al., 2022).

In addition to its edible byproducts, coconut palm yields a number of non-food byproducts, including activated carbon and shell. Charcoal, powder, fiber, handicrafts, furniture, and roofing. It can also serve as a fuel source for industries and rural areas. Intense research and technology commercialization are desperately needed to boost the nation's economy, give farmers another source of income, and improve their lot in life (Mithra, A., 2013).

The value-added products from tender coconut water were Packaged tender coconut water, Minimal processing of tender coconut, Snowball tender nut, etc. Products from mature coconut water include Bottled coconut water, Coconut water beverages, Coconut water concentrate, Frozen coconut water, Nata-de-coco, Coconut jelly, Coconut vinegar, etc. The value-added products from coconut kernel are Desiccated coconut, Coconut chips, Coconut milk, Coconut skimmed milk, Sweetened condensed skim milk, Bottled coconut milk, Coconut cream, Spray Dried Coconut Milk powder, Coconut syrup, Coconut jam, Yogurt, Margarine, Coconut mayonnaise, Coconut flour, dietary fiber from coconut residue, Coconut honey, Coconut cheese, fermented beverage concentrate, Coconut sap, Toddy etc. The products derived from unfermented toddy are Jaggery/palm sugar, Refined sugar, etc. Coconut by-products includes Coconut shell powder and coconut shell charcoal(Muralidharan, K., & Jayashree, A.,2011)

The majority of coconut oils used in the market are derived from copra. It can be made usingsun drying, smoke drying, or a combination of the two. Standard copra must be used as the beginning material to produce unrefined coconut oil, which needs to be processed before it can be consumed. Aflatoxin contamination and oxidative rancidity are risks associated with the handling and intense processing of copra for oil extraction and refining (Guarte RC et.al,1996).

A kind of vegetable oil obtained from coconut is called virgin coconut oil (VCO). In the case of virgin coconut oil, it is extracted from fresh coconut meat not from the copra. The process of extraction takes place by mechanical or natural means. The process takes place under a controlled temperature, so it preserves all the nutritional content and nutritionally beneficial than copra oil (Marina et al. 2009b).

Micronutrients and both saturated and unsaturated fatty acids have been present in virgin coconut oil. Virgin coconut oil is unrefined and has not been treated with synthetic chemicals. It contains a lot of lauric acid, which is good for health and gives more energy and quicker recovery from illness. It helps in the processes of nutrient absorption and food digestion (Khairati, 2023 and Iswati & Nuraini, 2023).

About 90% of the fat in coconut oil is saturated, with the remaining 10% being unsaturatedfat primarily made up of oleic acid (6%), and linoleic acid (2%) (S. Sabahannur and S. Alimuddin, 2022).

In a comparison with copra oil, Nevin and Rajamohan (2004), found that VCO elevates high-density lipoprotein (HDL) cholesterol and decreases total cholesterol, triglycerides, phospholipids, low-density lipoprotein (LDL) and very low-density lipoprotein (VLDL) cholesterol in serum and tissues.

To maintain human health in the current health picture, which is marked by the largest prevalence of cardiovascular diseases, consumption of oil and fats that can lower the cholesterol level in serum and tissues is required (Nevin and Rajamohan, 2006)

Virgin coconut oil has slightly more lauric acid (46.05–52.6%) than coconut oil. Greater quantities of lauric acid and other medium-chain fatty acids, such as caproic, caprylic, and capric acids (G.G. Dumancas et.al, 2016).

Lauric acid is converted into monolaurin, which is a very valuable compound, which has antiviral and antibacterial properties (DebMandal & Mandal, 2011)

VCO stands distinct from the other vegetable oils due to its high level of lauric acid. Thelauric acid in VCO changes into monolaurin, which boosts immunity and protects newborns from bacterial, viral, and protozoal diseases. Its numerous benefits come from the preserved vitamins and antioxidants, the antiviral, and antimicrobial properties of the lauricacid components, and the medium chain fatty acids' simple digestion (Satheeshan K N et.al,2019).

There are a few different methods of producing virgin coconut oil, each with its unique process. Some common methods include:

- **Dry method**: Coconut oil is extracted from coconut milk by heating it in hot extraction procedures. By heating coconut milk to 100–120°C for 60 minutes, or until the water evaporated entirely, the VCO could be extracted. In order to extract the volatile coconut oil (VCO) from coconut milk, the protein is cooked slowly in a VCO cooker to coagulate it. The oil is then released from the stubborn residue by filtering through muslin fabric and heating the leftover residue one more time to extract even more oil (Srivastava et al., 2016)

- **Fermentation method**: The virgin coconut oil is extracted by fermentation is often done without the use of heat. Because of unregulated conditions and the existence of undesirable microbes, this spontaneous fermentation process causes contamination issues. As a result of the contamination, produces rancid-smelling, low-quality coconut oil, which is often yellow in colour (Neela & Prasad, 2012).

- **Centrifugation method**: This method was carried out by using a centrifuge machine to separate the oil from the coconut milk. Milk was centrifuged at various speeds between 6000 and 12000 rpm for a duration between 30 and 105 minutes (Nour et.al 2009).

- **Enzymatic method:** Complex carbohydrates including cellulose, hemicellulose, mannans, and others make up the enzymatic plant cell wall (Christensen 1991). Due to the breakdown of the cell wall and to extract the oil certain enzymes are used at a 1% level. Then extract 74% of the coconut oil, certain degradation enzymes such as cellulase, α-amylase, polygalacturonase, and protease were used (Che Man et al. 1996).
- **Low-temperature method:** A technique for making VCO is to refrigerate the coconut milk. The refrigerated coconut milk is divided it into two phases: the lower, watery phase, and the top, cream phase. To further isolate VCO, the cream was heated gently for a few hours in a thermostat oven (Songkro et al. 2010).
- **Supercritical carbon dioxide extraction technique:** The method for VCO extraction based on the ultra-critical carbon dioxide extraction technology was disclosed by Norulaini et al. (2009). The yield of the VCO in this process is directly

proportional to the pressure. Compared to previous researchers' methods, this one produced a higher yield.

Each of these methods has its advantages and can result in slightly different characteristics in the final virgin coconut oil product. Consumers may prefer one method over another based on factors such as flavour, aroma, nutrient content, and production efficiency. In this study, hot process, fermentation process, and centrifugation process were used to extract the virgincoconut oil.

According to Marina et al. (2009), this study reveals that the virgin coconut oil obtained by the fermentation method presents a higher antioxidant capacity than refined, bleached, and deodorized coconut oil. the virgin coconut oil obtained by fermentation exhibited the best antioxidant activity and the largest scavenging effect on 1,1-diphenyl-2-picrylhydrazyl. The two main phenolic acids in virgin coconut oil are Ferulic acid and p-coumaric acid.

According to Andrikopoulos et al. (2002), Several factors affect the overall performance of the oil. Temperature, length of heating, air contact, type of vessel used, degree of unsaturation, etc are some of the important factors.

RELEVANCE OF THE STUDY

These days, virgin coconut oil has become popular due to its many medical and physiological advantages. Today's consumers choose healthier food oils that are natural and chemical-free. Due to the inclusion of MCFA and vitamin E, which is one of the components that contributes to the antioxidant activities, virgin coconut oil has been shown to have health-promoting effects. For the extraction of VCO, several extraction methods have been investigated and applied. The natural phytonutrients and nutritious composition of oils, as well as the yield of oil, are greatly influenced by the selection of extraction techniques and conditions. Due to its advantages of being high in quality and low in cost, solvent-free extraction methods of VCO, such as the hot process, fermentation process, and centrifugation process, have been concentrated in the edible oil industry. This was equally important for consumers as well as producers alike.

The present study aims to determine the quality and other physicochemical properties of virgin coconut oil produced from the West Coast Tall coconut variety. Through this study, attempt has been made to compare the effects of different processing methods on the physicochemical properties which include colour, aroma, moisture, acid value, and iodine value. Additionally comparing the lauric acid content and vitamin E content can offer information about nutritional and health-promoting qualities of the oil.

Therefore, this study was undertaken to examine the lipid profile, antioxidant capacity, and physico-chemical characteristics and evaluate the quality of Virgin coconut oil obtained bydifferent methods of separation.

OBJECTIVES

- To extract virgin coconut oil from the West Coast tall variety (Cocos nucifera) using different methods such as hot process, fermentation process, and centrifugation process
- To compare the quantity of virgin coconut oil obtained by different processing methods and evaluate the efficiency of each method in terms of oil yield.
- To assess the lauric acid content of virgin coconut oil produced by different methods.
- To assess antioxidant activity in terms of vitamin E content of virgin coconut oil produced by different methods.
- To assess sensory attributes, and the quality of virgin coconut oil produced by different methods.
- To identify potential benefits and drawbacks of each processing method in terms of time, and energy requirements.
- To recommend the most suitable processing method for producing high-quality virgin coconut oil with optimal yield and physico-chemical properties.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

2.1 Virgin coconut oil

A kind of vegetable oil obtained from coconut is called virgin coconut oil (VCO). Micronutrients and both saturated and unsaturated fatty acids have been present in virgin coconut oil. Virgin coconut oil is unrefined and has not been treated with synthetic chemicals. It contains a lot of lauric acid, which is good for health and gives more energy and quicker recovery from illness. It helps in the processes of nutrient absorption and food digestion (Khairati, 2023 and Iswati & Nuraini, 2023).

The *Philippine National Standard* (2007*),* for VCO officially defines VCO as, the oil extracted from the mature, fresh kernel of the coconut. The extraction process was by mechanical or natural method, with or without the heat. The extracted oil did not pass through chemical refining, bleaching, or deodorizing and which does not lead to the alteration of the nature of the oil. So Virgin coconut oil doesn't need to be processed further and it is suitable for human consumption.

Virgin Coconut Oil (VCO) is processed differently from commercial coconut oil; it is often derived from fresh coconut kernels without the use of chemicals. Rich in vitamins, minerals, and antioxidants, VCO is known as the "mother of all coconut oils." oils. VCO is a coconut- based food grade value-added product with a wide range of uses for people (Satheesh, 2015).

2.2 Biological activity and health benefits of virgin coconut oil

VCO has an antidiabetic effect, therefore it can be utilized as an alternative to reducing blood glucose levels. Lauric acid, a medium-chain fatty acid (MCFA) found in VCO, can increase the synthesis of insulin in beta cells within the pancreas. According to the study's findings, virgin coconut oil may lower blood sugar levels (Rahmawati et al., 2023)

Nevin and Rajamohan (2004) examined the impact of virgin coconut oil (VCO) in contrast to copra oil (CO), consumption on a range of lipid indicators. They concluded that

VCO, which is produced through a wet process, is more advantageous than copra oil in lowering lipid components because it increases the levels of high-density lipoprotein in serum and tissues while decreasing levels of low-density lipoprotein, phospholipids, Total Cholesterol, and very low-density lipoprotein. VCO can also raise the concentration of HDL, i.e. good cholesterol.

Saturated medium-chain fatty acids, which are abundant in coconut oil, appear to be cholesterologenic; however, research on animals revealed that this was not the case because the fats were used to make hydrogenated coconut oil. A little amount of the hydrogenation process is saturated. Animals that suffer from essential fatty acid deficit do so because hydrogenated coconut oil contains linoleic acid, an essential fatty acid that causes cholesterogenic reactions (Cecille et al. 2010).

This experiment evaluated the impact of daily consumption of virgin coconut oil (VCO) onplasma lipoprotein levels and adverse events. 35 Thai volunteers in good health, ages 18 to25, are used in the study population. In this study, the result was when compared to the control regimen, daily VCO intake significantly elevated high-density lipoprotein cholesterol by 5.72 mg/dL among the 32 participants including 16 males and 16 females. The two regimens did not differ in how total cholesterol, low-density lipoprotein cholesterol, or triglyceride levels changed. While using VCO, a few volunteers complained of mild diarrhoea; nevertheless, no significant adverse effects were noted. And the conclusion of this study was when young, healthy adults consumed 30 mL of VCO daily, their high-density lipoprotein cholesterol significantly increased. After taking VCO every day for eight weeks, no significant safety concerns were noted (Chinwong et al., 2017)

According to Feei and Lee (2016), cardiovascular disease is one of the leading cause of death. A diet high in polyunsaturated fatty acids like virgin coconut oil (VCO) has been responsible for reducing the risk of cardiovascular disease. According to this research findings, Virgin coconut oil has positive benefits in reversing the biochemical distruptions linked to cardiovascular disease and it reducing the risk of cardiovascular disease.

Virgin coconut oil produced through chilling and fermentation method have high antioxidant activity than refined bleached and deodorized coconut oil. Virgin coconut oil extracted from fermentation process had the high scavenging effect on 1,1- diphenyl-2-

picrylhydrazyl (DPPH). And also, the highest antioxidant activity based on the β-carotene-linoleate bleaching method (Marina et al., 2009).

Depending on the extraction process used, the number of antioxidants in VCO varies. Because polar phenolic compounds are more soluble in non-polar coconut oil at high temperatures, phenolic-dependent antioxidant capabilities are anticipated to be greater for hot extraction VCO than for cold extraction VCO (Kapila et al. 2009).

According to Ramadan et al. (2003), antioxidants can be used as inhibitors of singlet oxygen production, reducing agents, pro-oxidant metal complexes, and free radical scavengers.

Tocopherols, which are included in VCO, are advantageous naturally occurring antioxidantsthat may protect oil against rancidity and oxidation in the air (Enig 2000).

Compared to copra oil, VCO has higher levels of vitamin E and polyphenols. According to animal studies rats given diets containing these coconut oils for 45 days appeared to have higher levels of antioxidant enzymes (Nevin and Rajamohan 2006).

Lauric and capric acid, which are present in VCO, are known for having special antibacterial properties. Lauric acid is converted into Monolaurin in the body and it is only found in breastmilk. It contains antiviral, antibacterial, and antiprotozoal properties. So that can be destroyed viruses coated in lipids, including CMV, herpes, HIV, and influenza (Enig 1999).

In this study the virgin coconut oil obtained by different method like fermentation, centrifugation, enzymatic extraction, and the microwave heating method was assessed. Then the outcome of the study was VCO has many positive health effects to the human body. Lauric acid contains 45 to 52 %. In the digestive system VCO breakdown into lauric acid, 1-monolaurin, and 2-monolaurin by the enzyme lipase. These components are good antimicrobial lipids due to the presence of both hydrophilic and lipophilic groups. Lauric acid and monolaurin can be used as antibacterial, antifungal, and antiviral agent. They also have the ability to destroy gram-positive bacteria such as S. aureus and fungi and viruses including vesicular stomatitis virus (VSV), herpes simplex virus (HSV), and visna virus

(VV) (Nitbani et al., 2022).

Through a number of mechanisms, polyphenols present in the virgin coconut oil regulate and lessen inflammation, which helps to prevent cancer and other illnesses. Thus, it is important to this part to provide an overview of anti-inflammatory effects of VCO. By lowering serum alkaline phosphatase activity, granuloma formation, and transudative weight, VCO exhibits an inhibitory effect on chronic inflammation. Additionally, VCO had an antipyretic effect in yeast-induced hyperthermia as well as a modest analgesic impact on the writhing reaction caused by acetic acid (Intahphuak et al., 2009).

When compared to coconut oil, the administration of VCO has demonstrated a considerable antithrombotic impact. It was discovered that experimental animals fed VCO had higher levels of antioxidants and vitamins than animals fed sunflower oil. Blood coagulation factor levels were maintained while cholesterol and triglyceride levels were lowered with dietary treatment of VCO. The biologically active unsaponifiable components of VCO, which include vitamins, may be responsible for these qualities. It contains phytosterols, polyphenols, pro-vitamin A, and vitamin E (Nevin G et al. 2006).

VCO is a rich source of Medium-chain fatty acids. So it has antifungal activity. A study conducted in Nigeria found that VCO is an important antifungal agent when compared to fluconazole. Fluconazole is used as a first line of treatment for drug-resistant Candida albicans. VCO is more effective than fluconazole against Candida albicans. As a result, it can be used to treat fungal infections brought on by Candida species (Ogbolu et al., 2007).

2.3 Methods for the extraction of virgin coconut oil

2.3.1 Hot Process

Coconut oil is extracted from coconut milk by heating it in hot extraction procedures. The heating process denatures the proteins in coconut milk, which destabilizes the milk emulsion. By heating coconut milk to 100–120°C for 60 minutes, or until the water evaporated entirely, the VCO could be extracted. To extract the volatile coconut oil (VCO) from coconut milk, the protein is cooked slowly in a VCO cooker to coagulate it. The oil is then released from the stubborn residue by filtering through muslin fabric and heating the leftover residue one more time to extract even more oil (Srivastava et al., 2016).

2.3.2 Dry process

Using either the sun-dry or oven-dry method, the coconut kernel was heated under carefully regulated circumstances to eliminate moisture content while avoiding microbial infiltration in this dry process. The dried kernel was then physically pressed to extract its oil. To lower the moisture level of the shredded coconut meat before extracting the oil, we have used two DME techniques in this study: oven-dried (DME-OD) and sun-dried (DME-SD). The grated coconut meat was dried for the DME-OD process in an oven set to 40°C for four hours. The grated coconut meat was sun-dried for three to four hours in order to prepare it for the DME- SD process. The coconut meat that had been grated was dried for four hours at 40°C in an oven. The grated coconut meat for the DME-SD technique was dried for three to four hours in the sun. The VCO was then created by pressing the dried, grated coconut meat with a modified mechanical jack. Until it was needed again, the separated and purified VCO was kept chilled (Ghani, N. A. A., et.al.,2018).

2.3.2 Fermentation process

In wet processing, the virgin coconut oil is extracted by fermentation is often done without the use of heat. Because of unregulated conditions and the existence of undesirable microbes, this spontaneous fermentation process causes contamination issues. As a result of the contamination produce rancid-smelling, low-quality coconut oil, which is often yellow in colour. Thus, in semi-controlled settings, the induced fermentation method using certain probiotic microbe species (Neela & Prasad, 2012).

In the controlled condition of fermentation, the coconut milk was sterilized to avoid contamination by unwanted microorganisms present in the coconut milk. Then a pure culture of L. plantarum was used in fermentation for the production of virgin coconut oil. The yield of virgin coconut oil from natural fermentation was comparatively low as compared to induced or controlled fermentation. For natural fermentation the yield was 25.68±0.96% while for controlled fermentation was 28.47±1.07%. The virgin coconut oil produced by natural fermentation and induced fermentation have physicochemical parameters such as iodine value, acid value, peroxide value, saponification value, specific gravity, refractive index, insoluble impurities, free fatty acid content, fatty acid composition is within the limit of APCC standard. But in the case of moisture content, they are little higher than that of

APCC values. The moisture content of virgin coconut oil extracted by natural fermentation is 0.52% and induced fermentation is 0.56% and the APCC value is 0.1 - 0.5%. The tocopherol content present in both virgin coconut oils is about 6 mg / 100g. the virgin coconut oil extracted by fermentation method has poor quality of free fatty acids and high peroxide value due to the presence of high moisture (Seneviratne & Jayathilaka, 2016b).

2.3.3 Centrifugation process

The yield of VCO was 13.53% at 12000 rpm for 120 minutes, according to the results.1. At 40°C, the maximum yield of VCO was achieved using centrifugation. investigated the possibility of centrifugation in demulsifying coconut milk that was purchased from a local market and centrifuged at various speeds between 6000 and 12000 rpm for a duration between 30 and 105 minutes. The results showed that this method improved the demulsification of coconut milk more quickly than the fermentation method and produceda larger yield. (Nour et.al 2009)

2.3.4 Enzymatic method

Complex carbohydrates including cellulose, hemicellulose, mannans, and others make up the enzymatic plant cell wall (Christensen 1991). Due to the breakdown of the cell wall andto extract the oil certain enzymes are used at a 1% level. Then extract 74% of the coconut oil, and certain degradation enzymes such as cellulase, α-amylase, polygalacturonase, and protease were used (Che Man et al. 1996). By dissolving the structural cell wall components of the oil seeds—mannan, galactomannan, arabinoxylogalactan, and cellulose—cell wall degrading enzymes can be utilized to extract oil.

2.3.5 Low-temperature method

One popular technique for making VCO is to refrigerate the coconut milk. The refrigeratedcoconut milk is divided into two phases: the lower, watery phase, and the top, cream phase. To further isolate VCO, the cream was heated gently for a few hours in a thermostat oven (Songkro et al. 2010).

Nevin KG et al. (2008) found that solid endosperm from mature coconuts was used to create VCO. The coconut milk was pulverized, blended into a thick slurry, and then

strained through cheesecloth before being stored in the refrigerator for 48 hours. The milk was heated to a low temperature (500 ^{o} C) in a thermostat oven for 48 hours, and the resulting VCO wasthen filtered through cheesecloth.

According to Hamid MM et al. (2011), fresh coconut meat was gathered and mechanically pressed to produce coconut milk during the wet process of producing VCO. The milk was stored at 100 degrees Celsius to separate the water from the coconut butter. It was then heatedto 450C, the oil was extracted by centrifugation, and it was estimated that 30–40% of the oilwas recovered.

2.3.6 Supercritical carbon dioxide extraction technique

The method for VCO extraction based on the ultra-critical carbon dioxide extractiontechnology was disclosed by Norulaini et al. (2009). The yield of the VCO in this process isdirectly proportional to the pressure. Compared to previous researchers' methods, this one produced a higher yield.

2.4 Quality characteristics of virgin coconut oil

According to Codex Alimentarius (2006) and the Asian Pacific Coconut Community (APCC) (2006) "Virgin oils" can be defined as vegetable oils that should be suitable for human consumption in their natural state. The commercially available refined, bleached, and deodorized coconut oil (RBD CNO) is the basis for the current codex standard for coconut oil (Codex Alimentarius 2006). In 2006, the APCC set a standard for VCO in response to the unique demands of coconut producers. Currently there are two standards for VCO i.e. Phillipines National Standard designated as PNS/BAFPS 22:2004 and APCC. However, in India, there are no such standards available to PFA regarding VCO. (Marina et al., 2009)

Table 1: APCC criteria of quality characteristics for virgin coconut oil.

Parameter	Maximum value or range
Moisture (%)	0.1
Volatile matter, 120 °C (%)	0.2
Free fatty acid (%)	0.2
Peroxide value, meq/kg	3
Density, g/ml	0.915-0.920
Refractive index, 40 °C	1.4480-1.4492
Insoluble impurities (%)	0.05
Saponification value, mg KOH/g oil	250-260
Iodine value	4.1-11
Unsaponifiable matter (%)	0.2-0.5
Total plate count	0.5
Color	Colorless

(APCC, 2009)

According to FSSAI, virgin coconut oil is the type of oil expressed mechanically or naturally from the kernel of Cocos nucifera. The oil extraction is done without the application of heat, and also not lead to any alterations to the oil. The virgin coconut oil is not needed to refining and, it is suitable for human consumption. It should be clear and free from suspended foreign matter. And also free from rancidity. The oil did not contain any added colouring substances, flavouring substances, and mineral oils. The virgin coconut oil should following the standards given below:

Table 2: FSSAI criteria of quality characteristics for virgin coconut oil.

Parameter	**Maximum value or range**
Refractive index, 40 °C	1.4480-1.4492
Moisture (%)	Not more than 0.5 percent by weight
Insoluble impurities (%)	Not more than 0.05 percent by weight
Saponification value, mg KOH/g oil	Not less than 250
Iodine value	4.0-11
Unsaponifiable matter	Not more than 0.5 percent by weight
Acid value	Not more than 4.0
Polenske Value	Not less than 13
Peroxide value, meq/kg	Not more than 15 milliequivalent per kg of oil

(Bassi et al., n.d.)

2.5 Physico-chemical properties of VCO

A study was done on the commercial virgin coconut oil (VCO) that is traded in Indonesia and Malaysia. The lauric acid level of the VCO samples ranged from 46.64 to 48.03 percent, with no noticeable variation. Lauric, capric, and myristic acids were the maintriacylglycerols that were present in the oils. The range of iodine values, 4.47 to 8.55, suggests the presence of a few unsaturated bonds. The range of the saponification value was 250.07 to 260.67 mg KOH/g of oil. Its good oxidative stability was indicated by the low peroxide value (0.21–0.57 mequiv oxygen/kg). The relatively low free fatty acid level (0.15-2.25) indicated that the VCO samples were of high quality. These findings imply that VCO has chemical qualities comparable to those of RBD coconut oil, with the extra advantage of having a higher phenolic content. Commercial virgin coconut oil collected from the Malaysian and Indonesian markets was tested and compared. In this study, the Iodine value ranged from 4.47 to 8.55. this iodine value indicates that only a few unsaturated bonds are present in the virgin coconut oil. Commercial virgin coconut oil collected from the Malaysian and Indonesian markets was tested and compared. In this study free fatty acid content of 0.15–0.25 was fairly low, showing that VCO samples were of good quality (Hamid 2015)

A comparative analysis was conducted on the qualities and physico-chemical characteristics of virgin coconut oil (VCO), which was extracted from coconuts at three distinct stages of maturity: immature (IMC), mature (MC), and overlay mature (OMC). VCO from OMC had the high recovery rate (95.64%), followed by those from MC (84.40%) and IMC (61.06%), in that order. The maturity stage plays an important role in the production yield of virgin coconut oil but it is not influenced to the quality parameters of the virgin coconut oil such as fatty acid composition and physicochemical properties. Every VCO sample had a look similar to water. The lipid hydrolysis and oxidation is low and it denotes that the maturity stage is not influences the oil oxidative stability. The virgin coconut oil contained medium chain fatty acids (MCFA), with lauric acid (C12:0) accounting for the majority of the fatty acid content (49.74–51.18 g/100 g) (Patil U et.al ,2016).

According to Satheeshan et.al., (2019), hot-extracted virgin coconut oil (HVCO), cold- extracted virgin coconut oil (CVCO), and coconut oil (CO) are tested and analyzed the various quality parameters. The analysis was takes place to determine whether there is variation in these parameters among the different methods of its production. Moisture has a significantly ($p<0.0001$) effect on various techniques. Color have significantly ($p<0.0001$) affected by various techniques. While the acid value did not change significantly among samples. While the iodine values did not change significantly among samples. While the free fatty acid did not change significantly among samples. Vitamin E have significantly ($p<0.0001$) affected by various techniques. (Satheeshan et al., 2019)

According to Seneviratne et al. (2002), coconut oil extracted by wet methods often has less free fatty acid content than coconut oil made using dry methods. The amount of free fatty acids or the acid value given by the producers of virgin coconut oil is about 0.02 % as lauric acid. The acid value of commercial coconut oil generated by pressing copra (CO) is significantly higher than that of coconut oil extracted by boiling coconut milk (TCO) (0.31

$\pm$ 0.10 vs 2.51 $\pm$ 0.34 mg KOH/1g oil: P = 0.0036).

According to Seneviratne, K., & Jayathilaka, N., (2016) free fatty acids are created by hydrolysing the triglycerides of coconut oil. An oil's acid value indicates how much free acid is contained in the fat. Triglycerides make up the majority of oil's composition. As a result of the lipase enzyme's action, these triglycerides hydrolyze to produce free fatty acids. Microorganisms or broken cells or tissues from the coconut oil extraction process can be the source of the enzyme. Coconut oil that has been extracted fresh has no acidity. An indication of aged oil is its acidity. Because of inadequate coconut oil extraction and storage practices, the hydrolysis of oil can produce free acid more quickly. The iodine value of virgin coconut oil does not change with the method of extraction, but it is affected by the quality of the coconut used for the production of virgin coconut oil. If the same quality coconut is used for the process then the iodine value is comparatively the same. The purpose of this study is to identify saturated and unsaturated fatty acids in crude palm oil (CPO), cocoa beans, virgin coconut oil (VCO), and palm kernel seeds by using gas chromatography (GC-FID). VCO has 90.896% saturated fatty acids, according to the results of GC-FID analysis. Lauric acid makes up the largest portion of VCO (45.567%) (Sabahannur & Alimuddin, 2022).

Comparative research was done on the qualities and characteristics of virgin coconut oil (VCO), which is produced from coconuts at three distinct stages of maturity: overlay maturecoconut (OMC), mature coconut (MC), and immature coconut (IMC). VCO from OMC hadthe best recovery rate (95.64%) ($p<0.05$), with MC and IMC having the next-highest rates (84.40%) and 61.06%), respectively. Every VCO sample had a look similar to water and contained medium chain fatty acids (MCFA), with lauric acid (C12:0) accounting for the majority of the fatty acid content (49.74–51.18 g/100 g). Every VCO had myristic acid (C14:0) in the range of 18.70–19.84 g/100 g. Every VCO sample's quality criteria met Asian Pacific Coconut Community (APCC) requirements. oil oxidative stability was unaffected bymaturity stages. Maturity stages were therefore crucial to recovery, but they exhibited no influence on the resulting VCO's physicochemical characteristics and fatty acid makeup(Patil et al., 2016).

Virgin coconut oil (VCO) has a high content of medium-chain fatty acids, which sets it apart from cooking oils that contain long-chain fatty acids. This property could make VCO a functional food with possible health advantages. Our goal in this research is to examine thephysicochemical characteristics, antioxidant potential, and metal composition of the VCO that was extracted using four distinct processing techniques: fermentation, chilling and centrifugation, direct microexpelling oven-dried, and direct microexpelling sun-dried processes. We discovered that every VCO complies with the Asian and Pacific Coconut Community (APCC) standard in terms of its physicochemical characteristics, which include moisture content, refractive index, viscosity, iodine value, saponification value, peroxide value, free fatty acid, and fatty acid content. The majority of the fatty acid composition in all of the VCO is lauric acid, which ranges from 48.40% to 52.84%. The VCO's metal concentrations were found to be within the required APCC limit, and its total phenolic content and DPPH radical-scavenging activity (IC 50) were found to be in the range of 1.16–12.54 mg gallic acid equivalents (GAE)/g and 7.49–104.52 mg/ml, respectively (Ghani, N.A. A., et.al.,2018).

Nevin, and Rajamohan, (2004) in this study compared the effects of consuming virgin coconut oil (VCO) with copra oil (CO) and found that VCO obtained through a wet processreduced level of total cholesterol (TC), triglycerides (TG), phospholipids, LDL, and very low-density lipoprotein (VLDL) while increasing levels of high-density lipoprotein

(HDL) in serum and tissues. Consequently, VCO was more beneficial in lowering lipid components than copra oil. Higher concentrations of vitamin E are found in virgin coconut oil that is extracted using cold, wet processes. Tocopherols, or vitamin E, are susceptible to high temperatures and situations of copra processing. This explains why tocopherols are typically absent from copra oil. However, virgin coconut oil extraction involves the utilization of mild temperature conditions. Consequently, there are assertions that tocopherols are present in virgin coconut oil.

During storage, oxidation can cause. Coconut oil to degrade and have a sour smell. In this study assesses the quality of coconut oil while it is being stored by including tocopherol, anantioxidant. Wet extraction is used to extract the oil. Tocopherol is added as an antioxidant at different concentrations such as 0, 0.5, 1.0, and 1.5% w/v. After two months of room temperature storage, the oil samples were assessed for quality every 2,4,6, and 8 weeks. Theoils' moisture content, free fatty acid content are all measured. The study's findings that virgin coconut oil's moisture content remains constant whether antioxidants are added. During storage, The oils' free fatty acid content is measured. The study's findings that free fatty acid was impacted by the addition of antioxidants, whereas oils treated with antioxidants had higher free fatty acid content (Karouw et al., 2021).

A beneficial oil called virgin coconut oil (VCO) is taken out of young, fully-grown coconut kernels. There are many different breeds of coconuts in the world, but not all of them are used to make VCO. By assessing the physicochemical characteristics of a few selected conventional (Bodiri, Red dwarf, and Green dwarf) and hybrid (CRISL-2013, CRISL-2014, and CRISL-2020) types, the study seeks to discover possible sources of VCO. Oil was extracted using the cold press method, and the quality of the VCO was assessed using metrics such as the peroxide value, free fatty acid (FFA) value, moisture and volatile matter content, color, fatty acid profile, and total phenolic content. The findings showed lower, considerably variable amounts of moisture, volatile matter content (0.06%–0.15%), and FFAs (0.05%–0.10%). Peroxides were not found in the oil, and their color fell between values 1 and 2 on the Lovibond color scale. All of the samples' major fatty acids were foundin the coconut oil, however, only the VCO of conventionally grown coconuts contained linolenic acid. The samples' total phenolic content varied significantly, ranging from 21.44 to 82.69 mg GAE/kg of oil, with traditional-based VCO samples exhibiting the

greatest amounts of phenolic content. The study's findings indicated that all varieties- aside from Green dwarf- are reliable sources of high-quality VCO output (Rangana, Dilan & Wickramasinghe, Indira., 2023)

2.6 Uses and Applications of virgin coconut oil

VCO is used as cooking oil and it is an important source of energy in diet. VCO is used asa substitute for buttermilk in filled milk, filled cheese, and ice cream. It is also used as a skinand hair conditioner. (Dumancas et al., 2016)

VCO has been shown to have a number of positive benefits on the skin. VCO can defense against UVB-induced erythema and pigmentation, and some experimental research was carried out. Taking VCO orally improves its protective qualities (Merlin et al. 2008).

According to Reza Zamiri et al. (2011), silver nanoparticles were created via laser ablation of a silver plate submerged in VCO. It was ultimately determined that employing VCO to manufacture silver nanoparticles was an environmentally safe method.

In a variety of industries, including food, medicine, cosmetics, and nanotechnology, VCO plays a noteworthy role. These uses have led to its classification as valuable oil. Numerous researchers have reported various manufacturing techniques and VCO applications inseveral scientific domains (Satheesh, 2015).

This oil has become an important factor in the field of health foods in recent years. Patients are appreciating its various benefits, dietitians are promoting its use, and celebrities are usingit. This oil is said to offer several health advantages. These include advantages for maintaining healthy skin and hair, reducing stress, maintaining a healthy weight and cholesterol level, immunomodulatory effects, cardiovascular applications, and, more recently, Alzheimer's disease (Kappally, S., et.al., 2015).

Higher levels of several skin components and a shorter period for complete epithelization were signs that VCO-treated wounds healed substantially more quickly. In wounds treated with VCO, pepsin-soluble collagen significantly increased, suggesting a higher degree of collagen cross-linking. Higher collagen turnover was also observed to be associated with enhanced Glycohydrolase activity. It was discovered that there was an increase in antioxidant enzyme activity along with decreased glutathione and

malondialdehyde levels. It was discovered that the treated wounds had reduced levels of lipid peroxide. Comparing VCO-treated wounds to controls, a histological analysis revealed increased fibroblastproliferation and neovascularization. The synergistic action of the several biologically active minor components in VCO is responsible for its positive effects (Nevin & Rajamohan, 2010).

Medium-chain fatty acids are more polar and hydrophilic in nature. It is capable of dissolving a wide range of polar compounds that are insoluble in traditional fats and oils. So they are typically used in the flavor industry. VCO is regarded as a superior cooking oil because it was superior to virgin olive oil (VOO) in terms of oxidative stability (Henna and Tan 2009).

It was stated that a combination of various essential oils, including lavender, eucalyptus, andlemon oils, together with VCO, were utilized to make oils for massage. To evaluate the preparation's quality attributes, the physical, chemical, and microbiological qualities of the massage oil were evaluated. stated that because VCO's massage oil products were clear of microbiological contamination, consumers should feel safe using them (Sarunyoo Songkroet al. 2010).

Some studies have revealed that coconut oil is an organic biofuel. And it can serve as a dieselreplacement. So it is an alternative to the kerosene blend. The economic viability of producing coconut oil for fuel could be attributed to the comparatively low cost of labor and nuts (Herkules et al. 2010).

VCO also has a preservative capacity. The meat is immersed in VCO for preservation. VCO can reduce the moisture content and bacterial colony count. This increased the shelf life of the meat (Salam et al. 2009).

EXPERIMENTAL PROCEDURE

CHAPTER 3

EXPERIMENTAL PROCEDURE

Experimental design is the technique of doing research objectively and under control in order to optimize precision and derive particular conclusions about a hypothesis statement is knownas experimental design (Bell, 2009).

The experimental procedure followed for the study entitled "**Properties of Virgin Coconut Oil from West Coast Tall Coconut Processed by Different Methods**" is given under the following headings:

3.1 Selection of coconut

3.2 Extraction of virgin coconut oil

3.2.1 Hot Process

3.2.1.1 Preparation of coconut for milk

3.2.1.2 Preparation of coconut milk

3.2.1.3 Settling of the coconut milk

3.2.1.4 Cream separation

3.2.1.5 Slow heating of coconut cream and oil recovery

3.2.2 Wet process

3.2.2.1 Fermentation method

3.2.2.1.1 Preparation of coconut for extracting milk

3.2.2.1.2 Preparation of coconut milk

3.2.2.1.3 Settling the coconut milk in a fermentation container

3.2.2.1.4 Oil Separation

3.2.2.1.5 Filtration

3.2.2.1.6 Drying

3.2.2.2 Centrifugation method

3.2.2.2.1 Preparation of coconut for milk

3.2.2.2.2 Preparation of coconut milk

3.2.2.2.3 Cream separation

3.2.2.2.4 Oil Separation

3.3 Determination and comparison of yield of virgin coconut oil by different processingmethods

3.4 Determination and comparison of sensory and physicochemical properties of virgincoconut oil by different methods

3.4.1 Aroma

3.4.2 Colour

3.4.3 Moisture

3.4.4 Acid value

3.4.5 Iodine value

3.5 Assessment of the lauric acid content of virgin coconut oil by different methods

3.6 Assessment of antioxidant activity in terms of vitamin E content of virgin coconut oilproduced by different methods

3.7 Determination of stability during storage

3.7.1 Moisture

3.7.2 Acid value

3.1 Selection of coconut

The variety of the coconut used in the present study was West Coast Tall coconut (WCT)(*Cocos nucifera*).

Coconut Selection: The maturity of coconut is a very important factor in the quality and recovery of VCO especially in processes involving the coconut milk. Coconuts which are mature enough as indicated by yellow-brownish colour approximately one year old and sloshing when shaken were taken as samples.

West Coast Tall is an important variety of coconut. Ordinary or Common Tall Variety is another name for the WCT type of coconut. The WCT variety was used in this study because of the high availability of this variety of coconut in Kerala. Five numbers of coconut were used for each method of extraction. Coconuts are collected from the Institute of Coconut DevelopmentBoard, Aluva, Ernakulam.

The important coconut variety seen along India's west coast is West Coast Tall (WCT). Undergood management conditions, it gives a high yield. Due to its ability to grow in a variety of soil types and agroclimatic conditions, WCT has been widely cultivated. The plant typically grows to a height of 7.5 meters and produces 36 leaves on average. The fruits range in color from green to greenish-yellow to brown. The shape of the coconut was round or oval in shape.This cultivar starts to produce after planting in favorable conditions in roughly 6 to 8 years. Annually it produces ninety-six nuts on average. This species helps make products for the home, like coir, coconut oil, and copra. (Thomas et al., 2022)

The nuts used to create virgin coconut oil are fully ripe, often between 11 and 12 months old. When the husk matures, it will be golden to brown and sloshing when shaken. The milk from the coconut fruits was to be extracted, and only non-sprouted coconuts were chosen (Chowdappa, 2016).

Plate 1: WCT Coconut Tree (Cocos nucifera)

Plate 2: Coconut

3.2 Extraction of virgin coconut oil

The extraction process of virgin coconut oil was done by three methods. The first method wasthe hot process.

3.2.1 Hot Process

The extraction of virgin coconut oil involves various steps. The procedure of hot process is obtained from ICAR – CPCRI, Kasaragod (2016). The steps followed for the extraction of virgin coconut oil by hot process consists of the following steps:

3.2.1.1 Preparation of coconut for milk

3.2.1.1.1 Dehusking of the Coconut

A manual coconut dehusker was used to remove the shell from the coconuts after harvest.

Plate 3: Dehusking

Plate 4: Dehusking

Coconut milk preparation is the first step in all the methods of virgin coconut production. Preparation of coconut milk consisted of below steps:

3.2.1.1.2 Weighing of the coconut

Five mature WCT varieties of coconuts are selected for each method of processing of virgin coconut oil. The coconuts were weighed using a weighing balance. The weighing balance was turned on and set preferred measurement i.e., in grams. Placed a small container on the weighing balance and calibrated it to zero. Placed the coconut on the

container and recorded the weight displayed on the scale. Three consequent weights were taken from which the average weight was recorded.

Plate 5: Weighing of coconut

3.2.1.2 Preparation of coconut milk

3.2.1.2.1 Splitting of the coconut

Splitted the coconut into two halves mechanically by using a strong hammer. Removed thecoconut water. It is then cleaned with potable water.

Plate 6: Coconut half

3.2.1.2.2 Coconut milk extraction process

Scraped coconut was collected and weighed using a weighing balance. The weighing balance was turned on and set preferred measurement i.e., in grams. Placed a small container on the weighing balance and calibrated it to zero. Placed the scraped coconut on the container and recorded the weight displayed on the scale. Then three consequent weights were taken.

Scraped coconut was fed into a mechanical device that grinds it. Approximately 400 g of scraped coconut was placed in the mixer grinder jar. By using half of the boiled and cooled water ground the scraped coconut. Extracting coconut milk was a crucial step in preparing virgin coconut oil. Coconut milk was extracted by using a cleaned cotton cloth. The ground coconut meat was squeezed using a clean cotton cloth. It is important to maintain hand hygieneto prevent contamination. Hands were washed thoroughly with soap and water after which wore food-grade hand gloves. The coconut milk may contain any residues like small pieces ofcoconut meat etc. So, the coconut milk was filtered to remove these residues.

Plate 7: Scrapped coconut

Plate 8: Preparation of coconut milk

Plate 9: Filtering of the coconut milk

3.2.1.3 Settling of the coconut milk

Protein stabilizes the oil-water emulsion that characterizes coconut milk. It is necessary to break the protein bond in coconut milk using heat, enzymes, or another mechanical method to extract the oil. Theextracted coconut milk was allowed to stand in the refrigerator, for a maximum of three hours. After thesettling, coconut skim milk was extracted and it is a very healthy beverage that contains protein and other elements including calcium, potassium, phosphorus, niacin, thiamine, and riboflavin. It can be recovered for human consumption if the setup is done in the refrigerator or ice box. When coconut milkis allowed to settle at room temperature, the skim milk becomes sour and unfit for human consumption.

3.2.1.4 Cream separation

After the settling of the coconut milk, the cream part is separated from the coconut skim milk.The cream was separated by scooping the cream from the top.

3.2.1.5 Slow heating of the coconut cream and oil recovery

A slow heating method was adopted for oil recovery. The oil recovery from coconut cream wasa slow process, and it took more time.

3.2.1.5.1 Stage 1 (Pre-preparatory stage)

An uruli roaster or VCO cooker is used to coagulate the protein and extract the oil from coconut milk. The coconut cream which is separated was placed on the VCO uruli roaster.

Plate 10: VCO Uruli roaster

3.2.1.5.2 Stage 2 (Starting stage)

Coconut cream will start to coagulate and release oil after being slowly heated for two to threehours. It is possible to let the temperature rise to 100 °C during the first hour of heating. LPG was the fuel source for the heater.

The uruli roaster is kept on the flame. First one to two hours it was kept on medium flame. And after that, it was changed to high flame. At this stage temperature is raised to 100°C. During this stage, the moisture of the coconut milk was reduced.

Plate 11: After 30 minutes of heating

Plate 12: After 1 hour of heating

3.2.1.5.3 Stage 3 (Oil separation stage)

After that, the temperature is lowered to 90° C to allowed the protein to coagulate. Oil startedto separate when the temperature dropped to 90 °C. LPG was the fuel source for the heater.

Plate 13: Protein began to coagulate

Plate 14: Continue the coagulation

3.2.1.5.4 Stage 4 (Final stage)

When the VCO cake is evenly turned into a brown colour the gas was turned off and removedthe uruli from the flame.

Plate 15: VCO cake began turns brown

Plate 16: All the VCO cake turns brown

3.2.1.5.5 Stage 5 (Filtration stage)

The mixture is strained through a muslin cloth or stainless-steel mesh to remove the VCO fromthe protein-rich residue (VCO cake). Oil is filtered to remove the adhering fine particles of VCO cake, if any, that have passed through the muslin cloth.

Plate 17: VCO prepared by Hot Process

3.2.1.5.6 Stage 6 (Removal of moisture)

Drying is required to ensure that all residual moisture is removed to prolong the shelf life of the VCO. Drying of the oil can be achieved by placing the extracted oil in a double-walled boiler at 50°C for fifteen minutes to bring the moisture level between 0.1 to 0.2 %

3.2.2 Wet process

The wet method of virgin coconut oil production involves extracting the oil from fresh coconut meat using water or a combination of water and enzymes. The wet method includes different methods like the fermentation method and centrifugation method.

3.2.2.1 Fermentation method

The extraction of virgin coconut oil involves various steps. The procedure of the hot process is obtained from ICAR – CPCRI, Kasaragod (2016). The steps followed for the

extraction of virgin coconut oil by fermentation method consists of the following steps:

3.2.2.1.1 Preparation of coconut for extracting milk

Coconut milk preparation is the first step in all the methods of virgin coconut production.Preparation of coconut milk consists of below steps:

3.2.2.1.1.2 Dehusking of the Coconut

A manual coconut dehusker was used to remove the shell from the coconuts after harvest.

Plate 18: Dehusking

Plate 19: Dehusking

3.2.1.1.1 Weighing of the coconut

Five mature WCT varieties of coconuts are selected for each method of processing of virgin coconut oil. The coconuts were weighed using a weighing balance. The weighing balance was turned on and set preferred measurement i.e., in grams. Placed a small container on the weighing balance and calibrated it to zero. Placed the coconut on the container and recorded the weight displayed on the scale. Three consequent weights were taken from which the average weight was recorded.

Plate 20: Weighing of coconut

3.2.2.1.2 Preparation of coconut milk

Coconut milk preparation is the first step in all the methods of virgin coconut production.Preparation of coconut milk consists of below steps:

3.2.2.1.2.1 Splitting of the coconut

Splitted the coconut into two halves mechanically by using a strong hammer. Removed thecoconut water. It is then cleaned with potable water.

Plate 21: Coconut half

3.2.2.1.2.2 Coconut milk extraction process

Scraped coconut was collected and weighed using a weighing balance. The weighing balance was turned on and set preferred measurement i.e., in grams. Placed a small container on the weighing balance and calibrated it to zero. Placed the scraped coconut on the container and recorded the weight displayed on the scale. Then three consequent weights were taken.

Scraped coconut was fed into a mechanical device that grinds it. Approximately 400 g of scraped coconut was placed in the mixer grinder jar. By using half of the boiled and cooled water ground the scraped coconut. Extracting coconut milk was a crucial step in preparing virgin coconut oil. Coconut milk was extracted by using a cleaned cotton cloth. The ground coconut meat was squeezed using a clean cotton cloth. It is important to maintain hand hygieneto prevent contamination. Hands were washed thoroughly with soap and water after which wore food-grade hand gloves. The coconut milk may contain any residues like small pieces ofcoconut meat etc. So, the coconut milk was filtered to remove these residues.

Plate 22: Scrapped coconut

Plate 23: Preparation of coconut milk

Plate 24: Filtering of the coconut milk

3.2.2.1.3 Settling the coconut milk in a fermentation container

After the coconut milk is extracted, then the milk is let to stand for 20 to 24 hours. The oil naturally separated from the protein and water in the right circumstances. The VCO separationis caused by airborne lactic acid bacteria that operate on the coconut milk mixture and have theability to break protein bonds. To avoid bacteria, mold, or yeast from growing above the coconut milk in the fermentation container, covered it with a loose-fitting cloth once it has beenadded. It is necessary to maintain a fermentation temperature in the vicinity of 35 – 40°C where the fermenting container is situated. Additionally, the area's relative humidity needs to be keptto a maximum of 75%. Food-grade, translucent plastic or glass containers should be used to make the fermentation container. Its large aperture will make it simple to remove the fermentedcurd.

Plate 25: Fermentation process

3.2.2.1.4 Oil Separation

After the settlement period of 20 - 24 hours, four distinct layers were present in the fermentingcontainer. The sticky sediment was the lowest layer. The fermented skim milk layer is the following layer. Skim milk that has lost its nutritional value for human consumption. The subsequent layer was extracted to recover the VCO. The floating fermented curd was the top layer. There's also a good amount of trapped oil in the fermented curd. By carefully, separatingthe distinct layers, the oil can be separated. By the careful adjustment of the knobe of the separating funnel, the different layers can be

separated into different vessels.

Plate 26: Oil separation

3.2.2.1.5 Filtration

The separated oil was filtered. Because it had some adhering fermented curd particles. The filtration process was done by using sterile cotton wool, filter paper, or filter cloth in a large funnel's opening.

Plate 27: Filtering

3.2.2.1.6 Drying

Drying is required to ensure that all residual moisture was removed to prolong the shelf life ofthe VCO. The extracted oil was placed in a double-walled boiler at 50°C for fifteen minutes tobring the moisture level between 0.1 to 0.2 %.

Plate 28: VCO prepared by fermentation method

3.2.2.2 Centrifugation method

The virgin coconut oil extracted by centrifugation method was done at Aashaan & Co. Coconut Product, Calicut, Kerala, and collected the same for in-depth study. The procedure was given from coconut development board.

3.2.2.2.1 Preparation of coconut for milk

Coconut milk preparation was the first step in all the methods of virgin coconut production. Preparation of coconut milk consists of the following steps:

3.2.2.2.1.1 Weighing of the coconut

Five mature WCT varieties of coconuts were selected for each method of processing of virgincoconut oil. The coconuts were weighed using a weighing balance. The weighing balance was turned on and set preferred measurement i.e., in grams. Placed a small container on the weighing balance and calibrated it to zero. Then placed the coconut on the container and recorded the weight displayed on the scale. Three consequent weights were taken.

3.2.2.2.1.2 Deshelling

Deshelling is the process of removing the hard fibrous outer shell of the coconut to access theedible part. The process is done by manual method using a hammer.

3.2.2.2.1.3 Testa removal

Testa is the outer brown skin of the white coconut meat. Before preparing virgin coconut oil, the testa of the coconut kernel was removed to ensure that the resulting coconut oil was pure and free from any impurities. The testa removal can be done manually. Peeled off the thin brown layer from the white kernel using a knife. The white coconut meat was thoroughly rinsed with potable water and removed remained testa particles and also removed the impurities present in it.

Plate 29: Testa removal process

Plate 30: Testa removed coconut

3.2.2.2.2 Preparation of coconut milk

A coconut milk extractor is a machine used to separate coconut milk and low-fat coconut wet powder from shredded coconut. Testa removed white coconut meat was cut into small pieces and weighed by using a weighing machine. The weighing balance was turned on and set preferred measurement i.e., in grams. Placed a small container on the weighing balance and calibrated it to zero. Then placed the testa removed small pieces of coconut meat on the container and recorded the weight displayed on the scale. Three consequent weights were taken. It was added to the machine. Extracted the coconut milk from the pulp and collected themilk in a separate container.

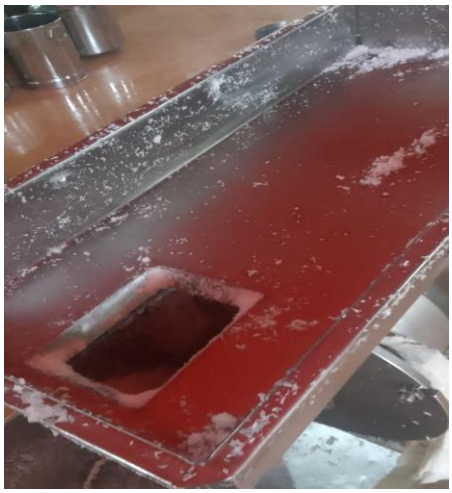


Plate 31: Coconut milk extractor

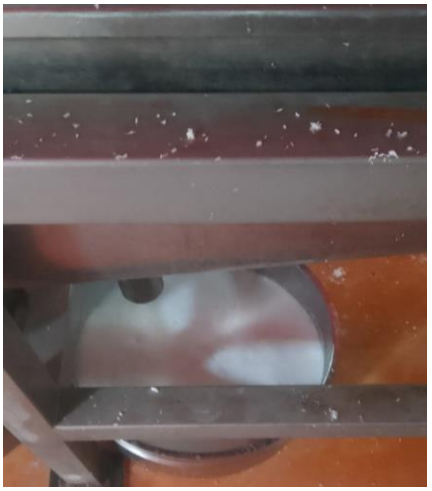


Plate 32: Extracted coconut milk

3.2.2.2.3 Cream separation

In the centrifugation method, the Virgin coconut oil was extracted by using a VCO centrifuging machine. The coconut milk was agitated for 15 minutes with a rotator. After removing the top layer of cream from the water layer, it was taken out and allowed to stored in the refrigerator overnight.

Plate 33: Cream separation

3.2.2.2.4 Oil Separation

The next day, after 20-24 hr the separated cream layer was centrifuged for 45 minutes at 6,000 rpm to isolate the virgin coconut oil from the aqueous layer. After three cycles of centrifugation,the virgin coconut oil was obtained.

Plate 34: VCO Centrifuging machine

Plate 35: Centrifugation process

Plate 36: VCO prepared by centrifugation method

3.3 Determination and comparison of yield of virgin coconut oil by different processing methods

Oil Yield refers to the amount of oil that can be derived from a nut or oilseed. It is usually represented as a % (eg., 50% by weight of coconut). The yield of the process was calculated based on the volume of VCO obtained compared to the volume of the coconut scrapped used,based on the below equation:

Yield = (Weight of extracted oil ÷ Weight of the scrapped coconut) × 100

3.4 Determination and comparison of sensory and physicochemical properties of virgin coconut oil by different processing methods

3.4.1 Aroma

"Sensory evaluation" is a scientific field that measures analyzes, and interprets responses to food and material features. They are experienced by the five senses such as sight, smell, taste,touch, and hearing (McSweeney and Gambaro, 2020).

The sensory evaluation was done by a sensory panel of 10 people consisting of staff at the Coconut Development Board Institute of Technology.

The virgin coconut oil was obtained by three different methods such as the dry method, fermentation, and centrifugation methods, which were evaluated by sensory evaluation. The active components that give various flavors are the essential oils (EOs) extracted from oil. Thereason APEOs are used so widely is because of their taste features and various odor-sensory properties. The developed products' acceptance of sensory attributes i.e. aroma was estimated using a numerical scoring test. A scale from 1–9 was used for the sensory evaluation. The 9-point hedonic rating scale used here is depicted in Table 1.

Table 3: 9-point hedonic rating scale

MARKS	DEGREE OF PREFERENCE
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 products for sensory evaluation were taken on separate transparent bottles and labeled as S1, S2, and S3. So, the panel members do not have any idea about the method of processing. It was presented to the panel members for evaluating aroma. The evaluation takes place in a peaceful space. The samples were placed on the table with respective pseudo labels. The panelists evaluated the samples and marked them in the hedonic scale provided to them.

3.4.2 Colour

Lovibond Universal Tintometer Model was used to determine, the colour of the VCO sampleswas assessed under the procedure outlined in the ISI of Food Analysis and IS 548 (part 1). The Lovibond scale (Y+5R) was used to express the colour value. The Lovibond scale was used formeasuring the colour of oils and fats.

- The desired size of the glass cell was cleaned with carbon tetrachloride and allowed todry.
- Filled it with the oil and placed the cell in position in the tintometer.
- Through adjusting the red, yellow, and blue bands of colour by slided the colour bands.Match the colour with colour of the sample.
- Reported the colour of the oil in terms of Lovibond units as follows:Colour reading = (a Y + 5 b R) or (a Y + 10 b R) in (*cell)

  Where,

  a = Sum total of the various yellow slides (Y) used

b = Sum total of the various red (R) slides used

Y + 5 R is the mode of expressing the colour of the light-colored oils

(ISI Handbook of Food Analysis, 1984 and IS 548 (part 1) – 1964, Methods of sampling andtest for Oils and Fats)

3.4.3 Moisture

According to AOAC (2000), and ISI of Food Analysis (1984) moisture of virgin coconut oilwas determined by this method:

- Two properly dried dishes were selected and the dish was placed on a weighing balanceand tared.
- Mixed the oil thoroughly by stirring.
- Weighed 5 – 10g of oil into the previously dried and tared dish.
- The dish was heated in an oven at 105 + / - 1^0 C for 1 h.
- Loosen the lid of the dish while heating.
- After heating, removed the dish from the oven and closed the lid.
- Placed in a desiccator containing phosphorus pentoxide or equivalent desiccant andcooled. Then weighed.
- Again, heated in the oven for a further period of 1 h, cool, and weighed
- Repeated this process until a change in weight between two successive observationsdoes not exceed 1 mg.
- Carried out the determination in duplicate.

The following formula was used to calculate the moisture and volatile matter content:

Moisture and volatile matter percentage = (W1 × 100) ÷ W

Where,

W1 = Loss in weight (g) of the

material on dryingW = Weight

in g of the material taken for test

(AOAC, 2000, and ISI Hand book of Food Analysis (part XIII) – 1984)

3.4.4 Acid value

The acid value is the number of milligrams of potassium hydroxide required to neutralize the free acids present in 1 gram of the substance. The triacylglycerols breakdown into free fatty acids and it negatively affects the quality of the substance i.e., virgin coconut oil. Oxidation ofany substance like triacylglycerols increases the acid value and got spoil and decreases the quality of the product. In the case of oils, it is an indicator of oxidation of oil which leads to gum and sludge formation besides corrosion. (Sharma & Jain, 2015)

The standard method of the Association of Official Agricultural Chemists (AOAC), ISI Handbook of Food Analysis, IUPAC, IS:548, and ISO 660 was utilized to evaluate the free fatty acid (FFA) content of the VCO.

- Mixed the oil thoroughly.
- Weighed 5g of oil in a 250 ml conical flask.
- Add 50 ml of freshly neutralized hot ethyl alcohol.
- Add 1 ml of phenolphthalein as an indicator.
- Heated the mixture at 75 to 85 ^{o}C for about 15 minutes in the water bath
- Titrated the heated solution while hot against alkali solution taken in the burette. It isimportant to shake vigorously during the titration.
- The endpoint is from colorless to light pink color and it persists for 15 seconds.

The acid value is calculated by the equation:

Acid value = $(56.1 \times V \times N) \div W$

V = Volume in ml of standard potassium hydroxide or sodium

hydroxide solution usedN = Normality of standard potassium

hydroxide or sodium hydroxide solution

W = Weight in g of the material taken for the test.

(ISI Handbook of Food Analysis, 1984., IUPAC (1979)., IS:548 (part 1)1964, methods of sampling and test for oils and fats., ISO 660:1996 Determination of acid value and acidity., andAOAC, 2000)

3.4.5 Iodine value

The iodine value is the measure of the degree of unsaturation of an oil. The amount of iodine in grams taken up by 100 grams of oil. Saturated oil or fat does not take up any iodine and their iodine value are zero. In the case of unsaturated fatty acids, they contain double or triple bonds,so they are more reactive and take up more iodine according to their bonds and their iodine value is also higher. The higher iodine number indicates that the substance is more reactive, less stable and high chance of oxidation and becoming rancid oil. (The Editors of Encyclopaedia Britannica, 1998)

Wijs technique (AOCS, 2004) was used to determine the VCO's iodine value (IV).

- Weighed accurately an appropriate quantity of the dry oil into a 500 ml glass stopperedconical flask
- 25 ml of carbon tetrachloride has been added to the sample and mix the contents well.
- Pipetted 25 ml of Wijs solution and added to the conical flask. Replaced the glassstopper after wetted with potassium iodide solution.
- Swirl for proper mixing and kept the flasks in the dark for 30 min for non-drying andsemi-drying oils and one hour for drying oils.
- Carry out a blank simultaneously.
- After standing, add 15 ml of potassium iodide solution, followed by 100 ml of recentlyboiled and cooled water, rinsed in the stopper also.
- Add 3ml of starch as an indicator.
- Titrated the liberated iodine with standardized sodium thiosulphate solution until theblue colour formed disappears after thorough shaked with the stopper on.
- Conducted blank determinations in the same manner as a sample but without oil.
- Blank and determination are made at the same time.

The following formula was used to calculate the iodine value,IV = (12.69 × (B - S) × N of $Na_2S_2O_3$) ÷ W

Where,

B = Volume in ml of standard sodium thiosulphate solution

required for the blankS = Volume in ml standard sodium

thiosulphate solution required for the sample N = Normality of

the standard sodium thiosulphate solution

W = Weight in iodine per 100 g oil

3.5 Assessment of lauric acid content of virgin coconut oil produced by different methods.

The primary fatty acid of coconut oil is lauric acid, which is present at approximately 45-53%. The metabolic and physiological properties of lauric acid account for many of the properties of coconut oil. Coconut oil is rapidly metabolized because it is easily absorbed and lauric acid iseasily transported.

Detailed studies have shown that the majority of ingested lauric acid is transported directly to the liver where it is directly converted to energy and other metabolites rather than being stored as fat. Such metabolites include ketone bodies, which can be used by extrahepatic tissues, suchas the brain and heart, as an immediate form of energy. Studies on the effect of lauric acid on serum cholesterol are contradictory. Among saturated fatty acids, lauric acid has been shown to contribute the least to fat accumulation. Lauric acid and monolaurin have demonstrably significant antimicrobial activity against gram-positive bacteria and several fungi and viruses. Today many commercial products use lauric acid and monolaurin as antimicrobial agents. (Dayrit, 2014)

The analysis was done at the Environmental services laboratory. The standard method of the Association of Official Agricultural Chemists (AOAC), ISI Handbook of Food Analysis, IUPAC, IS:548, and ISO 660 was utilized to evaluate the free fatty acid (FFA) content of the VCO.

- Mixed the oil thoroughly.
- Weighed 5g of oil in a 250 ml conical flask.
- Add 50 ml of freshly neutralized hot ethyl alcohol.
- Add 1 ml of phenolphthalein as an indicator.
- Heated the mixture at 75 to 85 ^{o}C for about 15 minutes in the water bath
- Titrated the heated solution while hot against the alkali solution taken in the burette. Itis important to shake vigorously during the titration.
- The endpoint is from colorless to light pink color and it persists for 15 seconds.

The lauric acid was calculated by the equation:Acid value = (20×V×N) ÷ W

V = Volume in ml of standard potassium hydroxide or sodium hydroxide solution usedN = Normality of standard potassium hydroxide or sodium hydroxide solution

W = Weight in g of the material taken for the test.

(ISI Handbook of Food Analysis, 1984., IUPAC (1979)., IS:548 (part 1)1964, methods of sampling and test for oils and fats., ISO 660:1996 Determination of acid value and acidity., andAOAC, 2000)

3.6 Assessment of antioxidant activity in terms of vitamin E content of virgin coconut oilproduced by different methods

Vitamin E is the primary lipid-soluble antioxidant. It is only obtained from the diet. Because of its antioxidant properties, it shows various vital tasks in the body. It is beneficial against oxidation and is connected to various diseases like cancer, aging, arthritis, and cataracts. Vitamin E may also help to prevent the synthesis of prostaglandins like thromboxane, which promote platelet clumping, as well as platelet hyperaggregation, which can contribute to atherosclerosis. (Rizvi et al., 2014)

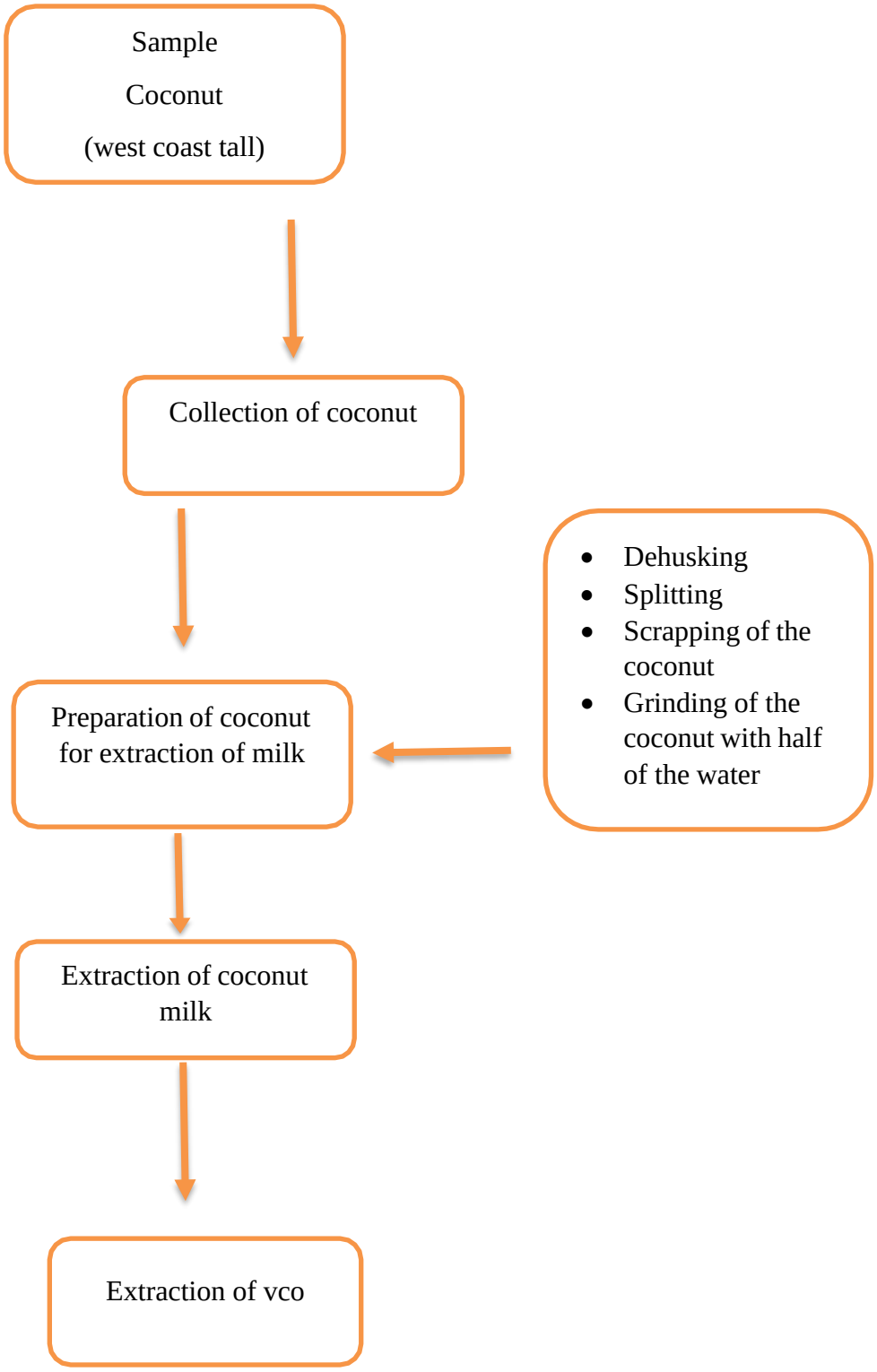
The analysis of vitamin E was done at the Environmental services laboratory. Vitamin V was determined by using a spectrophotometer. The procedure was done according to Tütem et al. (1997). The procedure for determining vitamin E is given below:

- Prepare a homogeneous sample ready for examination.
- To make a calibration curve, prepare standard solutions with known vitamin Econcentrations. This curve will assist in calculating the sample's vitamin E content.
- Follow the manufacturer's setup instructions for the spectrophotometer. For vitaminE analysis, select the proper wavelength, which is often about 280 nm.
- To account for any solvent interference, measure the solvent's baseline absorbance(devoid of the sample).
- Calculate the sample's absorbance at the selected wavelength. Note the absorbancereadings.
- Based on the sample's absorbance, use the calibration curve to calculate the amountof vitamin E present.
- Using the acquired absorbance value and the calibration curve, the concentration of vitamin E in the virgin coconut oil sample was determined.

3.7 Determination of stability during storage

The virgin coconut oil was stored in a clean and sterilized bottle. It was covered with a dark- colored cotton cloth to prevent light, and it was covered with a clean wrap to prevent air contact.These bottles were kept in the cupboard which is away from light. After stored for 4 weeks (1 month), the quality of the oils was assessed after 1-month period of storage. The AOCS method was used to analyze the oils' moisture content and acid value given in the page no: 43 & 44.

The figure given below depicts the research design of the study entitled "*Properties of VirginCoconut Oil from West Coast Tall Coconut Processed by Different Methods".*



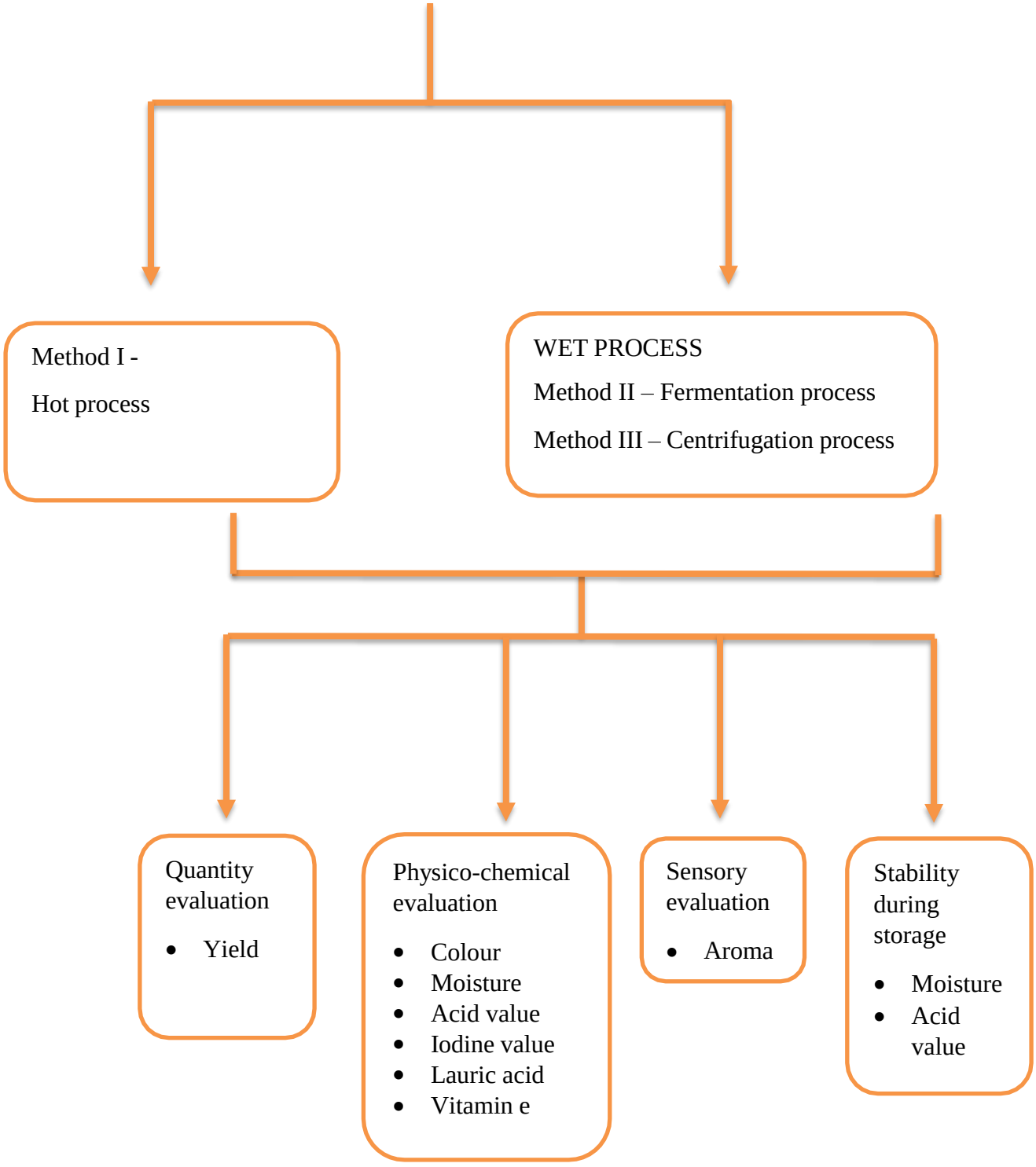


Figure 1: Research Design

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

Results and discussion of the present study entitled "***Properties of Virgin Coconut Oil from West Coast Tall Coconut Processed by Different Methods***" was undertaken to compare the properties of Virgin Coconut oil extracted by different methods such as hot process, fermentation process, and centrifugation process from the coconut variety West Coast Tall.The results of the study are discussed under the following headings;

4.1 Yield of virgin coconut oil from West Coast Tall coconut variety obtained by differentprocessing methods

4.2 Evaluation and Comparison of sensory and physicochemical properties of virgin coconutoil (VCO) obtained by different processing methods.

4.3 Lauric acid content of virgin coconut oil obtained by different processing methods

4.4 Vitamin E content of virgin coconut oil obtained by different processing methods

4.5 Evaluation of stability during storage of one month of virgin coconut oil extracted bydifferent methods.

4.6 Evaluation of potential benefits and drawbacks of each processing method in terms oftime and energy requirements

4.1 Yield of virgin coconut oil from West Coast Tall coconut variety obtained bydifferent processing methods

Virgin coconut oil (VCO) was extracted from coconut variety West Coast Tall by different three methods such as Hot process, Fermentation process, and Centrifugation process are evaluated. The yield obtained by different extraction processes is given in Table 4.

Table 4: Yield of virgin coconut oil by different methods.

Method of separation	**Hot Process**	**Fermentation method**	**Centrifugatio nmethod**
Weight of the coconut (g)	2062.95	1666.6	2030.28
Weight of scrapped coconut (g)	1000.60	823.4	1035.45
Weight of extracted oil (g)	213	128	212
Yield (%)	**21.29**	**15.54**	**20.47**

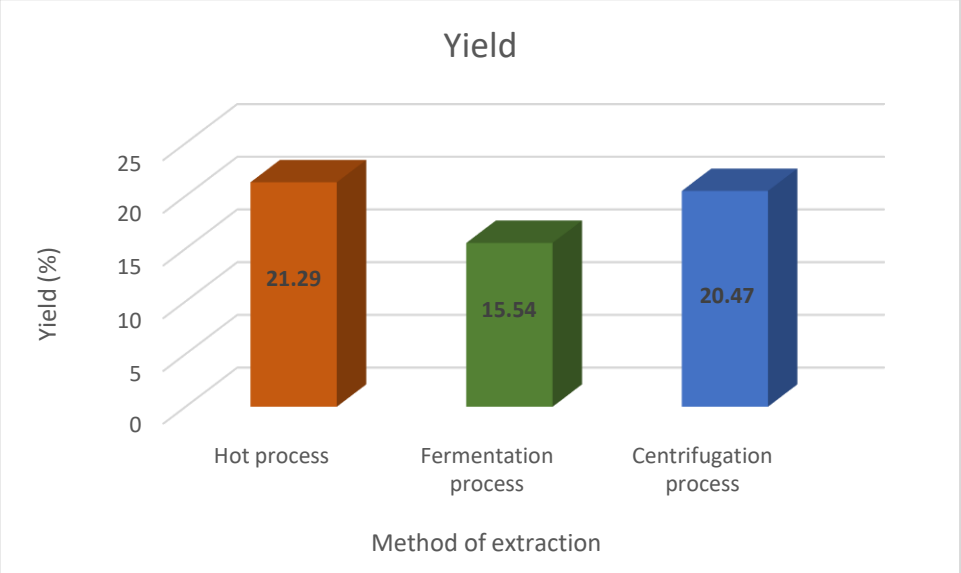


Figure 38: Yield of the virgin coconut oil extracted by different processes

From the above table, it is clear that there was variation in oil recovery depending on processing methods. The highest oil recovery (21.29%) was found in the hot process followed by the centrifugation process (20.47%) and low oil recovery (15.54%) was obtained in the fermentation method. The result suggested that the yield of virgin coconut oil depends on the method of extraction.

To extract the oil in hot process coconut milk was heated. In comparison to other techniques, the heat aids in the oil's separation from the coconut milk, producing a comparatively high yield. The process of fermentation entails letting the coconut milk spontaneously ferment for a while. Enzymes disintegrate the solid coconut during this process, releasing the oil. Although fermentation is a conventional procedure, it usually produces less oil than the heated approach. To separate the oil from the particles, centrifugation is used to spin coconutmilk at high speeds.

In conclusion, the data show that different extraction processes result in varying yields of virgin coconut oil, with the hot process and centrifugation process typically yielding larger yields than the fermentation method.

A comparative analysis of virgin coconut oil yield was conducted on oil extracted from coconuts at three distinct stages of maturity: immature (IMC), mature (MC), and overlay mature (OMC). VCO from OMC had a high recovery rate, followed by those from MC and IMC, in that order. The maturity stage plays an important role in the production yield of virgin coconut oil but it is not influenced by the quality parameters of the virgin coconut oil such as fatty acid composition and physicochemical properties (Patil U et.al,2016).

4.1.1 Evaluation and Comparison of sensory and physicochemical properties of virgin coconut oil (VCO) obtained by different processing methods.

4.1.2 Aroma

The aroma of virgin coconut oil affects the acceptability of the oil by the people. The different process of extraction of virgin coconut oil gives virgin coconut oil contains different kinds of aromas. The scores obtained for sensory evaluation by10 panelists are given in Table 5.

Table 5: Sensory evaluation scores of the aroma from VCO extracted from different methods

Panelists	Hot Process (9)	Fermentation process (9)	Centrifugatio nprocess (9)
Panelists 1	9	7	8
Panelists 2	9	7	9
Panelists 3	9	8	9
Panelists 4	9	7	9
Panelists 5	9	8	9
Panelists 6	9	7	8
Panelists 7	9	8	9
Panelists 8	9	8	9
Panelists 9	9	7	8
Panelists 10	9	8	9
Mean Scores	**9**	**7.5**	**8.7**
Interpretation	Good and strong aroma	Not good as compared to other methods.	Good and mild aroma

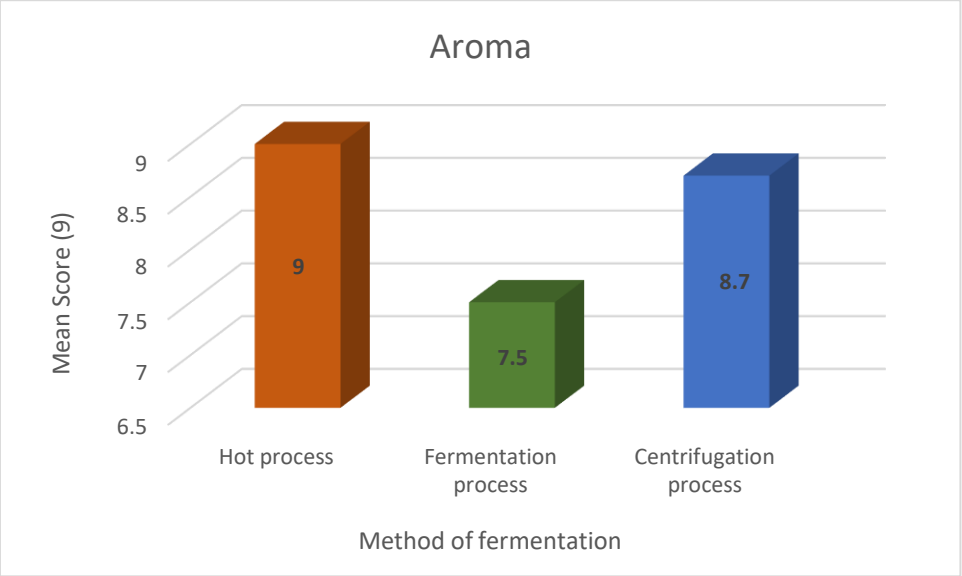


Figure 39: Aroma of the virgin coconut oil extracted by different processes

From the above table and graph, it is clear that mean scores obtained for aroma were different depending on processing methods. The panelists gave high scores for the hot process with an overall score of 9 followed by the centrifugation method having an overall score of 8.7, while the fermentation method got an overall score of 7.5.

The virgin coconut oil extracted by the fermentation method was found to be less acceptablefor consumption due to the off flavour of the oil. The hot process has a good and strong aroma due to the activation of the heat. The aroma of this oil was reported to be highly acceptable for consumption. The reason was attributed to the aroma of the hot processed virgin coconut oil has a small similarity to the copra oil. The aroma of virgin coconut oil extracted through the centrifugation process has a good and mild aroma and was acceptablefor consumption.

4.1.3 Colour

The colour of virgin coconut oil (VCO) that was extracted from coconut variety West CoastTall by different three methods such as Hot process, Fermentation process, and Centrifugation process were evaluated.

Colour is one of the important physical characteristics for the quality checking of virgin coconut oil. The Lovibond scale was used for evaluation. This scale gives a red and

yellow scale with zero or near-zero values. This suggests that these oils are suitable for use and havenot undergone any oxidation process (Ghazali et al., 2009).

The colour of the virgin coconut oil obtained in the different extraction processes is given inTable 6.

Table 6: The colour of the virgin coconut oil extracted from different processes.

Parameters	Hot Process	Fermentation	Centrifugation
Coloured/ Colourless	Coloured	Colourless	Colourless
Colour	Pale yellow	Similar to water	Similar to water
Color scale(Lovibond scale)	**1**	**0**	**0**

Plate 30: Colour of the VCO by Hot process, Fermentation process, Centrifugation process

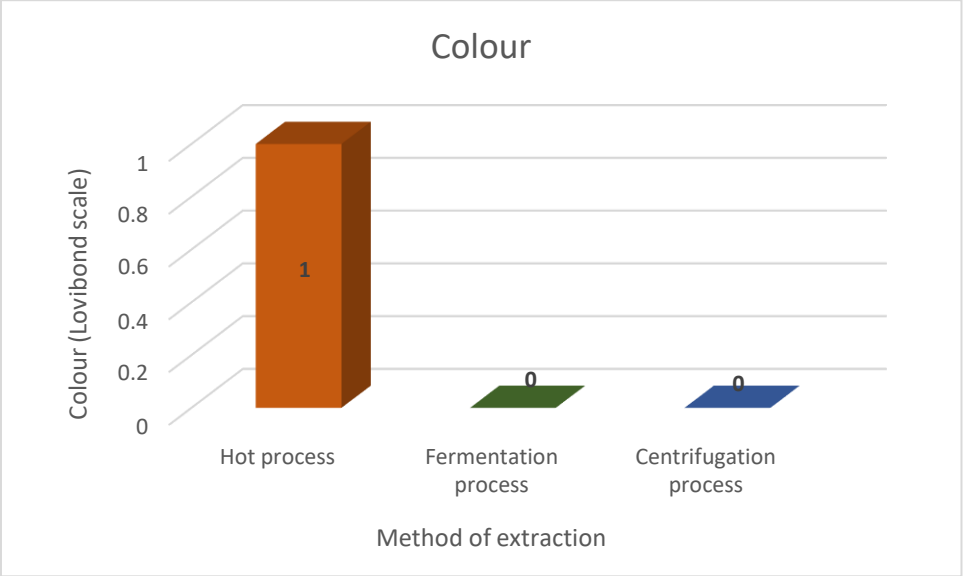


Figure 40: Colour of the virgin coconut oil extracted by different processes

From the above table and graph, it is clear that colour of the virgin coconut oil varied depending on processing methods. The virgin coconut oil obtained by Hot process was coloured, which shows a pale-yellow colour. The Lovibond scale gives scale value one, which means sum total of the yellow slides gave one and sum total of red slide gave zero. The hot processed virgin coconut oil shows pale yellow colour, so the Lovibond scale scoresone for the oil.

The virgin coconut oil processed by fermentation method and centrifugation method were colourless and similar to water. Which means sum total of the yellow slide and red slide of the Lovibond scale gave zero. Virgin coconut oil obtained by fermentation process and centrifugation process gave colorless virgin coconut oil and the Lovibond scale gives zero scores.

According to Patil U et.al (2016), comparative analysis conducted on the qualities and physico-chemical characteristics of virgin coconut oil (VCO), which was extracted from coconuts at three distinct stages of maturity: immature (IMC), mature (MC), and overlay mature (OMC), every VCO sample had a look similar to water.

Hot extracted virgin coconut oil (HVCO), cold extracted virgin coconut oil (CVCO), and coconut oil (CO) are tested and analysed the various quality parameters. Color have significantly ($p<0.0001$) affected by various techniques (Satheeshan et al., 2019).

4.1.4 Moisture

Immediately after extracting the oil moisture analysis was done. Duplicates of the sample were taken and moisture analysis was performed simultaneously. Moisture level in the extracted coconut oil affects the storage quality of the virgin coconut oil. The moisture levelin the differently extracted virgin coconut oil is given in the below table 7.

Table 7: The moisture content (%) of the virgin coconut oil by different methods.

Methods of extraction	Moisture (%)
Hot Process	
Sample 1	0.1396
Sample 2	0.1296
Average value	**0.13**
Fermentation process	
Sample 1	0.1817
Sample 2	0.1747
Average	**0.18**
Centrifugation process	
Sample 1	0.1435
Sample 2	0.1432
Average	**0.14**

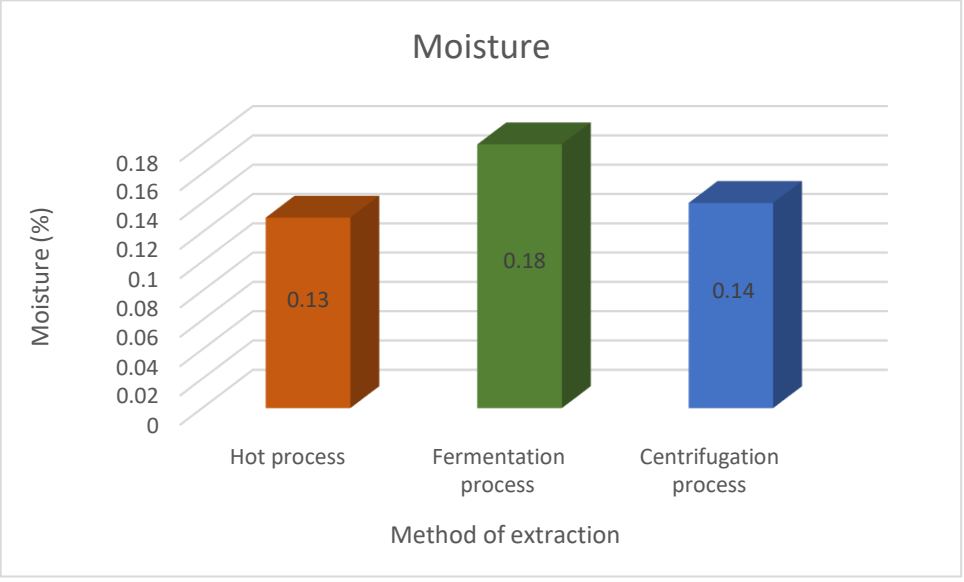


Figure 41: Moisture of the virgin coconut oil extracted by different processes

From the above tables and graph, it is clear that variation in moisture level depends on processing methods. The lowest moisture level was found in the virgin coconut oil obtainedby the hot process and the moisture level was 0.13% followed by the centrifugation method,0.14%. Higher moisture was obtained in the fermentation method and the moisture level was 0.18%. The lowest moisture level is optimum for virgin coconut oil. Here, the virgin coconutoil obtained by the hot process has the lowest moisture level.

The permitted level of moisture in APCC criteria of quality characterestics for virgin coconut oil is 0.1%. Moisture level from 0.1 to 0.2% is allowed. As per FSSAI allowed moisture level is up to 0.5 %. The moisture content of the three samples of virgin coconut oils is foundto be within the permitted level.

Due to the application of heat in the hot process, the moisture level in virgin coconut oil is comparatively low as compared to the other two methods. The moisture level of virgin coconut oil extracted by the hot process is 0.13%. The comparatively low moisture level indicates that moisture is successfully extracted from the oil using this approach. The moisture level in the fermentation method of virgin coconut oil is comparatively high as compared to other methods. The moisture level of virgin coconut oil extracted by the fermentation method is 0.18%. The higher moisture content in fermentation process than hot process may indicate that some moisture remains in the oil after extraction. The moisturelevel is high in the fermentation method, it is mainly due to the method of processing and the duration of the filtration process to extract pure and clear virgin coconut oil. The moisture level in centrifuged virgin coconut oil is 0.1433%. To separate the oil, centrifugation is used to spin coconut milk at high speeds. The high centrifugation force removes the moisture content from the virgin coconut oil. The moisture level is relatively low, similar to the hot procedure, indicating effective moisture removal during extraction. When compared to the fermentation method, the hot process and centrifugation process typically produce coconut oil with a lower moisture content.

According to Satheeshan et.al., (2019), hot-extracted virgin coconut oil (HVCO), cold- extracted virgin coconut oil (CVCO), and coconut oil (CO) are tested and analyzed the various quality parameters. Moisture has a significantly ($p<0.0001$) effect on various techniques.

4.2.4. Acid Value

The number of milligrams of potassium hydroxide required to neutralize the free acid present in one gram of the oil or fat under the prescribed conditions was determined. The acidity of the oil or fat indicated by its acid value is frequently expressed as free fatty acidspresent in the sample

Acid value is related to the moisture content of the virgin coconut oil and it denotes the quality of the virgin coconut oil. A higher acid value indicates a higher concentration of freefatty acids and an indicator of oil quality. Acid value is one of the important parameters forthe quality of the VCO. The acid value of the virgin coconut oil extracted by different methods is given in Table 8.

Table 8: The acid value of the virgin coconut oil extracted by different processes.

Method of extraction	**Acid value**
Hot Process	**0.24**
Fermentation process	**0.37**
Centrifugation process	**0.24**

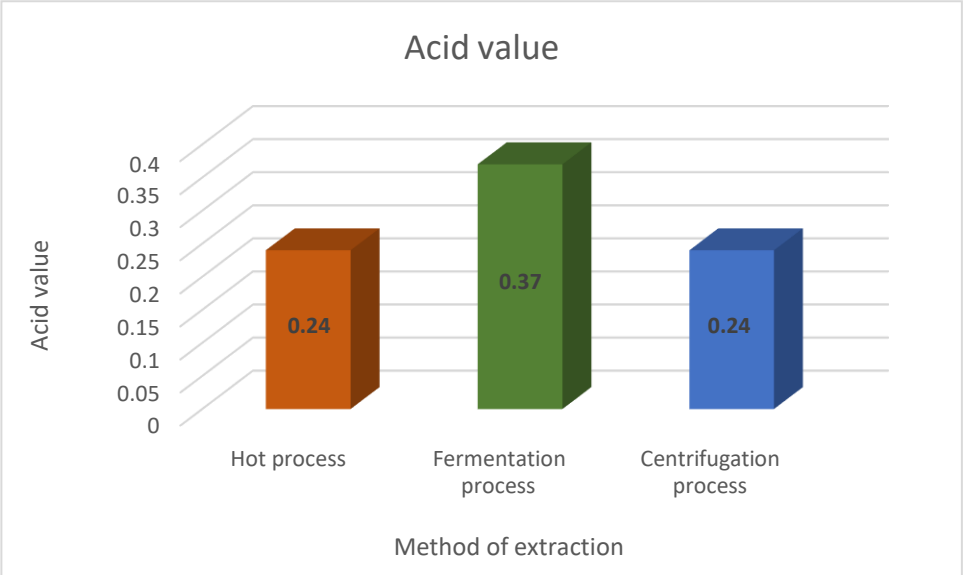


Figure 42: Acid value of virgin coconut oil processed by different methods

From the above table and graph, it is clear that variation in acid value depending on processing methods.. The acid values of virgin coconut oil extracted by different processes the hot process, the fermentation process, and the centrifugation process are 0.24, 0.37, and 0.24 respectively.

The permitted level of acid value in FSSAI criteria of quality characterestics for virgin coconut oil is up to 4. The acid value of the three samples of virgin coconut oils is found tobe under the permitted level.

Acid value indicates the oxidation of triacylglycerols. Increased acid value shows that the oil get spoil easily and it affects the quality of the product. Here the virgin coconut obtained by fermentation method had a higher acid value (0.37) as compared to other method indicating this oil has a higher chance to got spoil.

According to Seneviratne et al. (2002), coconut oil extracted by wet methods often has less free fatty acid content than coconut oil made using dry methods. The amount of free fatty acids or the acid value given by the producers of virgin coconut oil is about 0.02% as lauricacid. The acid value of commercial coconut oil generated by pressing copra (CO) is significantly higher than that of coconut oil extracted by boiling coconut milk (TCO) (0.31

$\pm$ 0.10 vs 2.51 $\pm$ 0.34 mg KOH/1g oil: P = 0.0036).

According to Seneviratne K & Jayathilaka N. (2016), free fatty acids are created by hydrolysing the triglycerides of coconut oil. An oil's acid value indicates how much free acid is contained in the fat. Triglycerides make up the majority of oil's composition. As a result of the lipase enzyme's action, these triglycerides hydrolyze to produce free fatty acids. Microorganisms or broken cells or tissues from the coconut oil extraction process can be the source of the enzyme. Coconut oil that has been extracted fresh has no acidity. An indication of aged oil is its acidity. Because of inadequate coconut oil extraction and storage practices, the hydrolysis of oil can produce free acid more quickly.

Hot extracted virgin coconut oil (HVCO), cold extracted virgin coconut oil (CVCO), and coconut oil (CO) are tested and analysed the various quality parameters. The analysis was takes place to determine whether there is variation in acid value among the

different methods of its production. While the acid value did not change significantly among samples (Satheeshan et al., 2019).

4.2.5. Iodine Value

According to Seneviratne K & Jayathilaka N. (2016) iodine value, also known as iodine number, is the amount of iodine in grams needed to saturate 100 g of oil. The degree to which the fatty acids in oils are unsaturated is indicated by the iodine value. An oil's high level of unsaturation is indicated by a high iodine value because iodine reacts with the doublebonds of fatty acids.

The iodine value in the differently extracted virgin coconut oil is given in below table 9.

Table 9: Iodine value of the virgin coconut oil extracted by different processes.

Method of extraction	Iodine value
Hot process	**6.14**
Fermentation process	**6.53**
Centrifugation process	**5.97**

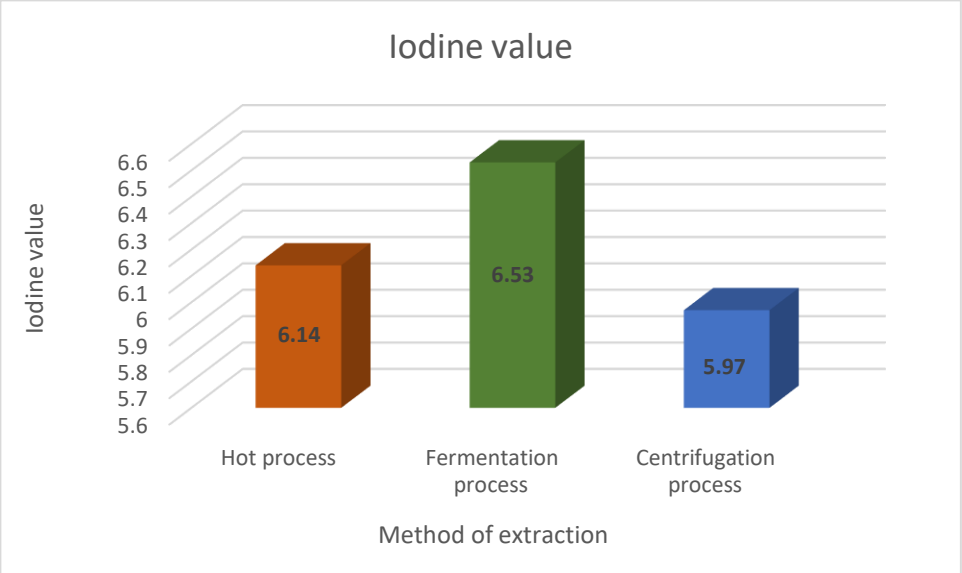


Figure 43: Iodine value of virgin coconut oil processed by different methods

From the above table, variation in iodine value depending on processing methods. The iodine values of virgin coconut oil extracted by different processes the hot process, the fermentation process, and the centrifugation process are 6.14,6.53, and 5.97 respectively.

The permitted level of iodine value in APCC criteria of quality characterestics for VCO and FSSAI criteria of quality characterestics for VCO is in the range of 4 to 11. The iodine valueof the three samples of virgin coconut oil comes under this permitted level.

The higher iodine value gives an idea about the proportion of unsaturated fatty acids, and it is more susceptible to oxidation and rancidity. Here, virgin coconut oil obtained by fermentation method had a higher iodine value and more chance of oxidation and rancidity.

The iodine value of virgin coconut oil does not change with the method of extraction, but itis affected by the quality of the coconut used for the production of virgin coconut oil. If the same quality coconut is used for the process, then the iodine value is comparatively the same(Seneviratne K & Jayathilaka N., 2016).

Commercial virgin coconut oil collected from the Malaysian and Indonesian markets was tested and compared. In this study, the Iodine value ranged from 4.47 to 8.55. this iodine value indicates that only a few unsaturated bonds are present in the virgin coconut oil (Hamid, 2015).

Hot-extracted virgin coconut oil (HVCO), cold extracted virgin coconut oil (CVCO), and coconut oil (CO) are tested and analysed the various quality parameters. The analysis was takes place to determine whether there is variation in iodine value among the different methods of its production. While the iodine values did not change significantly among samples (Satheeshan et al., 2019).

4.3 Lauric acid content of virgin coconut oil from West Coast Tall coconut variety obtained by different processing methods

One kind of medium-chain fatty acid that predominates in coconut oil is lauric acid. Lauric acid transforms into monolaurin in the body, which increases its usefulness for preserving health (Enig 1999). Lauric acid has also been linked to reducing cholesterol levels, encouraging weight loss through increased energy expenditure, and boosting the health of skin and hair because of its nourishing and moisturizing qualities. Three different forms of lauric acid, 1-monolaurin, and 2-monolaurin can be produced from VCO. These substancesare known to have superior antibacterial lipids and contain both hydrophilic and lipophilic groups. Moreover, broad-spectrum inhibitory properties make lauric acid and monolaurin useful as antiviral, antifungal, and antibacterial agents. Gram-positive bacteria, particularly.

S. aureus, fungi like C. albicans, and viruses like the vesicular stomatitis virus (VSV), and herpes simplex virus (HSV) can all be effectively destroyed by lauric acid and monolaurin (Nitbani et al., 2022).

The lauric acid level of virgin coconut oil (VCO) was extracted from coconut variety West Coast Tall by different three methods such as Hot process, Fermentation process, and Centrifugation process are given in Table 10.

Table 10: Lauric acid content in VCO

Method of separation	**Lauric acid content (%)**
Hot Process	**0.5**
Fermentation method	**0.6**
Centrifugation method	**0.5**

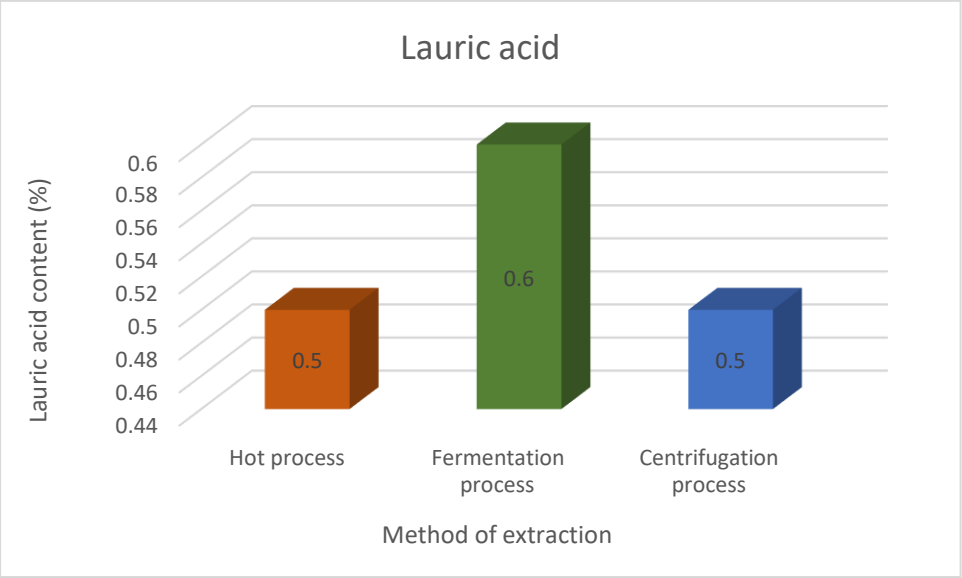


Figure 44: Lauric acid content of virgin coconut oil processed by different methods

From the above table and graph, it is clear variation in lauric acid content depending on processing methods. Higher concentrations of Lauric acid content are found in virgin coconut oil that is extracted using a fermentation process (0.6%), followed by a hot processand centrifugation process (0.5%).

The high concentration of lauric acid, a medium-chain fatty acid with several health advantages, found in virgin coconut oil is well known. The strong antibacterial, antiviral, and antifungal qualities of lauric acid make it effective in boosting immunity and warding off diseases.

A comparative analysis was conducted on the qualities and physico-chemical characteristics of virgin coconut oil (VCO), which was extracted from coconuts at three distinct stages of maturity: immature (IMC), mature (MC), and overlay mature (OMC). The virgin coconut oil contained medium chain fatty acids (MCFA), with lauric acid (C12:0) accounting for themajority of the fatty acid content (49.74–51.18 g/100 g) (Patil U et.al ,2016).

A comparative analysis was conducted on the qualities and physico-chemical characteristics of virgin coconut oil (VCO), which was extracted from coconuts at three distinct stages of maturity: immature (IMC), mature (MC), and overlay mature (OMC). The maturity stage plays an important role in the production yield of virgin coconut oil but

it is not influenced to the quality parameters of the virgin coconut oil such as fatty acid composition and physicochemical properties. The lipid hydrolysis and oxidation is low and it denotes that thematurity stage is not influences the oil oxidative stability (Patil U et.al ,2016).

A study was conducted to identify saturated and unsaturated fatty acids in crude palm oil (CPO), cocoa beans, virgin coconut oil (VCO), and palm kernel seeds by using gas chromatography (GC-FID). VCO has 90.896% saturated fatty acids, according to the results of GC-FID analysis. Lauric acid makes up the largest portion of VCO (45.567%) (Sabahannur & Alimuddin, 2022).

Commercial virgin coconut oil collected from the Malaysian and Indonesian markets was tested and compared. In this study free fatty acid content of 0.15–0.25 was fairly low, showing that VCO samples were of good quality (Hamid, 2015).

Hot extracted virgin coconut oil (HVCO), cold extracted virgin coconut oil (CVCO), and coconut oil (CO) are tested and analysed for the various quality parameters. The analysis was takes place to determine whether there is variation in these parameters among the different methods of its production. While the free fatty acid did not change significantly among samples (Satheeshan et al., 2019).

4.4 Vitamin E content of virgin coconut oil from West Coast Tall coconut varietyobtained by different processing methods

The collective title for a class of tocopherols and tocotrienols is vitamin E. Because tocopherols are strong antioxidants, α-tocopherol has a significant effect on preventing chronic diseases linked to oxidative stress (Brigelius-Flohé, R., & Traber, M. G.,1999). vitamin E is essential for immune system support, skin health, and preventing oxidative damage to cells. Producers may verify that their coconut oil provides these health advantages to customers by evaluating the vitamin E content, which increases the oil's worth as a functional food and beauty product.

The vitamin E level of virgin coconut oil (VCO) extracted from coconut variety West CoastTall by different three methods such as Hot process, Fermentation process, and Centrifugation process are given in Table 11.

Table 11: Vitamin E content in VCO

Method of extraction	**Vitamin E (mg/100ml)**
Hot Process	**0.03**
Fermentation process	**0.05**
Centrifugation process	**0.04**

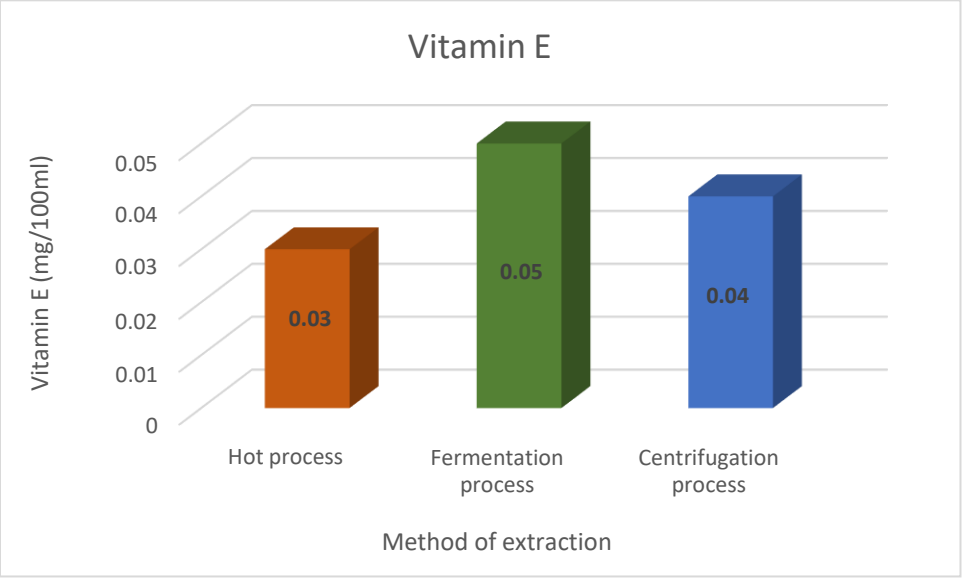


Figure 45: Vitamin E content of virgin coconut oil processed by different methods

All the samples of VCO were found to have vitamin which is usually absent in copra oil. Tocopherols, or vitamin E, are susceptible to high temperatures and situations of copra processing. This explains why tocopherols are typically absent from copra oil. From the above table and graph, it is clear that varying vitamin E content was obtained depending on processing methods. Higher concentrations of vitamin E are found in virgin coconut oil that is extracted using fermentation process (0.05 mg/100ml). Lower concentrations of vitamin E are found in virgin coconut oil that is extracted using hot process, (0.03 mg/100ml). In the centrifugation process concentration of vitamin E content is in between the other two methods, (0.04 mg/100ml).

Vitamin E, which is present in virgin coconut oil, is essential for defending cells against harm from free radicals. Virgin coconut oil's capacity to fight oxidative stress, can cause several health problems like inflammation, early aging, and chronic illnesses. Furthermore, vitamin E improves the health of the skin by protecting it from UV damage, feeding and hydrating the skin, and lessening the appearance of wrinkles and scars.

Higher concentrations of vitamin E are found in virgin coconut oil that is extracted using cold, wet processes. However, virgin coconut oil extraction involves the utilization of mild temperature conditions. Consequently, there are assertions that tocopherols are present in virgin coconut oil. (Nevin and Rajamohan, 2004)

Hot extracted virgin coconut oil (HVCO), cold extracted virgin coconut oil (CVCO), and coconut oil (CO) are tested and analysed the various quality parameters. The analysis was takes place to determine whether there is variation in these parameters among the different methods of its production. Vitamin E have significantly ($p<0.0001$) affected by various techniques. (Satheeshan et al., 2019)

4.4 Evaluation of stability in terms of moisture content and acid value during storageof one month of virgin coconut oil extracted by different methods.

Stability was studied in terms of moisture and acid values stored for one month. The virgincoconut oil was stored in a bottle that was covered with a cotton cloth and kept in a dark cupboard to prevent light and air contact. The keeping period is one month, and after one month the stability of the virgin coconut oil is checked. Moisture content is one of the important parameters to check the stability during storage. Due to the contact with

the atmosphere, there is a high chance of absorption of moisture from the atmosphere and the oil is turned into rancid. Percent moisture during storage is presented below;

4.5.1 Moisture

The moisture level of virgin coconut oil (VCO) after one month, is given in Table 12.Table 12: Stability in moisture (%) content of virgin coconut oil during storage

Sample	Moisture (%)
Hot process	
Sample 1	0.1594
Sample 2	0.1590
Average	**0.16**
Fermentation process	
Sample 1	0.2018
Sample 2	0.2016
Average	**0.20**
Centrifugation process	
Sample 1	0.155
Sample 2	0.155
Average	**0.15**

Table 13: Comparison of moisture (%) content of virgin coconut oil during before and afterstorage of one month

Method of extraction	Moisture before 1 month (%)	Moisture after 1 month (%)	Moisture difference
Hot process	0.13	0.16	0.03
Fermentation process	0.18	0.20	0.02
Centrifugation method	0.14	0.15	0.01

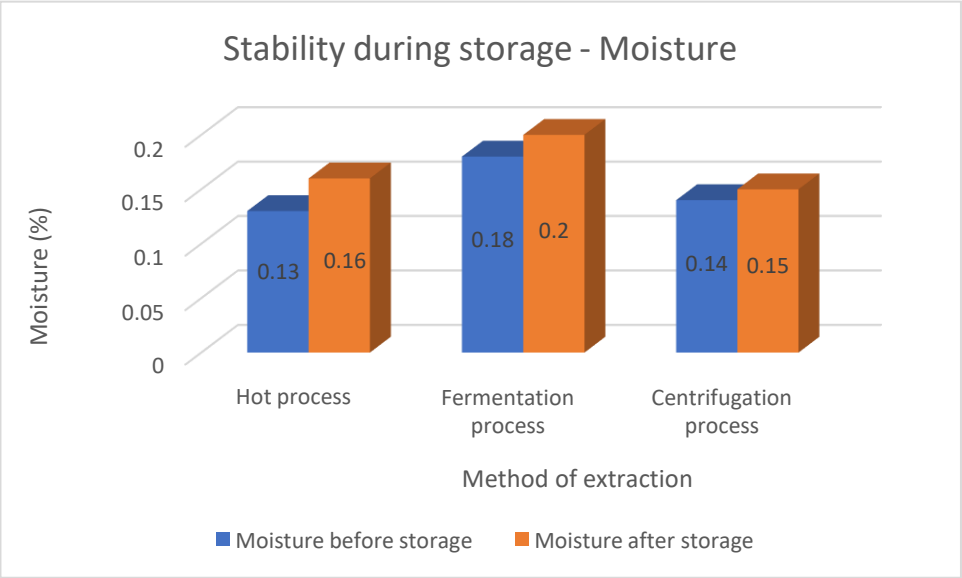


Figure 46: Stability during storage in terms of moisture of virgin coconut oil processed bydifferent methods

It is clear from the tables and graph that the processing techniques employed affected the variance in moisture content over the course of a month's storage. In the case of the hot process, the moisture is increased from 0.13% to 0.16%. In the fermentation process, the moisture level is increased from 0.18% to 0.20%, and in the centrifugation process, the moisture is increased from 0.14% to 0.15%. In the hot process, the moisture difference while stored for one month was 0.03%. In the fermentation method, 0.02% of moisture was increased while stored for one month. 0.01% moisture difference was obtained in a month for centrifugation process. Here the results of moisture analysis show that there is a slight absorption of moisture. But the oil does not turn into rancid.

According to Karouw et al. (2021), during storage, oxidation can cause. Coconut oil degradesand has a sour smell. A study was conducted to assesses the quality of coconut oil while it is being stored by including tocopherol, an antioxidant. Wet extraction is used to extract theoil. Tocopherol is added as an antioxidant at different concentrations such as 0, 0.5, 1.0, and1.5% w/v. After two months of room temperature storage, the oil samples were assessed forquality every 2,4,6, and 8 weeks. The oils' moisture content, and free fatty acid content are all measured. The study's findings that virgin coconut oil's moisture content remains constantwhether antioxidants are added.

4.5.2 Acid Value

The acid value of virgin coconut oil (VCO) after one month, is given in Table 14.

Table 14: Stability in acid value of virgin coconut oil during storage and comparison of acidvalue before and after storage

Method of extraction	Acid value before storage	Acid value after storage	Acid value difference
Hot Process	0.24	0.34	**0.1**
Fermentation process	0.37	0.46	**0.09**
Centrifugation process	0.24	0.33	**0.09**

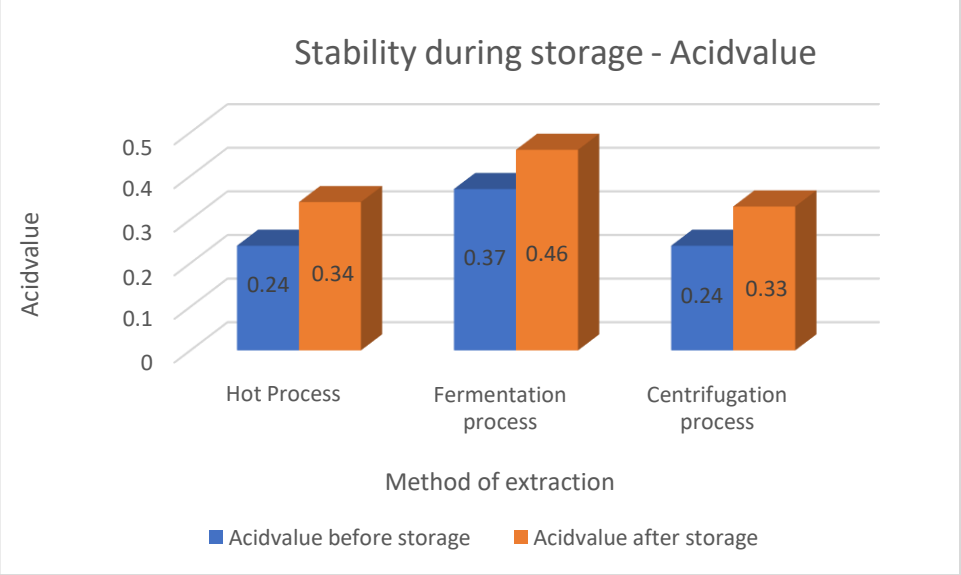


Figure 47: Stability during storage in terms of acid value of virgin coconut oil processed bydifferent methods

From the above tables, it is clear that the processing techniques employed affected the variance in moisture content over the course of a month's storage. The acid value is increasedfrom 0.24 to 0.34 in the case of the hot process and in the fermentation process the acid value is increased to 0.46. In the centrifugation process; the acid value is increased from 0.24 to 0.33. In the hot process, the acid value difference while stored for one month was 0.1. In the fermentation method, 0.09 of acid value was increased while stored for one month. 0.09 acid value difference was obtained in a month for centrifugation process. Whenthe moisture content is increased the acid values also increase exponentially. The acid valueis another parameter to analyze the stability of the virgin coconut oil during storage. The permitted level of acid value in FSSAI criteria of quality characteristics for virgin coconut oil is up to 4. The acid value of the three samples of virgin coconut oils after one month of storage is found to be under the permitted level.

It's interesting to notice that the VCO oils' acid values grew near the conclusion of the storageperiod, (Songkro,2019).

Comparison of Yield, Lipid profile, Antioxidant properties, Sensory and Physico-chemical characteristics of Virgin coconut oil processed by different methods

Table 15: Characteristics of virgin coconut oil processed by different methods

Characteristics	**Hot process**	**Fermentation process**	**Centrifugation process**
Yield (%)	21.29	15.54	20.45
Lauric acid content (%)	0.5	0.6	0.5
Vitamin E (mg/100ml)	0.03	0.05	0.04
Sensory evaluation			
Aroma (9)	9	7.5	8.7
Physico-chemical characteristics			
Color scale (Lovibond scale)	1	0	0
Moisture (%)	0.13	0.18	0.14
Acid value	0.24	0.37	0.24
Iodine value	6.14	6.53	5.97
Stability during storage			
Moisture (%)	0.16	0.20	0.15
Acid value	0.34	0.46	0.33

4.6 Evaluation of potential benefits and drawbacks of each processing method in terms of time, and energy requirements.

4.4.1 Hot Process

The hot process is one of the important methods of extracting virgin coconut oil. The methods have both benefits and drawbacks. The benefits and drawbacks of the hot process are mentioned below. The time and energy used for the extraction of virgin coconut oil is mentioned in the table:16

Table 16: Time and energy requirements for hot process

Sl.No	Hot Process	Time	Heat and Electrical Energy (used / not required)
1	Pre preparation stage	5 minutes	Not required
2	Starting stage	2-3 hour	Used
3	Oil separation stage	30 minutes	Used
4	Final stage	30 minutes	Used
5	Drying	15 minutes	Used
	Total	3 hours 25 minutes – 4 hours 25 minutes	Used

From the above table, it is clear that the total time taken to extract virgin coconut oil by the hot process was approximately 3 hr 25 mints to 4 hr 25 mints. LPG was the energy source of this method. The drying process takes place in the oven and electrical heat is used as energy.

4.4.2 Fermentation Process

The fermentation process is one of the important methods of extracting virgin coconut oil. The methods have both benefits and drawbacks. The benefits and drawbacks of the fermentation process are mentioned below. The time and energy used for the extraction of virgin coconut oil are mentioned in the below table:17

Table 17: Time and energy requirements for fermentation process

Sl.No	Fermentation process	Time	Electrical Energy (used / not required)
1	Fermentation	20 - 24 hr	Not used
2	Filtration	12 hr	Not used
3	Drying	15 minutes	Used
	Total	32 hr 15 minutes – 36 hr 15 minutes	Used

From the above table, it is clear that the total time taken to extract virgin coconut oil by the fermentation process was approximately 32 hr 15 minutes to 36 hr 15 minutes. The energy is only used in the drying step. The drying process occurs in the oven and electrical heat is used as energy.

4.4.3 Centrifugation Process

The centrifugation process is one of the important methods of extracting virgin coconut oil.The methods have both benefits and drawbacks. The benefits and drawbacks of the centrifugation process are mentioned below. The time and energy used for the extraction ofvirgin coconut oil are mentioned in the table:18

Table 18: Time and energy requirements for centrifugation process

Sl.No	Centrifugation process	Time	Electrical Energy (used / not required)
1	Cream separation	30 minutes	Used
2	Refrigeration time	20 – 24 hours	Used
3	Oil separation	1 hour	Used
	Total	21 hr 30 minutes – 25 hr 15 minutes	Used

From the above table, it is clear that the total time taken to extract virgin coconut oil by thecentrifugation process was approximately 21 hr 30 minutes to 25 hr 15 minutes. The VCO centrifuging machine was operated by electricity. All the steps occur in the VCO centrifuging machine. So all steps want energy to operate the machine.

4.4.4 Benefits of the extracting methods

The potential benefits of the extraction processs of virgin coconut oil are mentioned in the table:19

Table 19: Benefits of the extracting methods

Hot process	Fermentation process	Centrifugation process
• Important and widely used methods • High yield • Faster method • Stronger aroma and flavor • The moisture content was less	• Increases the bioavailability of lauric acid in the coconut oil. • Antioxidant content was high • This process require less manpower as compared to hot process	• Produces a clear virgin coconut oil • All the processes are done in the VCO centrifuging machine. So requires less manpower. • requires less time as compared to the fermentation process • High yield as compared to fermentation method

4.4.5 Drawbacks of the extracting methods

The potential drawbacks of the extraction process of virgin coconut oil are mentioned in thetable:20

Table 20: Drawbacks of the extracting methods

Hot process	Fermentation process	Centrifugation process
• Produce less pure andless nutrient dense oil • Requires high energy as heat energy • It is more labor intensive • Requires more care and attention during the heating process to prevent the overcookingor burning of the VCO cake	• Longer production time • The yield iscomparatively less • Process was influenced by various factors - temperature, humidityof the environment, Ph, microbial activity, etc • Alteration in these factors may leads to variability in the final product virgin coconutoil. • Fermentation process requires more care and attention • The smell of the fermented virgin coconut oil is not acceptable to all. • Some individuals are sensitive to fermented foods	• Require specialized equipment like VCO centrifuges, which are expensive • Due to high expense and huge size of the equipment, this type of production is not suitable for small scale production • There is a chance of loss of heat-sensitivenutrients

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

Virgin coconut oil is extracted from fresh coconut kernels without chemical processing and has high nutritional quality. The study entitled "*Properties of Virgin Coconut Oil from West Coast Tall Coconut Processed by Different Methods"* focused on the physicochemical properties, lauric acid content, vitamin E content, and stability during storage of Virgin coconut oil from West Coast Tall coconut processed by different methods.

The coconut samples were collected from the Institute of Coconut Development Board, Aluva, Ernakulam. The virgin coconut oil is extracted by methods such as the hot process, fermentation process, and centrifugation method.

In hot process, the coconut milk was allowed to stand in the refrigerator for 3 hours. After the settling, coconut skim milk was extracted and the coconut cream which was separated was placed on the VCO uruli roaster and turned on the flame. After one-two hours, the temperature is lowered to 90° C to allow the protein to coagulate. Oil started to separate. When the VCO cake was evenly turned into a brown colour and extraction of oil was completed. Then the oil was filtered and dried. In fermentation process after the coconut milk is extracted, the milk is let to stand for 20 to 24 hours. Fermentation temperature was in between 35 – 40°C and relative humidity was a maximum of 75%. After fermentation period, four distinct layers were present in the fermenting container. The sticky sediment was the lowest layer and the skim milk layer was the following layer. The subsequent layer was extracted to recover the VCO. Separated oil was filtered to remove adhering fermentedcurd particles. Filtration was done by using sterile cotton wool, filter paper, or filter cloth. Filtered virgin coconut oil was obtained. In centrifugation process, Coconut milk was agitated for 15 minutes with a rotator. After removing the top layer of cream from the water layer, it was taken out and allowed to be stored in the refrigerator overnight. After 20-24 hr the separated cream layer was centrifuged for 45 minutes at 6,000 rpm to isolate the virgin coconut oil from the aqueous layer. After three cycles of centrifugation, the virgin coconut oil was obtained.

In this experimental study, the yield of the virgin coconut oil, sensory and physicochemical properties of virgin coconut oil include Aroma, Colour, Moisture, Acid value, and Iodine value, nutritional parameters including Lauric acid content and Vitamin E content are analysed. Stability was studied in terms of moisture and acid values stored for one month.

The study indicated that the highest oil recovery was found in the hot process followed by the centrifugation process and low oil recovery was obtained in the fermentation method.

In the case of the Aroma of the virgin coconut oil, the panelists gave high scores for the hot process followed by the centrifugation method, while the fermentation method had the lowest score.

The virgin coconut oil obtained by the Hot process was coloured, which shows a pale-yellow colour. So, the Lovibond scale gives a scale value of one. The virgin coconut oil processed by fermentation and centrifugation methods was colourless and similar to water and the Lovibond scale gives zero scores.

The lowest moisture level was found in the virgin coconut oil obtained by the hot process and the moisture level was 0.13% followed by the centrifugation method, 0.14%. Higher moisture was obtained in the fermentation method and the moisture level was 0.18%. The lowest moisture level is optimum for virgin coconut oil. Here, the virgin coconut oil obtained by the hot process has the lowest moisture level.

The acid values of virgin coconut oil extracted by different processes the hot process, the fermentation process, and the centrifugation process are 0.24, 0.37, and 0.24 respectively. The higher acid value is present in the fermentation process, and lowest in the centrifugation process. The permitted level of acid value in FSSAI criteria of quality characteristics for virgin coconut oil is up to 4. The acid value of the three samples of virgin coconut oils is found to be under the permitted level. The acid value indicates the oxidation of triacylglycerols. Increased acid value shows that the oil spoils easily and it affects the quality of the product. Here the virgin coconut obtained by the fermentation method had a higher acid value (0.37) as compared to other methods indicating that it is more prone to spoilage.

The Iodine values obtained for virgin coconut oil extracted by different processes the hot process, the fermentation process, and the centrifugation process are 6.14, 6.53, and 5.97 respectively. The higher iodine value is found in the fermentation process, followed by the hot process. The lowest iodine value is present in the centrifugation process. The permitted level of iodine value in APCC criteria of quality characteristics for VCO and FSSAI criteria of quality characteristics for VCO is in the range of 4 to 11. The iodine value of the three samples of virgin coconut oil comes under this permitted level. The higher iodine value gives an idea about the proportion of unsaturated fatty acids, and it is more susceptible to oxidation and rancidity. Here, virgin coconut oil obtained by fermentation method had a higher iodinevalue and more chance of oxidation and rancidity.

Higher concentrations of Lauric acid are found in virgin coconut oil that is extracted using a fermentation process (0.6%), followed by a hot process (0.5%) and centrifugation process (0.5%). Three different forms of lauric acid, 1-monolaurin, and 2-monolaurin can be produced from VCO. These substances are known to have superior antibacterial lipids and contain both hydrophilic and lipophilic groups. Virgin coconut oil contains lauric acid, which is crucial due to the antibacterial, antiviral, and antifungal qualities of lauric acid and it makes it effective in boosting immunity and warding off diseases. Out of the three extraction techniques, fermentation process produces the highest concentration of lauric acid, whereas the hot process produces the lowest amount, due to the application of heat during extraction.

Higher vitamin E concentrations are found in virgin coconut oil that is extracted using a fermentation process (0.05 mg/100ml). Lower concentrations of vitamin E are found in virgin coconut oil extracted using a hot process, (0.03 mg/100ml). In the centrifugation process concentration of vitamin E content is in between the other two methods, (0.04 mg/100ml. Virgin coconut oil contains antioxidants, which are crucial for protecting cells from damage caused by free radicals. Out of the three extraction techniques, fermentation process produces the highest concentration of vitamin E, whereas the hot process produces the lowest amount, due to the application of heat during extraction.

The shelf life of the oil separated by different methods was studied in terms of moisture and acid value. Moisture of the virgin coconut oil was tested after 1 month of

proper storage. In the case of the hot process, the moisture is increased from 0.13% to 0.16%. in the fermentation process, the moisture level is increased from 0.18% to 0.20%, and in the centrifugation process, the moisture is increased from 0.14% to 0.15%. In the hot process, the moisture difference while stored for one month was 0.03%. In the fermentation method,0.02% of moisture was increased while stored for one month. 0.01% moisture difference was obtained in a month for centrifugation process. The permitted level of moisture in APCC criteria of quality characteristics for virgin coconut oil is 0.1%. Moisture level from 0.1 to 0.2% was allowed. As per FSSAI allowed moisture level is up to 0.5 %. The moisture content of the three samples of virgin coconut oils after 1 month of storage is found to be within thepermitted level.

After one month of storage, the acid value is increased from 0.24 to 0.34 in the case of the hot process and the fermentation process the acid value is increased to 0.46. In the centrifugation process; the acid value is increased from 0.24 to 0.33. The permitted level of acid value in FSSAI criteria of quality characteristics for virgin coconut oil is up to 4. The acid value of the three samples of virgin coconut oils after one month of storage is found to be under the permitted level.

So, from the above data, it is clear that yield, physicochemical properties, and nutrition properties were obtained depending on processing methods. The physicochemical properties of the virgin coconut oil obtained by the hot process were found to be better as compared to the fermentation process. The aroma was good and more acceptable as compared to other methods. The colour was pale yellow and moisture, and acid values were also lower as compared to other process methods. The iodine value of virgin coconut oil was higher thanthat of the VCO obtained by centrifugation process and lower than that of the VCO extracted by fermentation process. In the hot process, the moisture difference while stored for one month was 0.03%. The lauric acid content was lower than that of virgin coconut oil obtainedby fermentation process. Vitamin E content was lower than that of the other two methods. The time required to complete the hot process was 3 hours 25 minutes – 4 hours 25 minutes. Heat energy and electrical energy is used for the extraction. The hot process was the faster method and the time required for virgin coconut oil production was less as compared to the wet process method. And the drawbacks are also present. Application of high heat can produce a less pure and less nutrient-dense product and

degrades beneficial compounds in coconut oil. The energy requirement was also higher than heat energy. The hot process wasmore labour-intensive.

From the study, it is clear that nutritional properties like lauric acid and vitamin E content were higher in the virgin coconut oil obtained by the Fermentation method as compared to hot process and centrifugation process. However, the physicochemical properties are not good as compared to other methods such as hot and centrifugation processes. The aroma of the virgin coconut oil obtained by fermentation method was not good as compared to hot and centrifugation process, sometimes there is a chance to get off odour also. Colour is water-like and moisture, acid value, and iodine value are also higher as compared to other process methods. 0.02 % of moisture was increased while stored for one month. The total time required to complete the process was 32 hr 15 minutes – 36 hr 15 minutes, and electrical energy is used in the stage of drying. The fermentation process has a longer production time. The fermentation process is influenced by various factors such as temperature, the humidityof the environment, pH, microbial activity etc. Alteration in these factors may lead to variability in the final product of virgin coconut oil so it requires more care and attention. But this process requires less manpower.

The physicochemical properties of the virgin coconut oil obtained by the centrifugation process were found to be better as compared to the fermentation process. The aroma was good as compared to the fermentation process. The colour was water-like. Moisture contentin the virgin coconut oil was higher than that of the hot process and lower than that of the fermentation process. The acid value is the same as that of the hot process and the value is lower than that of the fermentation method. The iodine value is also lower as compared to the hot and centrifugation process. 0.01% of moisture was increased while stored for one month. However, the lauric acid is lower than that of virgin coconut oil obtained by the fermentation process. Vitamin E content was in between the other two methods. 21 hr 30 minutes – 25 hr 15 minutes was used to complete the total process of the centrifugation method and electrical energy was used throughout the process. The centrifugation process requires less time as compared to the fermentation process and the process requires less manpower. The centrifugation process may require specialized equipment like VCO centrifuges, which are expensive. High-speed centrifugation may generate heat and a chanceof loss of heat-sensitive nutrients.

To sum up, the present study entitled "*Properties of Virgin Coconut Oil from West Coast TallCoconut Processed by Different Methods"* aimed at comparing the properties of VCO obtained by three different methods showed that in terms of yield, the hot process is best followed by the centrifugation process. In the case of physicochemical properties, the hot process and centrifugation process gave the best results. In terms of nutritional content, thefermentation process was best, which gave a good amount of lauric acid and vitamin E as compared to other methods. The centrifugation process has a higher nutritional content than the hot process. In terms of time required to complete the process, the hot process required less time but manpower was high. The fermentation process and centrifugation process required more time than the hot process, and the manpower was less than that of the hot process. In terms of energy, all processes use either electrical energy, heat energy, or both tocomplete the process.

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