



Effect of Extraction Methods on the Physicochemical Properties, Fatty Acid Profile and Storage Stability of Virgin Coconut Oil

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Authors' contributions

This work was carried out in collaboration with all the authors. Author COA designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Authors SCA, DBK and OMA supervised and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this work was to evaluate the physicochemical characteristics and storage stability of virgin coconut oil (VCO) extracted using cold press and hot press processes. Data were collected and analyzed using complete randomization design (CRD). The work was done at the Department of Food Science and Technology, Rivers State University, Port Harcourt. Virgin coconut oil (VCO) was extracted from mature nuts of *Cocos nucifera*, using the cold and the hot process. Hot process gave significantly ($P < 0.05$) higher oil recovery of 58%, while cold process gave 52% oil recovery. Free fatty acid (FFA) content was 0.054% and 0.051% for cold press and hot press, respectively. Peroxide Value (PV) of the two oil samples were 1.173 mEq/kg and 1.288 mEq/kg for CPCO and HPCO, respectively. The physicochemical properties of VCO from both processes were not significantly ($P > 0.05$) different. Iodine value was 5.72 g/100 g and 6.09 g/100 g for cold pressed and hot pressed VCO, respectively. Lauric acid was the predominant fatty acid in the coconut oil samples, recording 49.30% in hot pressed coconut oil and 48.76% in cold pressed coconut oil. The melting point was found to increase while the smoke point decreased significantly ($P < 0.05$) for both cold pressed and hot pressed VCO after three months of storage at room

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temperature (28±20C). Percentage free fatty acid and peroxide values increased significantly from 0.054% to 0.742% and 1.173 mEq/kg to 2.274mEq/kg, respectively, after 3 months of storage at room temperature (28±20C). The overall result showed that coconut is a good source of vegetable oil, with good keeping quality. More also, there isn't much difference in the physicochemical quality of both hot press and cold press method of extraction.

Keywords: *Virgin Coconut Oil; extraction; physicochemical; storage stability; fatty acid.*

1. INTRODUCTION

Coconut (*Cocos nucifera* L) is known to be the most widely grown and economically important palm tree variety worldwide. It is one major source of food in the tropical and sub-tropical regions. Coconut is largely cultivated in Ceylon, the Philippines, Malaysia, India, Oceania and parts of West Africa including Nigeria [1]. It is one of the oldest crops grown in India and presently covers 1.5 million hectares in this country with a total production of over 10,000 million nuts. Every part of the plant is useful and, in many ways, support human life [2,3]. The fruit has multifarious utility; the tender coconut water is a sweet refreshing drink taken directly from the inner parts of coconut fruit [4]. For years' coconut has been produced in Nigeria for human consumption while in some countries in the world it is one of the economic legacies. Recently Nigeria is becoming conscious of its economic importance. Research and development on coconut-based food products has taken place over a long period of time and new knowledge and technologies have contributed to the diversification of products and byproducts which have in turn opened up new industries in world. Coconut fruit is very important fruit because of the nutritional value and the critical role that it plays in improving food security in the world. Its classified as a 'functional' food. Due to the healing properties and health benefits, coconut fruit is of special interest beyond its nutritional content, especially in traditional medicine. It is used in the alleviation of asthma, bronchitis, dysentery, flu, irregular or painful menstruation, ulcers and kidney stones [2]. The oil is also used to treat blisters and burns, improve skin tone and soothe sunburns. The oil provides health benefits such as; help prevent obesity by speeding up metabolism. Providing an immediate source of energy with fewer calories than other fats. It is a treasure trove of minerals, vitamins, antioxidants and is an excellent nutraceutical. It has about 50 percent lauric acids, a medium-chain fatty acid (MCFA) known to disrupts the lipid membranes of offending organisms and also having qualities similar to mother's milk, thus confirming its

disease-fighting ability [5]. Virgin coconut oil (VCO) is produced from the fresh coconut milk and can be defined as "oil obtained from the fresh, mature kernel of coconut by mechanical or natural means, with or without the use of heat, without undergoing chemical refining, bleaching or deodorizing, which does not lead to the alteration of the nature of oil" [6]. Mechanical process for extraction of coconut oil has greater advantage over the solvent extraction process, in terms of cost efficiency and production of virgin oil, which do not require refining, bleaching and deodorization. [7]. Virgin Coconut oil promotes thyroid health and helps to boost metabolism. It is known to cure damaged tissues and bruises, nourishes the brain, moisturizes the skin, reverses the neurodegenerative diseases and promotes gut health [5]. Coconut oil is becoming increasingly used worldwide for its nutritional and medical benefits.

About 60 percent of the coconut produce in Nigeria is consumed in the raw form, leaving the remaining for copra production and oil milling. Rethinam [8] reported that world coconut oil production has increased from 1,993000 MT (1960-1990) to 4,036,000MT in 2001, but the per cent share of coconut oil has considerably reduced from 9.58 to 5.99 per cent for the above period. According to [9] coconut oil contains 15% of the total fatty acids as the saturated short chain C6:0, C8:0 and C 10: 0 fatty acids. Nearly 50% is medium chain, Lauric acid (C 12:0) and coconut oil supplies only 2% of the lenoleic acid (C18: 2), and 6% oleic acid (C 18: 1), the only unsaturated fatty acids presence in coconut oil. The industrial application of coconut oil is mainly attributed to the presence of maximum lauric acid and glycerides, which are not present in any other vegetable oils [6].

Coconut oil extracted from fresh coconut meat without chemical processes is called virgin coconut oil (VCO). It is a recently emerging high demand product in the world and various types of cold presses are used for extraction of VCO from the coconut kernel at low temperature. According researched that coconut has maximum

digestibility coefficient and is more easily digested than any other fat including butter. According to [10] virgin coconut oil possesses greater benefits than solvent extracted copra oil since it retains most of the minor components in the active form and make virgin coconut oil a potential hypolipidemic and antiperoxidative agent. Marina et al. [6] remarked that Virgin coconut oil has added advantage as a nutraceutical and possess therapeutic values, which is beneficial to the health-conscious consumers. Getting an appropriate processing method that will optimize the recovery of this all-important oil, engendered the call for this study. Thus, the objective of this work was to produce virgin coconut oil (VCO) using cold press and hot press process, to characterize the oil extracted and to evaluate the quality of the virgin coconut oil after 3 months' period of storage.

2. MATERIALS AND METHODS

Mature Coconut fruits were procured from Oil Mill Market, Port Harcourt, Rivers State, Nigeria for the extraction of virgin coconut oil.

2.1 Extraction of Virgin Coconut Oil

The extraction of VCO was performed using the traditional Kitchen method as proposed by [11]. The coconut fruits were spited and the kernels grated. The grated kernel was place in a clean cheesecloth bag and squeeze tightly to extract the milk. In the Cold process, the extracted milk was allowed to stand for 36 hours. As the layers of oil and water became separated, the upper oil layer was simply decanted and the acquired oil prepared in triplicate and kept for further analysis (Fig. 1). In the hot process, extracted milk was left to stand for 36hours, cream was removed

from the top by scooping, the cream placed in a clean pot and heated to coagulate the protein, evaporate the residual water and release the remaining oil. Heating was done with medium heat making sure the temperature does not exceed 80°C. The oil was scooped out as soon as enough oil has separated, and the remaining passed through a stainless-steel strainer with muslin cloth. It was filtered for further clarification (Fig. 2).

2.2 Physicochemical Properties

Physicochemical properties were determined using AOAC [12] standard method. The physicochemical parameters determined were: Saponification value, iodine value, peroxide value, free fatty acids, Unsaponifiable matter, cloud point; melting point, smoke point and fire point, Refractive index and specific gravity. Refractive index of the coconut oil was read using Abbe Refractometer (model 2WAJ Wincom, China).

2.3 Fatty Acid Profile

Fatty acid profile of the oil was determine using the A.O.A.C [12] standard methods. Fatty acid methyl esters (FAME) were prepared from the extracted coconut oil. Oil samples was weighed (50g) into separate conical flasks and 3 ml of 0.5mol sodium methylate solution was added. Followed by addition of 3 ml acetyl chloride, 8 ml hexane and 10 ml of distilled water. The mixture was refluxed for 10minutes, after each addition and allowed to stand for 5 minutes to establish a two-phase solution. The upper organic phase was recovered into a vial for GC-FID analysis, using Agilent 7890A, coupled with flame-ionization detector (FID).

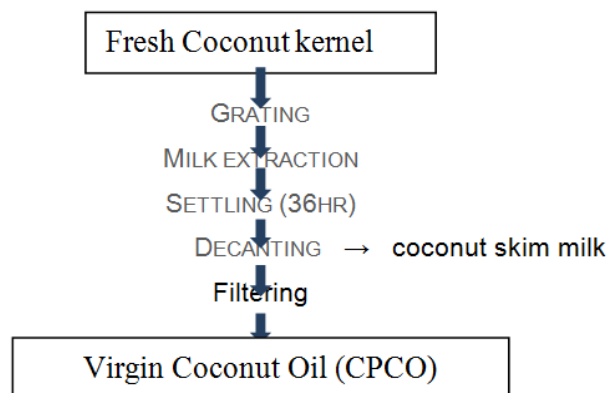


Fig. 1. Extraction of virgin coconut oil modified kitchen method (cold processed)

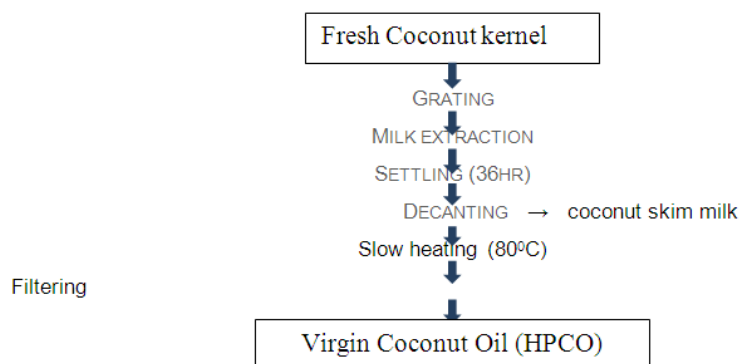


Fig. 2. Extraction of virgin coconut oil modified kitchen method (hot process)

2.4 Statistical Analysis

All the analyses were carried out in triplicate. Data obtained were subjected to Analysis of variance (ANOVA), differences between means were evaluated using Tukey's multiple comparison test, and significance accepted at $P < 0.05$ level. The statistical package in Minitab 16 computer program was used.

3. RESULTS AND DISCUSSION

3.1 Physical Properties of Cold Pressed and Hot Pressed Virgin Coconut Oil

Result for the physical properties of coconut oil extracted by cold pressed and hot pressed is shown in Table 1. The cloud point of cold pressed coconut oil (CPCO) was 9.00°C , this was significantly ($P < 0.05$) higher than that of the hot pressed coconut oil (HPCO), with value of 8.00°C . These values were all within the range of the standard cloud point of palm olein ($< 24^{\circ}\text{C}$) as recommended by the Food Safety and Standard Authority of India [13].

Cloud point is the isobaric temperature-composition plane of a multicomponent mixture (triglyceride) at which a decrease in transparency is observed due to the turbidity caused by phase separation [14].

There was no significant ($P > 0.05$) different in the slip melting point of cold pressed and hot pressed coconut oil (CPCO and HPCO) at 24.10°C and 23.90°C , respectively. These values were within the recommended CODEX standard of $\leq 24^{\circ}\text{C}$ for virgin coconut oil [15]. The slip melting point defines the temperature at which fat becomes sufficiently fluid to run or slip, or the temperature at which it softens [16].

The Smoke point of CPCO and HPCO were respectively 178.50°C and 180.25°C , these values were however not significantly ($P > 0.05$) different, indicating that cold or hot pressed methods of VCO extraction do not significantly influence the smoke point. Temperature at which vegetable oil gives off a bluish smoke when subjected to heat is referred to as the smoke point. Overheating vegetable might result to its decomposition and break down into glycerol and its component fatty acids [17]. The glycerol further undergo hydrolyses to produce a thin-blue acrolein smoke [18]. Relatively low smoke point of virgin coconut oil limits its use for high temperature deep frying operations. Smoke point serves as an indicator to the temperature limit which a particular cooking oil can be used [19]. The flash points of cold pressed and hot pressed virgin coconut oils were respectively 287.75°C and 290.00°C , these values were not significant ($P > 0.05$) different. Flash points of the samples were appreciably high as compared to the Indian specification for coconut oil (IS: 6220) of FP value $\geq 225^{\circ}\text{C}$ (Gopala-Krishna et al., 2010).

The density (DN) and Specific Gravity (SG) of coconut oil samples were respectively, $0.908 \text{ g/ml} - 0.909 \text{ g/ml}$ and $0.915 - 0.916$. These values agreed with CODEX standard SG of $0.908 - 0.921$ for virgin coconut oil [15] and Indian Standard (IS:6220) of $0.915 - 0.920$ for coconut oil [20]. An indication of the quality of vegetable oil with respect to its solid fat content and its weight at a particular temperature is made available through the knowledge of its specific density [21]. Density is expressed as the ratio of the weight of the oil to its volume at a given temperature [21], while the SG is the ratio of the density of oil to the density of equal volume of water at a particular temperature [21].

Refractive index (RI) values for virgin coconut oil extracted through cold pressed and virgin coconut oil extracted through hot press were both 1.4475. This value falls within the CODEX standard range of 1.448 – 1.450 (CODEX, 2009), Indian Standard of 1.448 – 1.449 [20] and Asian Pacific coconut community standard of 1.448 – 1.449 [22]. The refractive index is the ratio of the speed of light in a vacuum to the speed of light in the fat sample. It is related to the degree of saturation of the oil [23]. RI had been shown to provide hint on oxidative damage [24]. Refractive index of fat had been reported to increase with increase in chain length of the fat, and also with the number of unsaturated bonds present in the fat [16].

3.2 Chemical Properties of Cold Pressed and Hot Pressed Virgin Coconut Oil

Chemical properties of virgin coconut oil extracted through cold and hot press are shown in Table 2. Iodine values (IV) of CPCO and HPCO were, respectively 5.72 g/100 g and 6.09 g/100 g. These values were relatively lower than the Indian standard of 7.50 g/100 g – 10.00 g/100 g [20], this was probably due to varietal differences. The IV however, fall within the CODEX standard range of 6.0 g/100 g to

10.6g/100 g for coconut oil [15] low iodine value of coconut oil is an indication that the oil is rich in saturated fatty acids [25]. Iodine value is a simple chemical constant used to measure the degree of unsaturation or the average number of double bonds in an oil sample. It is the number of grams of iodine that could be used to halogenate 100 g of oil [16,26].

Free Fatty Acid (FFA) of coconut oil from different extraction were 0.054 and 0.051 for cold press and hot press, respectively, as shown in Table 2. All samples were appreciably lower than the Asian and Pacific Coconut Community (APCC) Standard [22] for virgin coconut oil (0.5%), the Indian Standard (IS: 6220) for virgin coconut oil (<1.00%) and the CODEX standard [15] for virgin coconut oil (<2.00%). FFA of 0.08% and 0.09% had been reported earlier by [27]. Low FFA in the oil sample is an indication of good storage stability. FFA are formed by the hydrolysis of an ester by moisture or lipase [28]. According to [29], hydrolytic rancidity could be due to hydrolysis of triglycerides of fats and oils by enzymes resulting in an increase in FFA of oil and fats. Low FFA of coconut oil indicates a good quality of virgin vegetable oil, that does not need further refining before use for food purposes.

Table 1. Physical properties of cold pressed and hot pressed coconut oil

Samples	CP(°C)	SMP(°C)	SP(°C)	FP(°C)	DN(g/ml)	SG	RI
CPCO	9.00 ^a ±0.000	24.10 ^a ±0.141	178.50 ^a ±0.707	287.75 ^a ±3.18	0.9092 ^a ±0.001	0.9162 ^a ±0.001	1.4475 ^a ±0.001
HPCO	8.00 ^b ±0.00	23.90 ^a ±0.141	180.25 ^a ±0.354	290.00 ^a ±0.000	0.9082 ^a ±0.001	0.9152 ^a ±0.001	1.4475 ^a ±0.001

Values are means ± SD of triplicate samples

Mean values bearing different superscripts in the same column differ significantly ($P < 0.05$)

Key: CPCO = Cold pressed coconut oil

HPCO = Hot Pressed Coconut Oil, CP = Cloud Point, SMP = Slip Melting Point, FP = Flash Point, Dn = Density, SG = Specific Gravity, RI = Refractive Index

Table 2. Chemical properties of cold pressed and hot pressed coconut oil

Parameters	Samples	
	CPCO	HPCO
Iodine Value (g/100 g)	5.72 ^a ±0.113	6.05 ^a ±0.071
Free Fatty Acid (%)	0.054 ^a ±0.05	0.051 ^a ±0.005
Peroxide Value (MEq/kg)	1.173 ^a ±0.306	1.288 ^a ±0.105
Saponification Value (mgkoH/g)	260.70 ^a ±0.141	259.40 ^a ±0.566
Unsaponification Matter (%)	0.115 ^a ±0.001	0.111 ^a ±0.001
Acid Value (mgkoH/g)	0.115 ^a ±0.001	0.104 ^a ±0.006
Ester Value (mgkoH/G)	260.59 ^a ±0.141	258.90 ^a ±1.131
MIV (%)	0.075 ^a ±0.07	0.055 ^a ±0.07
Oil Recovery (%)	52.00 ^b ±0.000	58.00 ^a ±0.001

Values are means ± SD of triplicate samples.

Mean values bearing different superscript in the row differ significantly ($P < 0.05$)

Key: CPCO = Cold pressed coconut oil

HPCO = Hot Pressed Coconut Oil, MIV = moisture impurities and volatile matters

Peroxide Value (PV) of the two oil samples were 1.173mEq/kg and 1.288mEq/kg for CPCO and HPCO, respectively. These values were also lower than the Asian Pacific Coconut Community Standard (APCC) of <3.00 mEq/kg. Low peroxide value of the extracted virgin coconut oil is due to the freshness of the mature coconut used. The peroxide value of vegetable oil is an indication of its degree of oxidation. Unsaturated fatty acids easily react with oxygen to form hydro-peroxides the higher the presence of unsaturated fatty acids in oil, the higher its susceptibility to oxidation. Coconut oil exhibit low rate of oxidation due to its low content of unsaturated fatty acids. Oxidative rancidity is higher in vegetable oils containing greater percentage of unsaturated fatty acids [30]. The peroxide values obtained were relatively low, indicating that the samples were highly stable against oxidative rancidity [20]. The peroxide value is the most common parameter used to characterize oils and fats [17,31]. It is the milliequivalent (mEq) of oxygen per kg of fat. Oxidation of an unsaturated oil takes place through the formation of hydro-peroxides, a product with peroxide value between 1 and 5 mEq/kg is classified at low oxidation state; that between 5 and 10 mEq/kg at moderate oxidation and above 10 mEq/kg is classified at high oxidation state. However, Codex gives a peroxide value limit of 15 mEq/kg for virgin oils in general [15].

Saponification value (SV) of virgin coconut oil (VCO) extracted using cold and hot process (CPCO and HPCO) were 260.70 mgKOH/g and 259.71 mgKOH/g, respectively. These results were within the standard limit for virgin coconut oil, 250 mgKOH/g - 260 mgKOH/g recommended by Asian Pacific Coconut Community (APCC) Standard [22], 248 mgKOH/g - 265mgKOH/g, range presented in CODEX standard [15] and saponification values greater than 250mgKOH/g presented in the Indian Standard [20]. The result also agreed with SV of 258.23 to 262.72 mgKOH/g and 258.8 to 263.7 mgKOH/g reported by [32] and [33] for virgin coconut oil (VCO) obtained using different methods of extraction. High saponification value gives an indicator for the suitability of vegetable oil for Industrial application. Such as; soaps and shampoo, pharmaceutical, and food processing [21]. Saponification value measures the esterified and free acids distributed in fats and oils, it is a measure of the alkali-groups in fats and oil and is defined as the mg KOH needed to saponify 1 g of oil [26]. Saponification value is the amount of potassium hydroxide (in mg) required to

neutralize the fatty acids that results from complex hydrolysis of 1g of oil [16]. It measures the average molecular weight or equivalent weight of fatty materials in the oils [33].

Unsaponifiable matter present in the extracted virgin coconut oil samples were 0.115% and 0.111% for CPCO and HPCO, respectively. Differences observed in these values were not statistically significant ($P>0.05$). The unsaponifiable components in VCO may include sterols, hydrocarbons (squalene, beta carotene), tocopherols and phenols. These are desirable bioactive components of vegetable oils [33]. USM presence in the coconut oil samples were low compared to CODEX standard (<1.5%), Indian Standard (<0.8) and Asian Pacific Coconut Community Standard (0.20 to 0.50%) [16,21,23]. The unsaponifiable matter of oil serves as a check for contamination by foreign materials such as mineral oils and damage to the oil by oxidation. Highly oxidized oils contain polymerized fatty acids which are extracted together with the unsaponifiable matter [33].

The ester value (EV) of CPCO and HPCO were respectively 260.59mgKOH/g and 258.90 mgKOH/g, respectively. High ester value of coconut oil is an indication that it has good flavour suitable for use in some food operations. Saponification value and the acid value of vegetable oils determines its ester value. It is an indication of the saponifiable fatty acids in the triacylglyceride excluding the free acids of the fat [22].

Moisture impurities and volatile matter (MIV) in both samples were bellow APCC set standard of <0.2% [23], Indian standard of <0.25% (Gopala Krishna et al., 2010) and CODEX standard of <0.20% [16]. Moisture impurities and volatile matter (MIV) are an important determinant of oil quality [29]. It is desirable to keep the moisture content low as it will increase the shelf life by preventing oxidation and rancidity processes. High moisture content promotes hydrolytic rancidity of vegetable oils and fats [30]. The oil recovery was 52.00% and 58.00% for cold and hot press, respectively. This showed that coconut is a good source of edible vegetable oil.

3.3 Changes in Physical Properties

3.3.1 Changes in Refractive Index (RI) of Virgin Coconut oil extracted through cold press (CPCO) and hot press (HPCO) during storage

Refractive index (RI) of cold pressed coconut oil ranged from 1.4470 to 1.4475 after ninety days

of storage at room temperature ($28\pm 2^{\circ}\text{C}$), while the RI of hot pressed coconut oil (HPCO) ranged from 1.4474 to 1.4480 during a three months' storage period, as shown in Table 3. There was no significant change in the refractive index (RI) of cold pressed and hot pressed virgin coconut oil throughout the 90 days' storage period, at room temperature. The stability of RI during storage is an indication that the unsaturated fats in the oil did not reduce significantly during the period of storage [34]. It correlates positively with the stability of iodine value during storage [35].

3.3.2 Changes in Slip Melting Point (SMP) of Virgin Coconut oil extracted through cold press (CPCO) and hot press (HPCO) during storage

From the result in Table 4, Slip melting point (SMP) of CPCO increased from 24.10°C - 24.63°C after 90 days of storage. Increase in SMP became Significant ($P<0.05$) from the second to the third month of storage. SMP of HPCO increased from 23.90°C - 24.49°C after 90 days of storage at room temperature ($28\pm 2^{\circ}\text{C}$). Increase in melting point was however, still within the CODEX standard limit of 24°C , for virgin coconut oil [16]. Significant ($P<0.05$) increase was also observed after 2 months of storage. The change in melting point of fat/oils during storage is probably due to polymorphic changes, as the fat molecules realign in order to attain a stable crystalline form [35]. This view was also supported by [17] and [36].

3.3.3 Changes in Smoke Point (SP) of Virgin Coconut oil extracted through cold press (CPCO) and hot press (HPCO) during Storage

Result in Table 5 showed a significant ($P<0.05$) reduction in smoke point (SP) of cold pressed coconut oil (CPCO) from 178.50°C to 175.50°C , after 90 days of storage. No significant change

($P>0.05$) in smoke point was seen on days 30 and 60, showing that there was no oxidative breakdown during this period. Reduction in smoke point of hot pressed coconut oil (HPCO) from 180.25°C to 178.00°C after 60days of storage was not statistically significant ($P>0.05$). Significant reduction to 176.00°C was only observed after 90 days of storage at room temperature, this was probably due to onset of oxidation.

The Smoke Point of the oil samples extracted through cold and hot process were not significantly ($P>0.05$) different compared column wise, for each month of storage. Significant reduction in smoke point after 90days of storage was likely due to increase in percentage free fatty acid (FFA) and Peroxide value of the oil samples. Earlier researchers established that Smoke point of vegetable oils is hindered by the presence of free fatty acids and other products of fat oxidation [36,16,17,18]. The use of coconut oil in deep frying, where high temperature is involved, is to a large extent limited by reduction in its smoke point during storage.

3.3.4 Changes in Specific Gravity (SG) of Coconut Oil Extracted through Cold Press (CPCO) and Hot Press (HPCO) during Storage

Specific gravity (SG) of oil sample CPCO increased significantly ($P<0.05$) from 0.9162 to 0.9260 after 90 days of storage, as shown in Table 6. SG however, do not change significantly by the 1st and 2nd months of storage. Significant ($P<0.05$) increase was noticed in 90 days. There was no significant difference ($P>0.05$) in the SG of the two oil samples, compared on monthly basis. Increase in specific gravity of oil with time is probably due to oxidative changes and the rearrangement and realignment of fatty acid triacylglycerol molecules, which result in increased saturation and solid fat content [37].

Table 3. Changes in Refractive Index (RI) of Virgin Coconut Oil extracted through cold press (CPCO) and hot press (HPCO) during storage

samples	Storage time (days)			
	Day 0	Day 30	Day 60	Day 90
CPCO	$1.447^a \pm 0.001$	$1.4480^a \pm 0.000$	$1.44705^a \pm 0.001$	$1.4475^a \pm 0.001$
HPCO	$1.4475^a \pm 0.001$	$1.4480^a \pm 0.000$	$1.4480^a \pm 0.000$	$1.4475^a \pm 0.001$

Values are means \pm SD of triplicate samples.

Mean values bearing different superscripts in the same row differ significantly ($P< 0.005$)

Mean with asterisk (*) in the same column differ significantly ($P< 0.05$)

Key: CPCO = Cold pressed coconut oil, HPCO = Hot Pressed Coconut Oil

Table 4. Changes in Slip Melting Point (SMP) of Virgin Coconut Oil extracted through cold press (CPCO) and hot press (HPCO) during storage

samples	Storage Time (days)			
	Day 0	Day 30	Day 60	Day 90
CPCO	24.10 ^b ± 0.141	24.15 ^b ± 0.071	24.52 ^a ± 0.007	24.63 ^a ± 0.071
HPCO	23.90 ^b ± 0.141	23.95 ^b ± 0.071	24.38 ^{ab} ± 0.177	24.49 ^a ± 0.021

Values are means ± SD of triplicate samples

Mean values bearing different superscripts in the same row differ significantly ($P < 0.005$)

Mean with asterisk (*) in the same column differ significantly ($P < 0.05$)

Key: CPCO = Cold pressed coconut oil, HPCO = Hot Pressed Coconut Oil

Table 5. Changes in Smoke Point (SP) of Virgin Coconut Oil during storage (°C)

Samples	Storage Time (days)			
	Day 0	Day 30	Day 60	Day 90
CPCO	178.50 ^a ± 0.707	178.00 ^a ± 0.000	177.00 ^{ab} ± 0.000	175.50 ^b ± 0.707
HPCO	180.25 ^a ± 0.354	180.20 ^a ± 0.283	178.00 ^{ab} ± 1.414	176.00 ^b ± 0.000

Values are means ± SD of triplicate samples.

Mean values bearing different superscripts in the same row differ significantly ($P < 0.005$)

Mean with asterisk (*) in the same column differ significantly ($P < 0.05$)

Key: CPCO = Cold pressed coconut oil, HPCO = Hot Pressed Coconut Oil

Table 6. Changes in Specific Gravity (SG) of Coconut Oil Extracted Through Cold Press (CPCO) and Hot Press (HPCO) during storage

Samples	Storage Time (days)			
	Day 0	Day 30	Day 60	Day 90
CPCO	0.9162 ^b ± 0.001	0.9165 ^b ± 0.001	0.9205 ^{ab} ± 0.001	0.9260 ^a ± 0.003
HPCO	0.9152 ^b ± 0.000	0.9153 ^b ± 0.000	0.9185 ^a ± 0.001	0.9195 ^a ± 0.001

Values are means ± SD of triplicate samples.

Mean values bearing different superscripts in the same row differ significantly ($P < 0.005$)

Mean with asterisk (*) in the same column differ significantly ($P < 0.05$)

Key: CPCO = Cold pressed coconut oil, HPCO = Hot Pressed Coconut Oil

3.4 Changes in Chemical Properties of Virgin Coconut Oil Extracted Through Cold Press (CPCO) and Hot Press (HPCO) During Storage at Room Temperature (28±2°C)

3.4.1 Changes in Iodine Value (IV) of Coconut oil extracted through cold press (CPCO) and hot press (HPCO) during Storage at Room Temperature (28±2°C)

Iodine value (IV) is a direct representation of the degree of unsaturation of vegetable oils. From the result in Fig. 3, Iodine value (IV) of CPCO decreased significantly ($P < 0.05$) from 5.72 to 5.08g/100g after 90 days of storage, however, there was no significant ($P > 0.05$) change in IV from day zero to day 60. Significant decrease in IV was only observed by the 3rd month of storage (day 90). Iodine value of HPCO also decreased significantly ($P < 0.05$) after 90 days of storage at room temperature from 6.05 g/100 g to 5.17 g/100 g). Reduction in iodine value of vegetable

oils during storage is probably due to oxidation. Oxidation, which consists of a complex series of chemical reactions, is characterized by a decrease in the total unsaturated content of oils due to abstraction of hydrogen adjacent to the double bond and the formation of free radicals during termination of autoxidation [38,35]. Iodine values of the virgin coconut oil samples after 90 days of storage were still within the Asian Pacific Coconut Community (APCC) standard of 4.10 to 11.00 g/100 g [22].

3.4.2 Changes in Percentage Free Fatty Acid (FFA) of Virgin Coconut oil extracted through cold press (CPCO) and hot press (HPCO) during Storage at Room Temperature (28±2°C)

Percentage free fatty acid (FFA) of cold pressed coconut oil (CPCO) increased significantly ($P < 0.05$) from 0.054 to 0.742% after 90 days of storage, this significant increase was observed from the 60days of storage (Fig. 4). Changes in Percentage FFA is a fast, reliable method to

monitor the breakdown of vegetable oil during storage. FFA of the hot pressed coconut oil also increased significantly ($P<0.05$) from 0.051% to 0.700% after 90 days of storage at room temperature ($28\pm 2^{\circ}\text{C}$). At the 2nd month of storage, percentage FFA of CPCO (0.140%) was significantly ($P<0.05$) higher than FFA of HPCO (0.131%). FFA of the coconut oil samples increased beyond the Asian Pacific Coconut Community (APCC) standard limit of 0.5% [22], this was probably due to onset of oxidation, however, it was still within the allowable range of $<2.00\%$ [15] and $<1.00\%$ Indian Standard [21]. This showed that coconut oil is chemically safe for use in food operations.

3.4.3 Changes in Peroxide Value (PV) of Virgin Coconut oil extracted through cold press (CPCO) and hot press (HPCO) during Storage at Room temperature ($28\pm 2^{\circ}\text{C}$)

Peroxide value of CPCO increased significantly ($P<0.05$) from 1.173mEq/kg to 2.274mEq/kg after 3 months of storage at room temperature ($28\pm 2^{\circ}\text{C}$), as shown in Fig. 5. Significant ($P<0.05$) increase was however, noticed after 60 days of storage. PV of HPCO also increased significantly ($P<0.05$) from 1.288mEq/kg to 2.195mEq/kg after 90 days of storage. There was no significant change in PV from months zero to two. Increase in PV was only observed after the 90 days of storage. The oil samples presented peroxide value within the established limits of $<10\text{mEq/kg}$ (CODEX standard for virgin

coconut oil) and $<3.00\text{mEq/kg}$ (APCC standard) throughout the period of storage [15,20]. Low PV during storage at room temperature is an indication that coconut oil has good storage stability. Peroxide values is used as an indicator of deterioration of oils. Fresh oils have values less than 10 mEq/kg. A rancid taste often begins to be noticeable when the peroxide value is between 20 and 40 mEq/kg [39]. Peroxide value (PV) is a useful indicator of oxidation.

3.5 Fatty Acid Profiles of Cold Pressed Coconut Oil (CPCO) and Hot Pressed Coconut Oil (HPCO)

As shown in Table 7, the predominant fatty acid in the coconut oil samples was lauric acid (48.76% in CPCO and 49.30% in HPCO). These values agreed with 47 to 50% lauric acid reported earlier by [33] and also within the APCC standard range of 45.0% to 53.0% for virgin coconut oil (APCC, 2009) and CODEX standard range of 45.1% - 53.2% [40]. Myristic acid content (20.92% in CPCO and 22.20% in HPCO) also fall within the standard range of 16.8% to 21.0% CODEX and APCC standards [40] [22]. CPCO contained 90.95% saturated fatty acids and 9.07% unsaturated fatty acids, out of which 6.85% is monounsaturated and only 2.22% is polyunsaturated (PUFA). HPCO contained 91.60% saturated fatty acids with only 8.40% unsaturated fatty acids. The predominant fatty acid specie noticed in the two coconut oil samples were medium chain saturated fatty acids.

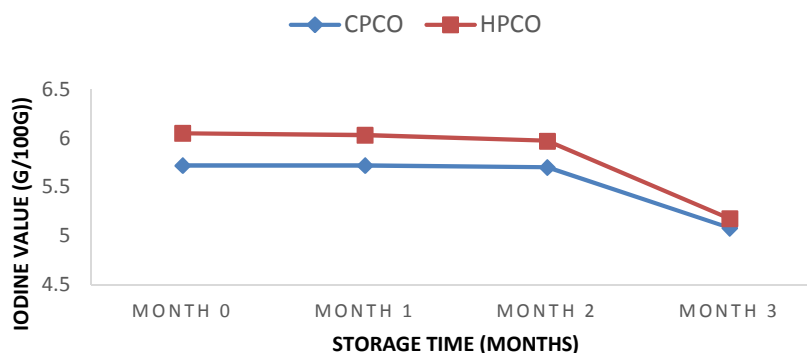


Fig. 3. Changes in iodine value (g/100 g) of virgin coconut oil extracted through cold press (CPCO) and hot press (HPCO) during Storage at Room Temperature ($28\pm 2^{\circ}\text{C}$)

Key: CPCO = cold press coconut oil, HPCO = hot press coconut oil

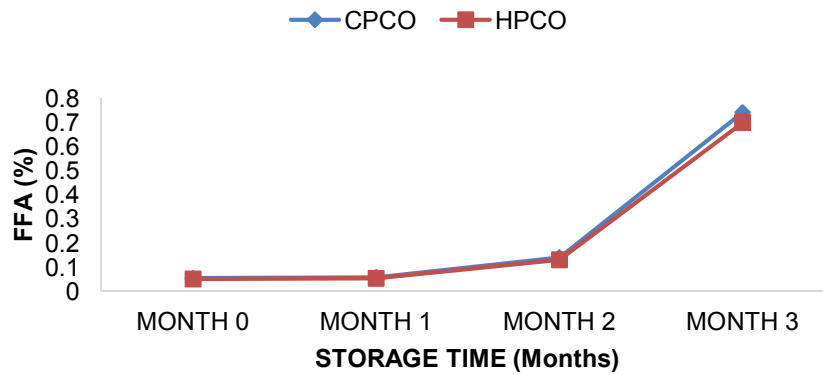


Fig. 4. Changes in percentage Free Fatty Acid (FFA) of virgin coconut oil extracted through cold press (CPCO) and hot press (HPCO) during Storage at Room Temperature ($28\pm 2^{\circ}\text{C}$)
 Key: CPCO = cold press coconut oil, HPCO = hot press coconut oil

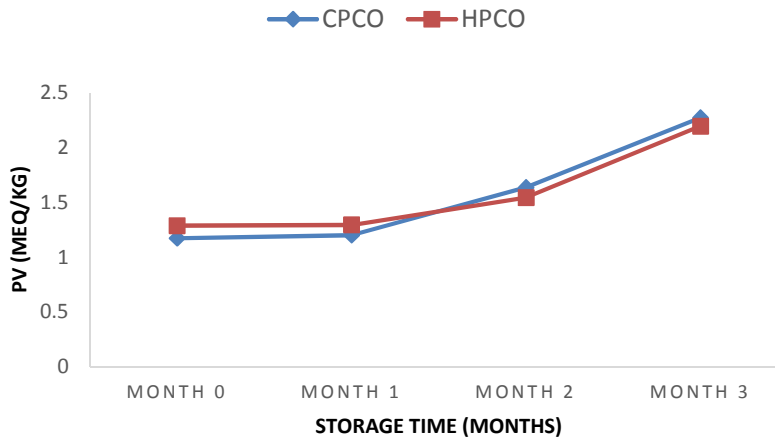


Fig. 5. Changes in peroxide value (mEq/kg) of coconut oil extracted through cold press (CPCO) and hot press (HPCO) during storage at room temperature ($28\pm 2^{\circ}\text{C}$)
 Key: CPCO = cold press coconut oil, HPCO = hot press coconut oil

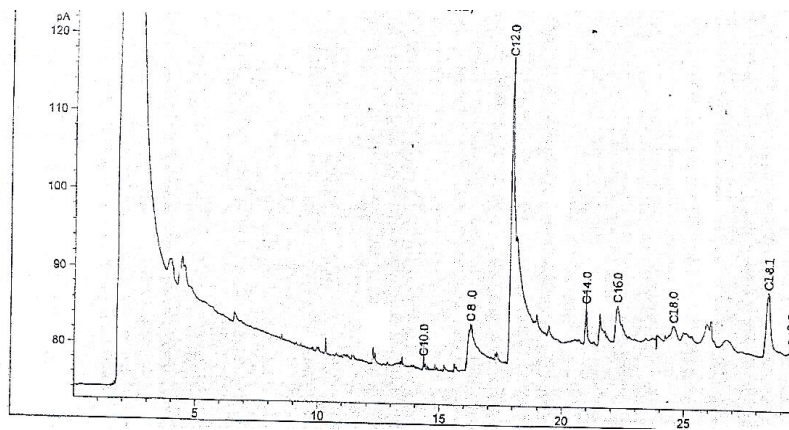


Fig. 6. Fatty acid GC chromatogram of cold pressed virgin coconut oil

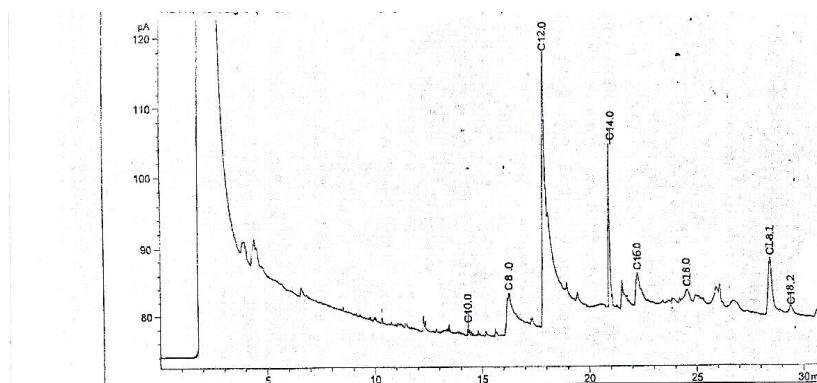


Fig. 7. Fatty acid GC chromatogram of hot pressed virgin coconut oil

Table 7. Fatty acid profiles of cold pressed coconut oil (CPCO) and hot pressed coconut oil (HPCO)

Fatty Acids (%)		Samples	
		CPCO (A)	HPCO (B)
Caprylic	C8:0	6.45	5.62
Caprioc	C10:0	5.56	5.2
Lauric	C12:0	48.76	49.3
Myristic	C14:0	20.92	22.2
Palmitic	C16:0	7.21	7.28
Stearic	C18:0	2.03	2
Oleic	C18:1	6.85	6.4
Linoleic	C18:2	2.22	2

Key: CPCO = Cold pressed coconut oil, HPCO = Hot Pressed Coconut Oil

This result showed that coconut provide fat that is mostly in the form of medium chain saturated fatty acids (MCFAs). MCFAs are saturated fatty acids with a carbon chain of 6 to 12 atoms. Of these MCFAs, lauric acid (C12) is predominant with antiviral and antimicrobial properties similar to monolaurin in human milk [22]. Monolaurin is antiviral and antibacterial, can destroys a wide variety of disease causing organisms [41]. It gives babies immunity to diseases and similar beneficial effects in adults [42].

According to the National Center for Biotechnology Information, lauric acid has many germ fighting, antifungal and antiviral properties that are very effective at ridding the body of viruses, bacteria and countless illnesses [43]. Lauric acid may also reduce cholesterol and triglyceride levels, which lowers heart disease and stroke risks [44]. Furthermore, the fats that are present in coconuts are less likely to clog arteries, because the body does not store coconut fats which makes coconut milk a healthy alternative to cow's milk when it comes to preserving heart's health [44]. Values obtained for Myristic acid in this study were similar to

myristic content of virgin coconut oil samples reported by [6,29] which ranged within 16.00 to 22.3%. Overall, all the percentage of fatty acids had their values within CODEX standard for coconut oil [41]. High content of MCFAs in virgin coconut oil make it a basic component for nutraceuticals and functional foods [45]. It possesses anti-inflammatory, antimicrobial and antioxidant properties (Fife, 2004). It is reported to be the world's only natural low-calorie fat, prevents deposition of fats thereby preventing obesity [46,47].

4. CONCLUSION

It was discovered from the work that cold pressed and hot pressed process gave 52% and 58% yield of virgin coconut oil (VCO), respectively. Indicating that the nut is a good source of vegetable oil. The physicochemical properties of VCO from both processes were not significantly ($P > 0.05$) difference. High content of medium chain saturated fatty acid (lauric acid; 48.76 to 49.30%) present VCO as a basic component for nutraceuticals and functional foods. The melting point was found to increase

while the smoke point decreased significantly ($P < 0.05$) for both cold pressed and hot pressed VCO after three months of storage at room temperature ($28 \pm 2^\circ\text{C}$). Peroxide value (PV) and free fatty acid (FFA) increased slightly during storage, this could be as the result of the storage container though these increases were still within the WHO/FAO (CODEX) standard of < 10 mEq/kg and $< 2\%$, respectively. Cold pressed and hot pressed method used for the extraction had no major significant impact on the quality of the oil. In conclusion for economical purpose the HPCO method will be better because of its high yield. However further study on the appropriate temperature for the HPCO is required and longer period of storage for both methods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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