Characterization Of Coconut Oil (Cocos Nucifera L.) From Commonly Cultivated Kenyan Varieties Extracted by Different Methods

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Abstract

The impacts of climate change and the need for implementing adaptation and mitigation measures The objective of this study was to characterize the effects of different extraction methods and varieties on the extraction yields and quality profile of the resultant coconut oil. Three mature coconut varieties (East Africa Tall, Tall Yellow and Dwarf) were collected and subjected to different oil extraction techniques (traditional method, modified traditional method, mechanical expression and soxhlet method). The quality characteristics of the oil were determined using established standard protocols. Soxhlet extraction exhibited the highest oil yield ranging from 45.4% to 58.4% followed by mechanical expression (39.2-50.1%) and the least was traditional extraction method (6.3 to 10.2%) yield depending on variety. The Dwarf variety gave significantly lower yields compared to the other varieties. The quality characteristics were within codex standards except for the high levels of free fatty acid in traditionally (0.42%) and mechanically (0.33%) extracted oil. Lauric acid was the dominant fatty acid at 47.5%-53.5% followed by myristic acid at 15.3-18.5% depending on variety and the method of extraction. The % saturated fatty acid in all varieties was >90%. Unlike in previous studies, arachidic acid was present in all varieties. The study has demonstrated that extraction methods and variety influence the oil yield and quality characteristics of coconut oil.

Keywords: Oil Extraction, Coconut Varieties, Fatty Acid Composition, Quality Characteristics

Introduction

Coconut is the most extensively grown and used palm in the world with approximately 12 million hectares in cultivation (FAO, 2014). It is a major source of income and food for about 10 million families from over 80 countries (Perera *et alet al*., 2010). Philippines, Indonesia, and India are the three most dominant countries accounting to approximately 72% of the world's planted coconut acreage. It is an important tree in most tropical islands and along the coastal regions of tropical Africa. It is commonly referred to as the tree of life because every part of the crop is utilized.

In Kenya the crop was introduced in the 16th century by the Portuguese and since then, it has grown to become one of the key sources of livelihood for many households especially in the coastal region (KCDA 2013). The area under coconut production is currently 47,401Ha producing about 91,636tons with an average value of 3.2 billion KES (FAOSTAT, 2016; ICRI, 2018) although these figures have been fluctuating over the years. The industry has grown over the years with the introduction of many cottage industries which mainly process virgin oil, copra oil, coconut cream, coconut milk and textile (NOCD, 2021). Although there seems to be an increasing trend in its utilization, the value-added products are still minimal and of low quality thus are not competitive in the market.

Coconut oil can be extracted by wet or dry extraction methods. In wet extraction, the coconut kernel does not undergo the drying process, while in dry method, the kernel is heated under specific conditions to remove the moisture to desired levels based on the extraction technique to be used (APCC, 2009). Wet methods employ chilling and thawing, fermentation, centrifugation, the use of enzymes or a combination of any of these processes to destabilize the coconut milk emulsion (Raghavendra and Raghavarao, 2010). Breaking the coconut milk emulsion is difficult due to its high stability. The steps involved in breaking the emulsion include creaming, flocculation and coalescence. Creaming process is achieved by the action of gravitational force resulting into two phases. This second stage is flocculation or clustering which is characterized by oil phase aggregation (Marina *et al.,* 2009). The last stage, coalescence involves rupturing the interfacial phase among the oil globules thus releasing them for collection (Onsaard E *et al.,* 2005). Wet extraction process results in virgin coconut oil which is more desirable than dry processing due to its ability to preserve the natural compositions and fragrance of the oil, as well as being free from chemicals (Marina *et al.,* 2009).

Dry method can be coupled with mechanical expression which can further be classified into continuous pressing (screw-type press) or the hydraulic method (Ionescu Mariana *et al.,* 2013). Screw type press involves a pressing force which is created by a screw shaft which rotates in a closed helical body. It is further categorized as either cold press or hot press method (Azadmard-Damirchi *et al*., 2011; Bhatol, 2013). Cold-press method is performed at low temperature (< 50°C) and pressure while on the contrary, the hot-press method is achieved at elevated temperatures and pressure (>50°C) (Yusuf, 2016). Hydraulic expression of oil on the other hand involves application of pressure through a ram to digested oleaginous material mash in a cylindrical cage. The cylindrical cage is normally perforated laterally resulting in an axial compaction and radial flow of oil (Owolarafe O.K., 2008). In a typical hydraulic pressing of vegetable oil seeds, three distinct stages (initial stage, dynamic stage and consolidation stage) can be observed. In addition, the dry method can also proceed for solvent extraction using different processing set-ups and conditions of extraction. It involves the use of chemicals (petroleum fractions) which are mixed with the dried flakes to extract the oil resulting in a mixture of oil and solvent (miscella) which is subjected to

controlled heat for a specified duration. Soxhlet method is one of the solvent extraction processes primarily applied for the extraction of oil from oleaginous materials. It is mostly applied for laboratory scale (Abdelaziz *et al*., 2014), but for large scale, this method requires the application of commercial solvent extractor (Ogunniyi, 2006).

On the other hand, information regarding the influence of coconut variety on oil yield and quality properties is inadequate. For instance, Banzon and Resurreccion, (1979) reported that no differences were observed in fatty acid profile of coconut oil obtained from four Philippine varieties. On the contrary, Umar *et al*. (1996) and Gucci *et al*. (2004) observed that intrinsic factors (plant cultivars and maturity) influence the quality properties of the oil. In Africa, there is in adequate published information on the influence of variety on the quality of oil from the leading countries, Ghana, Tanzania, Nigeria and Kenya in terms of coconut production (FAOSTAT, 2021). Based on these previous reports, it is evident that there exists an information gap in regard to the influence of variety on quality properties and therefore the need to conduct more studies in order to substantiate this knowledge gap.

Previous studies by Ghani *et al*., (2018), Cheetangdee *et al*., (2016), Okene, (2014) and Ruijie Liu *et al*., (2019)) have provided subtle information on ways of enhancing the oil yield for traditionally produced oil rather they mainly focus on alternative methods of oil extraction as a way of maximizing the yield. In addition, there are limited studies that demonstrate the percentage oil yield in regard to the moisture content of the coconut kernel. Different extraction methods are subjected to different processing conditions which influence the chemical properties of the resultant oil. In addition, previous studies by Ghani *et al*., (2018), Cheetangdee *et al*., (2016), Okene, (2014) and Ruijie Liu *et al*., (2019) did not outline the specific processing conditions to which the oil was subjected for each extraction method.

Moisture content, free fatty acid, and peroxide value are the common oil quality parameters while saponification value and fatty acid profile are identification parameters. These parameters can be used to compare oil to determine how specific processing conditions and variety impacts on quality. In conclusion therefore, as demonstrated by Amri, 2011; Marina *et al*., 2009b; Raghavendra and Raghavarao, 2010 it is evident that processing methods and conditions influence the yield and quality of the oil.

This study sought to characterize the oil yield and quality characteristics of coconut oil as influenced by different extraction methods and varieties.

Materials and Method

Sample Collection, Preparation and Analysis

Thirty fully mature coconut nuts (12-13 months old since pollination) each from East Africa Tall, Tall Yellow and Dwarf varieties were obtained from local farmers in Msambweni, Kwale County, Kenya using stratified random sampling technique. Indicator for maturity of the nuts was determined by observing a brown husk and shell and a sloshing sound made by the nuts upon been shaken (FAO, 2014). The nuts were de-husked and sorted. De-husked fresh nuts were processed within 7 days to prevent cracking and decay. The extraction methods and sample analysis were done in triplicate and results expressed in mean value and standard deviation. Statistical analysis was done by one way ANOVA ($p<0.05$) and multiple pair comparison by least significant difference (LSD).

Coconut Oil Extraction

Four techniques were used to extract coconut oil from the coconuts. Wet extraction involved traditional method and modified traditional method, while dry extraction involved mechanical expression and soxhlet extraction methods. The resultant oils were kept under nitrogen gas at 4 ºC and analyzed within a week.

Extraction By Traditional Method and Modified Traditional Method

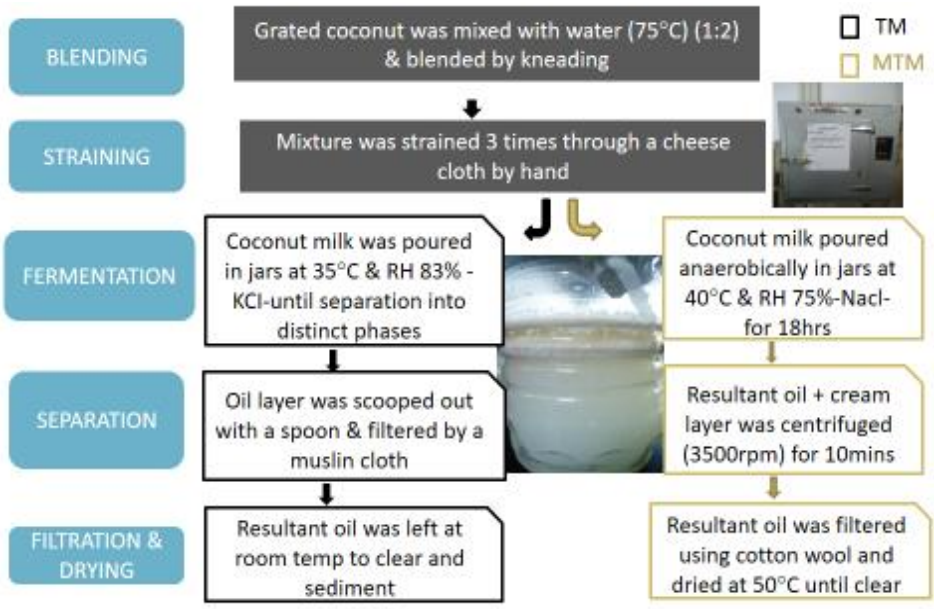

Figure 1: Process Flow Chart for Oil Extraction by Traditional (TM) & Modified Traditional Method (MTM)

Grated coconut kernel (1kg) was mixed with water in a food grade plastic bowl at 70°C at a ratio of 1:2 and kneaded by hand for 3 minutes. The mixture was strained three times by hand through a cheese cloth to obtain coconut milk.

For the traditional method, coconut milk was poured into plastic jars and put in an incubator at 35°C and a relative humidity of 83% which was obtained by using potassium chloride. These conditions were adjusted to suit the ones found along the area under study. The set up was left until a clear separation of the phases was achieved (2 days). The resultant oil phase was recovered by scooping the upper layer with a spoon. The oil was then left at room temperature for 7 days to settle.

For modified traditional method, coconut milk was poured into plastic jars and put in an incubator and the temperature raised to 40°C while the relative humidity was adjusted to 75% using sodium chloride and left for 20 hours until a clear separation of the phases was achieved. The resultant oil phase was recovered by scooping both the oil and curd phases and centrifuged at 3500 rpm for 10 minutes. The resultant oil was filtered using cotton wool and dried in an oven at 50°C for 2hours until it became clear. It was weighed, flushed with nitrogen gas and kept in dry dark bottles at 4°C prior to analysis.

Extraction By Mechanical Expression Method

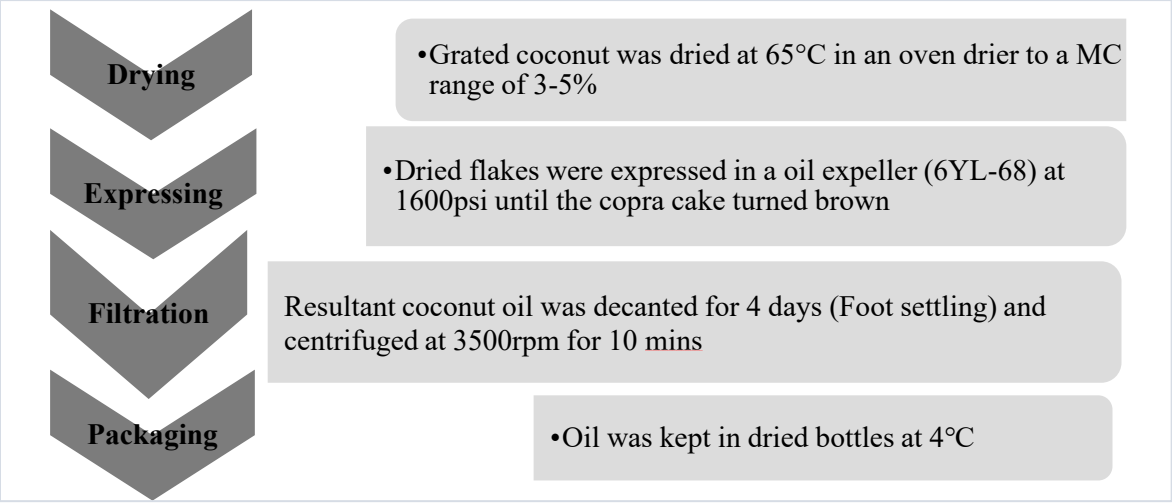

Figure 2: Process Flow Chart for Oil Extraction By Mechanical Expression

100g of grated coconut kernel was dried at 65°C in an oven drier to a moisture range of 3-5%. The dried flakes were expressed in a screw type press oil expeller (6YL-78A) at 1600psi in a continuous mode of operation. The resultant oil was left to decant (foot settling) for three days and centrifuged at 3500rpm for 10 minutes. The oil was weighed, flushed with nitrogen gas and kept in dry dark bottles at 4°C prior to analysis.Extraction By Soxhlet Method

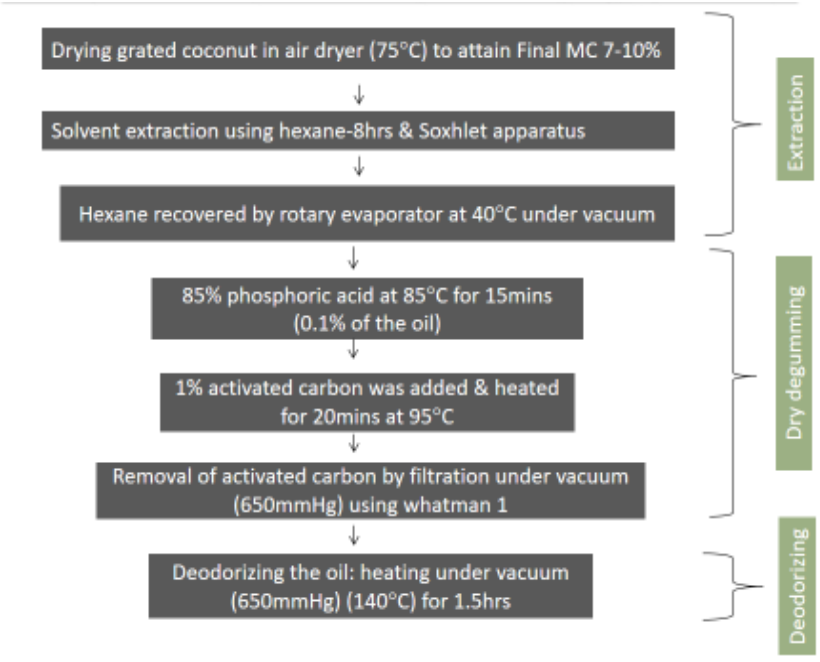

Figure 3: Process Flow Chart for Coconut Oil Extraction by Soxhlet Method

100g of grated coconut kernel was oven dried at 75 °C to a moisture content of 7-10% according to Amri, 2011. The oil was extracted from the dried coconut by solvent extraction using hexane in a soxhlet apparatus. Thermal cycling was done at 80°C for 8 hours and the solvent was recovered using a vacuum rotary evaporator at 40°C (Ixtaina *et al.*, 2011). The resultant oil was further degummed according to Canapi *et al*. 2005. The oil was preheated at 80°C and 85% phosphoric acid (0.1% w/w) was added and the temperature maintained at 85°C for 15 minutes. Activated carbon (1%) was added to the oil and the temperature increased to 95°C under vacuum (650mmHg) for another 15 minutes. The activated carbon was recovered by filtration with the aid of a vacuum (650mmHg) using filter paper (Whatman No. 1). The oil was deodorized by heating under vacuum (650mmHg) at 130°C for 1.5 hours. The oil was weighed, flushed with nitrogen gas and kept in dry dark bottles at 4°C prior to analysis.

Determination of Percentage Oil Yield

Coconut oil yield was determined using the gravimetric (w/w) method according to (AOCS, 1973) in equation 1.

$$Percentage\ yield = \frac{Weight\ of\ obtained\ oil\ (g)}{Weight\ of\ coconut\ flesh\ (g)} x100\% \quad (1)$$

Determination of Moisture Content

Kernel samples (5g) were determined according to (AOAC, 2000) where the oil was heated at a temperature of 105±5°C in a pre-dried beaker until cessation of rising bubbles of steam and incipient smoking (2hrs). Heated samples were cooled to room temperature in a desiccator and reweighed.

The moisture content was calculated according to equation 2.

$$Moisture\ content\ (\%) = \frac{Initial\ weight - Final\ weight}{Initial\ weight} x\ 100 \quad (2)$$

Determination of Peroxide Value (PV)

Peroxide Value (PV) was determined according to the standard method of IUPAC, 1992. First, 2g of oil were weighed in an Erlenmeyer flask followed by addition of 25ml of chloroform-acetic acid mixture (2:3) and the contents were mixed thoroughly. Saturated potassium iodide solution (1ml) was added and left in the dark for exactly 5 minutes, after which, 30 ml of distilled water and 1 ml (0.5%) starch indicator were added. The mixture was titrated against sodium thiosulfate (0.01N) until the disappearance of the blue colour. For the blank it was determined by the above procedure without oil. The peroxide value is expressed as mili-equivalents available oxygen/kg (m eqO2/kg) of sample and calculated according to equation 3.

$$PV = \frac{(Vt - Vo)xNx1000}{W} \quad (3)$$

Where, Vt and Vo are the volumes (ml) of sodium thiosulphate solution used to titrate the test sample and blank, respectively. N, the normality of sodium thiosulphate solution and W is the weight of oil sample (g).

Determination of Free Fatty Acid

Free fatty acid (FFA) content was quantified according to the standard method of IUPAC, 1992). Approximately 8g of oil was weighed into 250ml flask followed by the addition of 50ml of ethanol, which had been previously neutralized by adding 0.1N NaOH and 1 ml of 1% phenolphthalein solution. The samples were titrated against 0.1N NaOH until the appearance of a faint pink colour. The free fatty acids were expressed as % of lauric acid as indicated in the following equation:

$$FFA\ (as\ \%\ lauric\ acid) = \frac{VxNx20}{W} \quad (4)$$

Where, 'V' is the volume of NaOH solution, 'N' the normality of NaOH, 'W' is the weight of the oil and '20' is the equivalence factor of lauric acid.

Determination of Saponification Value

Saponification value (SV) was determined using AOCS Official Methods (AOCS, 2009). Two grams of filtered oil was mixed with 25 ml of 0.5N ethanolic potassium hydroxide and boiled under reflux for 60 minutes. The mixture was left to cool slightly at room temperature and subsequently titrated with 0.5N hydrochloric acid until the colour changes from pink to colourless after addition of 3 drops of 95% phenolphthalein. A blank sample was also prepared using the same method, without oil. Calculation was done as follows:

$$SV = \frac{(volume\ of\ blank\ titrant - volume\ of\ sample\ titrant)}{weight\ of\ oil}\, x\, N(HCL) x 56.1 \quad (5)$$

Determination of P-Anisidine Value (P-AV)

This was determined by the standard method according to (AOCS, 1998). Two grams of coconut oil sample was dissolved in 25 mL isooctane and the absorbance (A_1) of this oil solution measured at 350nm against a blank of isooctane. An aliquot (5 ml) of this oil solution, and 5 ml of isooctane (as blank) were transferred to each of two test tubes of 10 ml and 1 ml anisidine solution (0.25% g/v glacial acetic acid). After 10 minutes, the absorbance (A_2) was measured at 350nm against isooctane containing p-anisidine. p-AV was calculated according to equation 6.

$$p - AV = 25x\frac{1.2xA_2 - A_1}{W} \quad (6)$$

Determination of Percentage Fatty Acid Composition

The oil was converted to fatty acid methyl esters (FAMEs) according to the modified method described by Qian, (2003). First, 0.5g of oil was dissolved in 25ml n-hexane. Then, 5ml of the mixture was transferred into a test tube and mixed with 250µl 0.5M sodium methoxide. The mixture was then shaken vigorously in a vortex mixer for 60 seconds. Five milliliters of saturated sodium chloride solution was then added and the mixture again shaken vigorously for 15 seconds. After 10 minutes, 3ml of hexane layer containing FAME (the top layer) was transferred into a vial followed by addition of small amount of anhydrous sodium sulfate. Finally, approximately 1µl of sample was injected automatically in a GC (7890B, Agilent)-MS (5977B/MSD, Agilent). The conditions were set as follows: Oven temperature-140°C, holding time 10mins, increase to 250°C at 7°C/min and inlet/injector temperature of 250°C. Helium was used as the carrier gas

with a column flow rate 2ml/min. Auxiliary 2 temperature was set at 300°C and MS spectra obtained at m/z 40-500 counts. The capillary column dimensions was 30mx0.250mm with a diameter of 0.25micron. Peak identification was done by use of external standards of the respective FAMEs (Caproic, Caprylic, Capric, Lauric, Myristic, Palmitic, Linoleic, Oleic, Stearic and Arachidic).

The relative composition of individual fatty acid was reported by the normalization method using Agilent Mass Hunter Software (Agilent Technologies, Stevens Creek Blvd, Santa Clara, CA, United States).

Results and Discussion

Moisture Content And % Oil Yield from Coconut Varieties Using Different Extraction Methods

Table 1 shows kernel for the three varieties with different levels of moisture content. The lowest content was in Dwarf variety and the highest in East Africa tall variety as evidenced in both traditional and modified traditional methods. Upon drying, similar trend was observed as evidenced in both mechanical expression and soxhlet methods although there was no observed pattern among the varieties. The moisture content of the kernel influences the resultant yield of the oil and therefore it should be determined during extraction. Previous studies by Okene, (2014), Ruijie Liu *et al.*, (2019) have not been demonstrating this attribute and thus present difficulties in establishing the actual percentage of the oil yield. The respective oil extraction yields in Table 1 are presented in Table 2. As shown in Table 2, in all the extraction methods, Tall Yellow variety exhibited the highest oil yield in the range of 10.2-58.4% although this was not significantly different at $p<0.05$ from East Africa Tall variety at 8.4-56.4%, while Dwarf variety expressed the lowest yield at 6.3-45.4% across the extraction methods. Previous studies have also reported variation of oil yield with coconut varieties (Zunairah et al., 2015; E.J. Akpan. *et al.*, 2006; Sonia A., 2008).

Table 1: Moisture Content Of Coconut Kernel for the Different Extraction Methods

Coconut Variety	Moisture Content of The Kernel Per Extraction Method			
	TM	MTM	ME	SOX
East Africa Tall	49.10±1.21	49.10±1.21	4.33±0.82	7.40±0.44
Dwarf	46.35±1.14	46.35±1.14	3.92±0.66	7.93±0.53
Tall Yellow	48.63±0.92	48.63±0.92	4.60±0.87	7.11±0.71

n=3
Values are mean ± SD.
TM=Traditional Method; MTM= Modified Traditional Method; ME=Mechanical Expression method; SOX=Soxhlet method

All the extraction methods resulted into significantly different quantities of oil yield at $p<0.05$. Traditional method exhibited the lowest yield (6.30%), whereas the highest was obtained by soxhlet method (58.43%). In the modified traditional method, there was an increase in oil yield across all varieties compared to the traditional method. This increase could be partly attributed to centrifugation of the resultant layers. The adjustment of temperature and relative humidity in modified traditional method is believed to have accelerated the process of phase separation which took 20 hours compared to traditional method which lasted for 48 hours.

Table 2: Percentage (%) Oil Yield of The Coconut Varieties Obtained Using Four Extraction Methods

Coconut Variety	% Oil Yield Per Extraction Method			
	TM	MTM	ME	SOX
East Africa Tall	8.4±2.03b	14.6±1.72e	50.1±2.31h	56.4±0.74j
Dwarf	6.3±1.86c	10.8±1.63d	39.2±1.07g	45.4±0.83i
Tall Yellow	10.2±2.16a	17.7±2.04f	49.6±1.43h	58.4±0.95j

n=3
Values are mean ± SD
Values with different superscripts are significantly different at p<0.05

TM=Traditional Method; MTM= Modified Traditional Method; ME=Mechanical Expression method; SOX=Soxhlet method. The low yield in traditional method and modified traditional method could be attributed to the inability of the uncontrolled natural process to completely break the coconut milk emulsion. On the other hand, mechanically expressed oil either by hydraulic or screw press involves application of pressure to expel the oil (Arisanu, 2013). This explains the higher oil yield obtained through mechanical extraction. However, this percentage oil yield can vary significantly as influenced by restriction size of the noozle, screw speed, hull content, moisture content, temperature of the material and radial pressure (Mariana Ionescu *et al.,* 2015). Moreover, Arnaud Chapuis *et al.* (2014) has extensively demonstrated the optimization of oil expression using a screw-press. On the other hand, soxhlet extraction is an effective method of oil extraction with high oil yield and consistent performance. Its limitation is the high cost of production relative to traditional and mechanical expression methods (Bhuiya *et al*. 2015; Ikya *et al*. 2013). Muzenda *et al*. (2012) noted the ability of solvents to extract oil during extraction is enhanced by increasing the extraction time thus giving a higher yield.

Quality Characteristics of Coconut Oil Using Different Extraction Methods

Generally, all the quality attributes were within codex standards except for the high levels of free fatty acid in traditionally and mechanically extracted oil as shown in Table 3. Low moisture content means prolonged shelf-life of the oil. The moisture content variation in coconut oil relative to the extraction method has previously been reported (Yan Jer Ng *et al.,* 2021). The slightly high amounts of peroxides in the oils obtained by mechanical expression and soxhlet extraction methods could be attributed to high temperatures, atmospheric oxygen and chemicals during the extraction process (Elias *et al.,* 2005). However, mechanically expressed oil exhibited a higher peroxide value than solvent method disagreeing with previous report by (Dayrit FM *et al.,* 2011) and thus confirming that slight changes in the processing conditions greatly influence the quality of the resultant oil. Several sources have however reported maximum limits of lesser values (<3) (Fabian Dayrit *et al.,* 2011; APCC, 2003). Ghosh *et al.* (2016) has suggested the use of gamma irradiation to eliminate the established rancid-acid odour associated with the mechanical expression method.

Table 3: Quality Characteristics of East Africa Tall Coconut Oil Variety Extracted Using Four Different Methods

Extraction method	MC (%)	PV (meqO2/kg oil)	FFA (%)	SV mg KOH/g	p-AV
TM	0.21±0.01a	3.01±0.54c	0.42±0.03a	259.44±3.37a	0.22±0.02b
MTM	0.14±0.02b	2.49±0.04c	0.12±0.01c	258.08±2.43a	0.24±0.03b
ME	0.05±0.01c	4.60±0.12a	0.33±0.02b	254.87±6.12a	0.35±0.02a
SOX	0.07±0.01c	3.70±0.12b	0.09±0.02c	256.75±6.12a	0.20±0.02b
Codex std	≤0.5	≤15	≤0.2	248-265	<20

n=3
Values are mean ± SD
Values with different superscripts in the same column are significantly different at p<0.05
TM=Traditional Method; MTM= Modified Traditional Method; ME=Mechanical Expression; SOX=Soxhlet Method

High free fatty acid value in traditionally and mechanically extracted oil signifies a high rate of hydrolytic rancidity and moisture content (Raghavendra and Raghavarao, 2011). However, in this study the moisture content was low in mechanically extracted oil. Among the extraction methods, most of the properties showed significant differences at p<0.05 except for the saponification value and p-anisidine value. The high saponification value is attributed to high concentrations of short and medium chain fatty acids (Kirk, R. and Sawyer R. 1991). Coconut oil contains more ester saponifiable thus high potassium hydroxide was required to saponify the same amount of matter resulting to a high saponification value (William Odoom and Vida Opoku., 2015). On the contrary, anisidine value was low in all methods of extraction as the oil was still fresh. This value measures the secondary oxidation products (carbonyl content of oils) where Rossell, J. B., 2001and Subramaniam, R., 1997 reported maximum values of 2 and 10 respectively.

As shown in Table 4, the properties did not vary significantly at p<0.05 among the varieties with the exception of peroxide value and free fatty acids. This observation deviates from previous study by (Banzon and Resurreccion, 1979) which have reported non-significant variation but also in agreement with other studies which have reported significant variation with variety (Umar *et al*., 1996; Gucci *et al*., 2004). East Africa Tall exhibited the highest peroxide value while Dwarf variety exhibited the lowest although all the properties were within the codex standards. The significant differences in free fatty acid value among the varieties could be an indication of varying concentrations of hydrolytic enzymes in the oil because free fatty acid content is associated with enzymatic hydrolysis of triglycerides (Raghavendra and Raghavarao, 2011). Consequently, significant differences in the peroxide value could be as a result of varying levels of unsaturation in oil amongst the varieties which influences oxidative rancidity. Previous reports by Cunha and Oliveira, (2006), indicate that a high degree of unsaturation in fats and oils increases oxidative rancidity leading to a higher peroxide value.

Table 4: Quality Characteristics of East Africa Tall Coconut Oil Variety Extracted Using Four Different Methods

Coconut Variety	MC (%)	PV (meqO2/kg oil)	FFA (%)	SV mg KOH/g	p-AV
East Africa Tall	0.14±0.02a	2.49±0.04a	0.12±0.01b	258.08±2.43a	0.24±0.03a
Dwarf	0.14±0.01a	3.47±0.06c	0.21±0.02a	260.65±1.25a	0.24±0.04a
Tall Yellow	0.13±0.02a	2.04±0.02b	0.17±0.02a	257.3±1.54a	0.22±0.02a
Codex std	≤0.5	≤15	≤0.2	248-265	<20

n=3
Values are mean ± SD
Values with different superscripts in the same column are significantly different at p<0.05

Fatty Acid Composition (%) of Coconut Oil

Fatty Acid Composition (%) of Coconut Oil from Three Varieties

A total of ten fatty acids were identified as outlined in Table 5 in the three varieties. Generally, there was a significant variation at p<0.05 in fatty acid composition among the varieties although there was no observed trend with these variations. Among the varieties, the fatty acid values were within the Codex standards. Lauric acid was the most predominant fatty acid ranging from 47.5% for Dwarf variety to 53.5% for East Africa Tall variety. It was followed by myristic acid at 15.3-18.5% which was significantly lower in Tall Yellow variety relative to the other varieties. There was no observed trend in abundance with the other fatty acids, but oleic acid and palmitic acid were also in high concentrations. Interestingly, unlike previous studies, arachidic acid was found in all the three varieties but at low concentrations. This explains the higher values of saturated fatty acids (>90%). Polyunsaturated fatty acids were the lowest at ≤ 1% while monounsaturated fatty acids exhibited values of 6.6-8.6% across the varieties. Dwarf variety exhibited a lower concentration of saturated fatty acids (SFA) at 90.4% followed by Tall yellow at 91.6%. It also had the highest concentration of monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) respectively.

Table 5: Percentage (%) Fatty Acid Composition of Coconut Oil from the Three Varieties Extracted by Traditional Method

Fatty Acid	Chain Length	East Africa Tall	Dwarf	Tall Yellow	Codex Std
Caproic	C6:0	0.39±0.01b	0.47±0.01a	0.48±0.01a	ND-0.7
Caprylic	C8:0	5.99±0.22b	6.00±0.08b	6.55±0.16a	4.6-10.0
Capric	C10:0	6.49±0.21b	6.04±0.05c	7.25±0.32a	5.0-8.0
Lauric	C12:0	51.53±0.36a	47.54±0.30b	50.64±0.43a	45.1-53.2
Myristic	C14:0	17.42±0.15ab	18.45±0.20a	15.34±1.62b	16.8-21.0
Palmitic	C16:0	6.66±0.18b	8.27±0.13a	8.16±0.47a	7.5-10.2
Linoleic	C18:2	0.76±0.01c	1.04±0.01a	0.98±0.03b	1.0-2.5
Oleic	C18:1	8.29±0.58a	8.57±0.15a	7.41±0.02a	5.0-10.0
Stearic	C18:0	2.42±0.14c	3.53±0.07a	3.13±0.20b	2.0-4.0
Arachidic	C20:0	0.05±0.01b	0.09±0.01a	0.07±0.01ab	-
SFA (%)		92.60	90.40	91.60	-
MUFA (%)		6.60	8.60	7.40	-
PUFA (%)		0.80	1.00	1.00	-

n=3
Values are mean ± SD
Values with different superscripts in the same row are significantly different at p<0.05
(Source - Codex std-(FAO/WHO, 2003)

This study was in agreement with other previous studies that have indicated lauric acid as the most dominant of the fatty acids in coconut oil followed by myristic acid and thirdly palmitic acid (Mansor *et al.*, 2012; Marina *et al.*, 2009c; Raghavendra and Raghavarao, 2011). The variation in fatty acid concentration with variety has also been reported but the trends have not been similar (Umar *et al*. 1996; Gucci *et al*. 2004;

Banzon and Resurreccion, 1979). This implies that more studies are required to obtain conclusive information on this subject.

On the other hand, coconut oil has demonstrated the potential to protect against heart diseases, diabetes and cancer and other therapeutic properties against infectious diseases, however, knowledge about these properties has been mystified in medical journals as a result of a general prejudice against saturated fats and oils (Fife, 1998). The nut consists of approximately 90% saturated fats which differ from saturated fats from animal origin in that over 50% of the fats in coconut oil are short chain (SCFs) and medium chain fatty acids (MCFAs) as observed in lauric acid. These fatty acids enter the portal blood and are transported to the liver in a similar manner to carbohydrates unlike long chain fatty acids. More so, they supply energy more rapidly like carbohydrates in that they are quickly and easily metabolized into ketones in the liver and thus do not participate in the biosynthesis and transport of cholesterol (DebMandal and Mandal, 2011). This qualifies coconut oil as a reliable ketogenic diet (Harvey, *et al*, 2018). In particular, caprylic acid which was about 6% among the three varieties is often referred to as the "most ketogenic MCT" (medium chain triglyceride) due to its rapid breakdown from an 8-carbon fatty acid to ketone bodies (Vandenberghe, *et al.* 2017). This attribute of coconut oil has widely been utilized to manufacture nutritional drinks, infant formulas, and intravenous lipid infusions (Assunção, *et al*, 2009).

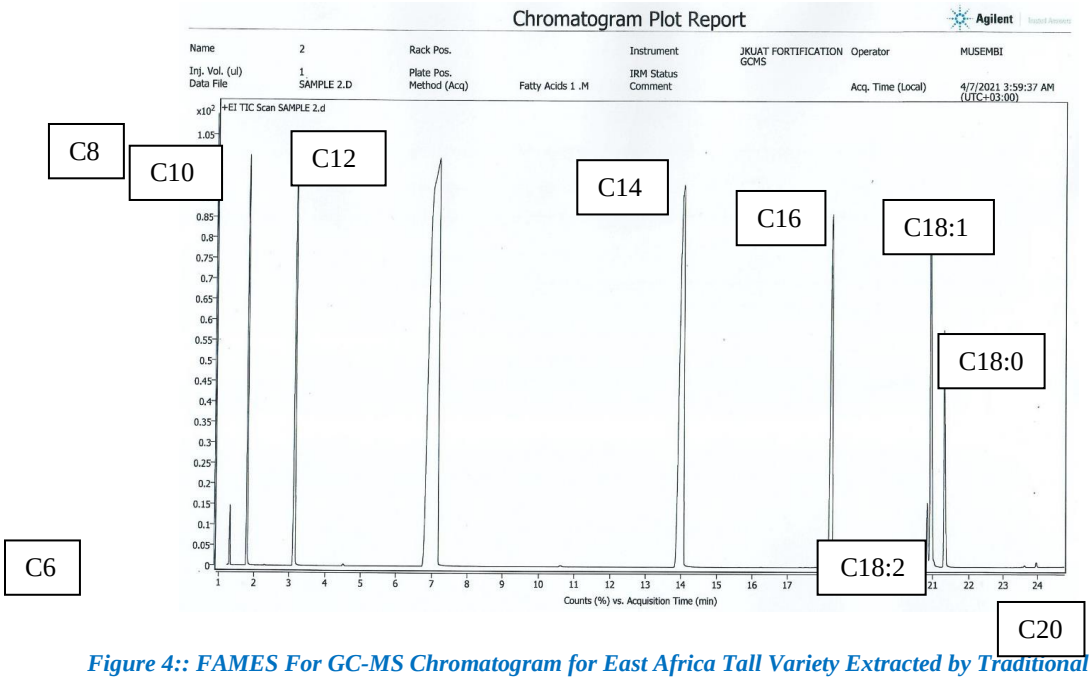

Figure 4:: FAMES For GC-MS Chromatogram for East Africa Tall Variety Extracted by Traditional Method

Plate 1 shows GC-MS chromatograms for the ten fatty acids identified in East Africa Tall variety by traditional method.

Fatty Acid Composition (%) of Coconut Oil Extracted by Different Extraction Methods

From Table 6, fatty acid content of soxhlet extracted oil varied significantly with those of other extraction methods with most of the values being higher especially for the short chain fatty acids. Although, seemingly, there was no observed trend with the fatty acid composition variation, it's notable that lauric acid values in the oil obtained by traditional and mechanical expression methods were higher than codex

standards at 53.3-53.5%. However, myristic acid for soxhlet extracted oil was significantly higher than for the oils obtained by the other methods. Interestingly, unlike in previous studies, arachidic acid was found in all oils obtained by the extraction methods although it was significantly higher in traditionally extracted oil. The other fatty acids composition did not show any significant variation for both traditional and mechanical expression methods agreeing with previous studies that extraction method does not affect fatty acid profile (Oseni *et al*, 2017; Mansor *et al*., 2012; Raghavendra and Raghavarao, 2011).

Table 6: Percentage (%) Fatty Acid Composition of Coconut Oil from East Africa Tall Variety Extracted by Different Extraction Methods

Fatty Acid	Chain Length	TM	ME	SOX	Codex Std
Caproic	C6:0	0.39±0.01b	0.11±0.01c	0.43±0.01a	ND-0.7
Caprylic	C8:0	5.99±0.22b	5.71±0.08b	7.61±0.32a	4.6-10.0
Capric	C10:0	6.49±0.21b	6.45±0.17b	7.72±0.01a	5.0-8.0
Lauric	C12:0	51.53±0.36b	53.34±0.10a	52.09±0.58b	45.1-53.2
Myristic	C14:0	17.42±0.15b	17.24±0.17b	19.38±0.65a	16.8-21.0
Palmitic	C16:0	6.66±0.18b	6.91±0.02b	7.23±0.14a	7.5-10.2
Linoleic	C18:2	0.76±0.01a	0.74±0.04a	0.34±0.26b	1.0-2.5
Oleic	C18:1	8.29±0.58c	6.88±0.16a	2.55±0.02b	5.0-10.0
Stearic	C18:0	2.42±0.14c	2.57±0.21a	2.60±0.15a	2.0-4.0
Arachidic	C20:0	0.05±0.01b	0.04±0.16b	0.06±0.31b	-
SFA (%)		92.60	92.40	97.10	-
MUFA (%)		6.60	6.90	2.60	-
PUFA (%)		0.80	0.70	0.30	-

n=3
Values are mean ± SD
Values with different superscripts in the same row are significantly different at p<0.05
TM=Traditional Method; ME=Mechanical Expression; SOX=Soxhlet Method
ND= Not detected
Source - Codex std-(FAO/WHO, 2003)

On the contrary, there was a striking observation regarding soxhlet extraction method and its effects on the fatty acid content of the oils. Firstly, linoleic acid was not detected although in other methods it was appreciably low. More so, the levels of oleic acid markedly diminished to 0.7% as compared to 6.3-6.9% in the other methods of extraction. The decrease of oleic and linoleic has been reported by He´non *et al.,* (1999) and Amaral *et al.,* (2006) who attributed it to isomerization more so at elevated temperatures and longer exposure time during processing. In addition, the level of saturation increased significantly to 97.5%. Limited studies are available to further elaborate on these observations.

Conclusion

In all the extraction methods, Tall Yellow variety exhibited the highest oil yield although it was not significant relative to East Africa Tall while Dwarf variety exhibited the lowest oil yield. On the other hand, in all the varieties, there was significant differences in oil yields in different extraction methods. Specifically, solvent extraction method exhibited the highest yield followed by mechanical expression and lastly modified and traditional method, respectively. More so, there was a significant increase in oil yield after centrifugation in modified traditional method relative to traditional method. Generally, most of the

quality characteristics were significantly different with different extraction methods, however, they were within codex standards except for the high levels of free fatty acids in traditionally and mechanically extracted oil. Fatty acid composition was non-significant among the extraction methods except in soxhlet method. Significant variation at $p<0.05$ in fatty acid composition among the three varieties was observed although there was no trend with these variations. In general, oil extraction method as well as coconut variety influences the % oil yield and quality characteristics of coconut oil.

The study further recommends more studies be conducted on the influence of variety on fatty acid composition to provide substantiative information.

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Conflict of Interest

The authors declare that there is no conflict of interest that exits in the submission of this manuscript, and the manuscript is approved by all authors for publication.

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