Effect of extraction methods on yield and some quality characteristics of coconut (*Cocos nucifera* L) oil

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Abstract: Oil extraction method has a direct influence on the quantity and quality of vegetable oil obtained from plant parts. This study evaluated the effect of three extraction methods (traditional, mechanical and chemical) on oil yield and selected quality characteristics (including some proximate composition, microbial content, physical and chemical properties) of coconut oil. The experiment was laid out in a completely randomized design and data obtained were subjected to the analysis of variance and each variable were compared using Duncan's new multiple range test at 95% level of confidence. The highest average oil yield of 82.7% (±3.03) was obtained from Chemical Extraction Method using n-hexane as solvent, Mechanical Extraction Method gave 72.9% (± 1.49) while the lowest oil yield of 61.3% (± 2.73) was obtained from Traditional Extraction Method. It was observed that extraction methods had significant influence on both the oil yield and quality of coconut oil; the quality attributes of the oil were comparable to acceptable standards for vegetable oil. The oil extracted is free from cholesterol and the results revealed that extraction method had a significant impact on the quantity and quality attributes of coconut oil. This study will solve the problem of underutilization of coconut oil amidst consumers, improve the economic value of coconut oil and the results obtained will be useful for food engineers, scientists, processors and agricultural engineers interested in oil extraction processes from coconut.

Keywords: vegetable oil, proximate analysis, oil characterization, oil quality, oil quantity

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1 Introduction

Coconut (*Cocos nucifera L*) is grown in about 93 countries in an area of 11.8 million hectares producing 10.9 million tons of copra equivalent (Hamid et al., 2011). It provides food, drink, medicine, health, shelter, aesthetics and wealth. Every part of coconut is used by mankind hence, it is known as 'Tree of Life' and 'Tree of Heaven' (Ahuja et al., 2014). One of the primary natural product produced from the dry coconut fruit (copra) is Coconut Oil (CO) which has been used from time immemorial as food, ingredient and functional foods; besides the usage in pharmaceuticals, nutriceuticals, cosmetics and industrial uses including bio fuel. Numerous health authorities advise regular consumption of coconut oil due to its high levels of saturated fat (similar to that of animal fat) (Neelakantan et al., 2020).

Coconut oil, or Copra Oil (CO) is an edible oil extracted from the kernel or meat of mature coconuts harvested from the coconut palm (Cocos *nucifera*). It has various applications due to its high saturated fat content, it is slow to oxidize and, thus, resistant to rancidification,

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lasting up to six months at 24°C (75°F) without spoiling. It serves as energy boost and it is used to relieve yeast infections, dryness and discomfort, it's also used by nursing mother to boost milk flow (Hernandez and Kamal-Eldin, 2013). Moreover, CO is an important medically efficacious food with abilities of increasing digestibility and controlling diabetics; it is also used in infant formulations for the treatment of malnutrition; when infants are fed with diets containing CO, it increases their absorption rate of Ca, Mg, and amino acids. CO is useful for slowing down degenerative process by improving mineral absorption, aiding supply of energy to cells (because it is easily absorbed without the need of enzymes) and improving insulin serration and utilization of blood glucose (Narayanankutty et al. 2016). CO also helps in weight reduction, improves cardio vascular health, supports immune system, protects against disease because of its metabolic properties, inhibits induction of carcinogenic properties, and can be used for body lotion/cosmetics for hair and skin oil, natural shampoo, herbal / medicinal oils, scent- making, and beauty care products because it prevents wrinkles and sagging on the skin surface. However, if CO is not properly extracted, the nutritional and medical properties might be destroyed because the extraction method employed has a direct effect on both the quantity and quality of the oil produced.

Vegetable oils can be extracted either traditionally, chemically or mechanically. The traditional method (known as wet extraction process) involves roasting of the kernels using firewood as fuel, pounding and crushing of the roasted kernels by mortar and pestle or between two stones; mixing the crushed mass with warm water, cooking of the mixed paste in order to obtain the oil by floating, skimming and drying of the oil by further heating; this method is tedious, time consuming, energy wasting, drudgery-prone, inefficient, low in yield and poor in quality and the oil obtained may come with a distinct smell (Kate et al., 2014); though, there is an efficient utilization of the by-products such as the hard shell and the oilseed cake (Targais et al., 2011). The chemical extraction method involves the use of a solvent to dissolve the oil residing in the seed, and the separated mixture is later heated to evaporate the solvent and obtain the oil; this method is highly efficient with over 98% oil recovery (Bargale, 1997; Ibrahim and Onwualu, 2005; Aremu and Ogunlade, 2016a, 2016b; Ogunlade and Aremu, 2019, 2020), but requires large infrastructure, high initial costs and level of technical expertise. Moreover, the oil and cake obtained from this method will contain some traces of the solvent and large quantities of highly flammable solvents are also used which poses fire and pollution hazard. Mechanical oil expression on the other hand involves passing preconditioned oilseed through a screw press, where a combination of high temperature and shear is used to crush the oilseed to release the oil. The oil expression efficiency of the mechanical method depends on the oilseed and several pre-treatment conditions. This method generally involves very low initial and operating costs compared to the solvent extraction method, and is relatively free of any polluting or fire hazardous substances (Bamgboye and Adejumo, 2007; Ogunlade and Aremu, 2019, 2020); it is one of the simple methods commonly used to extract oil from oleaginous plants. The method employed in extraction of oil is an important processing operation because it has direct effect on the quality and quantity of the oil obtained (Hamid et al., 2011).

Seneviratne and Dissanayake (2005) reported the effect of extraction method on quality of coconut oil using mechanical expression and boiling water to extract scraped coconut kernels; various researchers that have reported the CO quality using varying methods of extraction are:

(1) Mansor et al. (2012) applied different extraction methods including fermentation, chilling and thawing and enzymatic treatment method to produce Virgin Coconut Oil (VCO) and reported that the oil conformed physicochemically to the standards established by the Asian and Pacific Coconut Community (APCC) and Codex Alimentarius Commission with the highest fatty acid being lauric acid ranging from 46.36% – 48.42%, while the principal triacylglycerol (TAG) is La: Lauric with 17.94%

– 19.83% of the total TAG. It was reported that the different extraction methods showed some significant differences on physic-chemical properties of VCO.

(2) Oseni et al. (2017) used six different techniques of coconut oil extraction, which were employed to produce VCO and Refined Coconut Oil (RCO) including enzymatic, chilling and thawing, centrifugation, natural-fermentation and induced-fermentation processes. Highest oil yield (83%), and peroxide value (1.06 meq kg^{-1} oil) was obtained for RCO while VCO gave higher antioxidant activity. Induced-fermentation method of extraction showed relatively high oil yield and antioxidant activity than other methods of extraction.

(3) Ghani et al. (2018) applied four extraction methods (chilling and centrifugation; fermentation; direct micro expelling-oven dried; and direct micro expelling-sun-dried processes) and also reported that all the VCO conform to APCC standard. All of the VCO produced contains lauric acid in the range of 48.40%–52.84% of the fatty acid content. The metal contents in the VCO were within the acceptable range of the recommended APCC limit.

(4) Ibrahim et al. (2019) investigated the influence of extraction methods (hydraulic and solvent) on physico-chemical characteristics of CO and established that extraction methods affect the oil yield, physical and chemical characteristics, fatty acid composition and chemical composition of coconut oils; hydraulic method was reportedly better than solvent extraction.

(5) Ndife et al. (2019) extracted CO using natural fermentation, centrifugation, freeze-thaw and solvent extraction protocols and analyzed the oil for physical, chemical, sensory, microbial sensory properties. The smoke and fire points had 173.75°C-176.60°C and 262.45°C - 266.65°C respectively and solvent oil had the highest saponification (261.33 mg KOH g^{-1}) and acid values (0.77 mgKOH g^{-1}); contained more lauric (46.22%-48.16%) and myristic (18.03%-19.83%) acids and they were also richer in vitamins A (6.22-18.65 ug g^{-1}) and E (2.92-4.28 mg/100 g) than D and K while fermentation oil had the highest microbial count (12.93×0^2 cfu mL^{-1}) whereas solvent oil had the lowest (5.05×0^2 cfu mL^{-1}). He concluded that the methods used for extraction had significant impact on oil quality and the physico-chemical properties and fatty acid compositions of the coconut oils were comparable to international standards.

Literature review revealed extraction methods affect the quantity and quality of CO; however, there is dearth of information on the comparison of CO quality from traditional, chemical and mechanical methods, this study however aimed at evaluating the effect of three major extraction methods (traditional, mechanical and chemical) on the quality characteristics (including some proximate composition, microbial content, physical chemical properties) of the coconut oil.

2 Materials and methods

Sample procurement and preparation: The coconut used for this experiment was sourced locally from “Oba” market in Akure, Ondo state, Nigeria. The samples were thoroughly cleaned and defective ones were discarded. All experiments were conducted at the Department of Food Science and Technology, Federal University of Technology, Akure, Nigeria, (Coordinates: 7.3045° N, 5.1367° E) between May to August, 2019.

Oil extraction methods: three different methods of oil extraction methods were employed in this study, including traditional (wet milling method), mechanical and chemical extraction method as detailed below:

(1) **Traditional (wet milling) method:** the coconut samples were manually shelled and the meats were carefully scrapped from the shells using a sharp knife. The pieces of coconut were further blended at a medium speed until they are shredded with a little addition of water. The coconut milk is further filtered and placed in a muscling’s cloth (or cheese cloth) over a wide mouth jar, and the cloth is wrapped around the coconut mixture in order to squeeze the milk into jar, the process continued until the last drop was obtained and the resident oil in the coconut mixture has been obtained. The jar is leased unattended to for at least 24 hours to allow the coconut milk and oil to separate

naturally, at this stage, a layer of curd appeared at the top of the jar. The jar was left at room temperature after which the curd was scooped out with a spoon and discarded while the pure virgin coconut oil was obtained after evaporation at 105°C as described by AOAC (2005).

2) **Mechanical extraction:** a manually operated 5 ton hydraulic press with fixed head perforated holding basket and circular receptacle with downspout was used for mechanical expression of oil from coconut in similar manner to Ibrahim et al. (2019). All materials in direct contact with the coconut meat were made of stainless steel. The coconut was manually dehulled and shelled before pressing, 2.5 kg grated meat per load (4 to 5 nuts) was used for each run of experiment

3) **Chemical extraction method:** AOAC (2005) direct gravimetric method for extraction of vegetable oil was employed using n-hexane of boiling point 80°C. The coconut was sorted out, dehulled, decorticated, washed and blended. The blended coconut is poured into a small sow cloth in two places and placed into the thimble of the soxhlet extractor as the solvent dissolves and removes the oil from the coconut. Reflux condenser was attached and extraction was carried out for an approximate of 8 hours after which the solvent was distilled off by removing the traces of solvent through heating of the flask containing oil using air-oven method.

Oil yield: this was determined in accordance with Phillipines Agricultural Engineering Standard (PAES 230 - 231: 2005) for oil expellers as reported by Aremu and Ogunlade (2016a, 2016b), Ogunlade and Aremu (2019, 2020). It was obtained as the ratio of the weight of oil obtained from each method of extraction to the weight of kernels used as presented in Equation 1. All extractions were conducted six (6) times each and average values are reported. The weight of the kernels was made constant for each method of extraction and the weight of oil obtained and kernels used were measured using an Electronic Compact Scale (SF 400A, 5000g x 0.001g)

$$Oy = \frac{Wo}{Wi}\ x\ 100\% \qquad (1)$$

Where: Oy is the oil yield (%), Wo is the weight of oil obtained (g) and Wi is the weight of kernels used for the experiment (g).

Quality characterization: the extracted oil was subjected to quality characterization and the parameters of determined include some proximate and chemical content (like crude protein, total titratable acid, free fatty acid, saponification value, and pH), microbial content (total viable count, coliform count, mold count), physical properties (flash point, specific gravity, boiling and melting point) as highlighted below:

Proximate and chemical properties:

Crude protein: this was determined using micro-Kjeldahl method (AOAC, 2005). Equations 2-3 were used for obtaining the crude protein AOAC (2005):

$$\%\ Total\ Nitrogen = \frac{(titre - black)x\ normality\ of\ acid\ x\ N_2}{Weight\ of\ sample} \qquad (2)$$

$$Nitrogen\ factor = 6.25$$

$$Crude\ protein = \%\ total\ nitrogen\ x\ 6.25 \qquad (3)$$

Total titratable acid: this was obtained as the total amount of acid in the solution as determined by the titration using a standard solution of sodium hydroxide (titrant) in g/100 mL as described by AOAC (2005) Standard method of evaluations.

Free fatty acid: this was determined in accordance with AOAC (2005); the acid value was calculated using Equation 4 while the free fatty acid (ffa) was obtained from acid value mathematically using Equation 5 (Ajiwe et al., 1997; Mohammed and Hamza, 2008; Sulieman et al., 2013; Deepika et al., 2014)

$$Av = \frac{Titration\ (ml)x\ 5.61}{Weight\ of\ oil\ sample\ used} \qquad (4)$$

$$FFA = Av\ x\ 0.503 \qquad (5)$$

Saponification value (Sv): This was obtained using titre metric method as described by Ashaye and Olusoji (2006), Anyasor et al. (2009), and Dagnachew et al. (2015). The Sv was obtained using Equation 6:

$$Sv = 56.1\ N\frac{(X-Y)}{W} \qquad (6)$$

Where: Sv is the sapoinification value (mg KOG g^{-1}), N is the Normality of HCl acid used, X is the Volume of

H_2SO_4 for blank (mL), Y is the volume of H_2SO_4 for sample (mL), 56.1 is the equivalent weight of potassium hydroxide, W is the Weight of oil used (2 g)

pH: The pH of the oil was taken using a standard pH meter (Hanna meter model H196107; 0.01 pH, ± 0.05pH, United Kingdom) was used for pH determination. The pH electrode was dipped into the oil and after a few minutes of equilibration, the pH reading of the sample was taken and recorded.

Microbial analysis: The determination of the total aerobic count of the coconut oil was performed by the method outlined in the compendium of methods for the microbiological examination of foods, with some modifications (APHA, 1992; Ndife et al., 2019).

Physical properties: Flash point: A petri dish was filled with 25 mL of the melted fat and a thermometer was hung with the aid of a clamp and dipped inside the fat, ensuring that the thermometer does not touch the bottom of the dish and placed on a hot plate. The sample was heated until a sufficient vapour was produced. When the flame was applied, it causes burning for a period which was recorded (AOAC, 2005)

Specific gravity: The density bottle was cleaned, dried, weighed and filled with distilled water, then immersed in a bath at 20^{o}C until the water inside reaches 200c. The outside of the bottle was wiped and weighed. The bottle was emptied dried and filled with the melted fat at 25^{o}C. It was later kept in a bath, wiped and weighed again (AOAC, 2005). The specific gravity was obtained using Equation 7.

$$Specific\ gravity = \frac{weight\ of\ oil\ (g)}{Equivakent\ weight\ of\ water} \quad (7)$$

Boiling point: a clap was suspended and a thermometer was carefully dipped half way into the boiling bath so as not to touch the wall or bottom of the beaker, the thermometer was allowed to stand in the boiling oil for two minutes and the thermometer reading was recorded using Lisa (2019) standard methods.

Melting point: a capillary tube was filled with oil about 3 mm high. The capillary tube was placed close to the tip of the thermometer and melting point apparatus was set closer to the thermometer at a level high enough to make rapid determination of melting point, the melting point was obtained in accordance with WiredChemist (2019) Procedure.

Statistical analysis: The experiment was laid out in a completely randomized design (CRD) and the effect of extraction methods (traditional, chemical and mechanical) on coconut oil quality and yield were subjected to Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) version 17.0 while Duncan's New Multiple Range Test (DNMRT) was used to compare the treatment means at 95% level of confidence. Moreover, mean and standard deviation values were obtained using Microsoft Excel 2013 package.

3 Results and discussion

Influence of extraction methods on coconut oil yield: the highest average oil yield of 82.7% (±3.03) was obtained from chemical extraction method using n-hexane as solvent, mechanical extraction method gave 72.9% (± 1.49) while the lowest oil yield of 61.3% (± 2.73) was obtained from traditional extraction method as presented in Figure 1. The high oil yield from chemical method may be attributed to the use of n-hexane which is a non-polar solvent capable of dissolving fats coupled with prolonged exposure to heat, that is, 80°C for 8 h which is enough to increase the viscosity of the oil resident in the kernels and cause a free flow to the surface during extraction processes; a similar trend was reported by Oseni et al. (2017) in the investigation of the effect of extraction techniques on the quality of coconut oil using induced fermentation, natural fermentation, enzyme, centrifugation, chilling and thawing produced and refined oil where the use of n-hexane in the refined coconut oil gave the highest oil yield of 83.23% (Agarwal and Bosco, 2017). Mechanical extraction method gave an average oil yield which is in tandem with reports of Seweh et al. (2016), and in his work, the effects of extraction method and geographical location on the Physico-chemical Properties of Shea (*Vitellaria paradoxa*) Butter were evaluated.

Mechanical extraction gave more oil than traditional and this could be attributable to the high pressure which forces the fat out of the cells of the kernel (Seweh et al., 2016; Ibrahim et al., 2019); some traces of oil can still be noticed in the cake obtained from mechanical method which can still be recovered with the use of solvent however, the difference between the oil yield of the thee extraction methods is insignificant at 95% level of confidence.

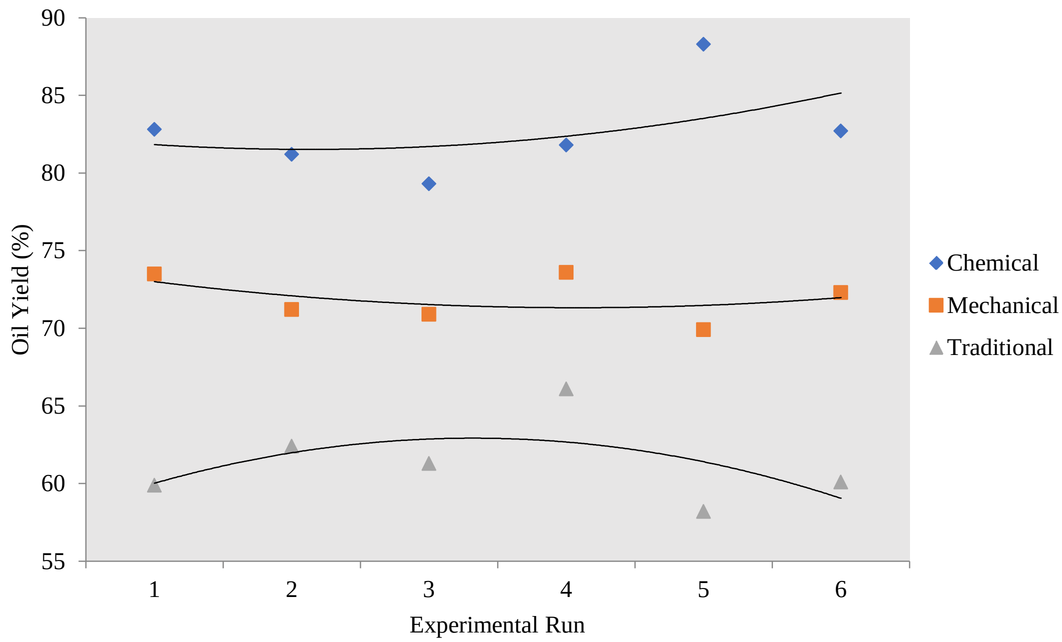

Figure 1 Effect of extraction methods on oil yield

Influence of extraction method on some coconut oil Proximate and chemical composition: the effect of extraction method on the crude protein, total titratable acid, free fatty acid, saponification value and pH of coconut oil is presented in Table 1. It was observed that extraction method had a significant impact on the crude protein of the coconut oil. Highest crude protein content (2.39%) was obtained for mechanical extraction method while the lowest protein content 1.68 was obtained for chemical extraction method. The lowest value for the use of solvent could be attributable to the impact of n-hexane on the protein content unlike the virgin oil produced from mechanical and traditional methods, this finding is similar to the reports of Ouilly et al. (2017) for *Lannea kerstingii* seed oil and Ibrahim et al. (2019) for coconut oil; Peng et al. (2019) for *Paeonia ostii*.

The highest total titratable acid (TTA) of 0.58±0.25 was obtained for traditional extraction method while the lowest value of 0.25±0.01 was obtained for mechanically extracted oil. The result shows that the extraction method has a significant difference on the TTA of the coconut oil. The result obtained is in tandem with Anyasi et al. (2014) for banana fruits, Islam et al. (2013) for mango pulp, Kothalawala et al. (2018) for coconut oil. TTA is used in the determination of total acid concentration present in food products.

The FFA ranged from 1.73 to 2.21 mg KOH g^{-1} as presented in Table 1. Chemical oil extraction method has the highest value and this could be due to the effect of the solvent used in the extraction of the oil, a similar trend was reported by Seweh et al. (2016). Free fatty acid is the percentage by weight of a specified fatty acid (e.g. percent oleic acid). High concentrations of free fatty acids are undesirable in crude vegetable oils because they result in large losses of the neutral oil during refining. In refined vegetable oils, the lower the free fatty acid the more acceptable the oil is to man in terms of palatability. Soxhlet extraction has the highest FFA followed by the traditional method. The increase in acid and free fatty acid value can also be due to oxidation and hydrolysis processes occurring in kernel oil which causes reduction in the amount of unsaturated fatty acids (Aremu et al., 2015). The low FFA value for traditional and mechanical extraction may be an advantage in terms of human consumption (Passera, 1981).

Saponification value is a measure of oxidation during storage, and also indicates deterioration of the oils; the value obtained ranged from 248.52 – 263.28 mg KOH g^{-1} for traditional and chemical extraction methods respectively. The value obtained falls within acceptable limits of CODEX standard of 248 – 265 mg KOH g^{-1} of oil (FAO, 2009). The high Saponification value of coconut oil may be attributable to short and medium chain trigycerides (Ngassapa and Othman, 2001; Krishna et al., 2010; Oseni et al., 2017). An increase in saponification value in oil increases the volatility of the oils, it enhances the quality of the oil because it shows the presence of lower molecular weight components in 1 g of the oil which will yield more energy on combustion.

Table 1 Effect of extraction method on some proximate and chemical properties of coconut oil

Extraction method	Proximate and chemical properties				
	Crude protein	Total titrable acid (%)	Free fatty acid (mg KOH g^{-1})	Saponification value (mg KOH g^{-1})	pH
Traditional	2.37±0.01[a]	0.58±0.01[a]	1.73±0.50[a]	248.52±2.59[a]	4.9[a]
Chemical	1.68±0.01[b]	0.54±0.01[b]	2.21±0.75[b]	263.28±2.74[b]	5.1 [a]
Mechanical	2.39±0.01[a]	0.25±0.01[c]	1.78±0.00[a]	251.08±3.97[a]	4.5 [a]

Note: Each values represent the mean obtained from 10 replicates ± SD. Different superscripts within the same column denote significant difference ($p<0.05$).

The pH result shows that soxhlet extraction method has the highest pH value of 5.1 while mechanical expression has the lowest pH value of 4.5. There was no significant difference between the extraction methods. The values obtained are in the same range with Kothalawala et al. (2018) for coconut milk. The effect of extraction method on the proximate and chemical properties of coconut oil is presented in Table 1

Influence of extraction method on total microbial content of coconut oil: the effect of extraction method on the microbial content of the coconut oil is presented in Table 2.

Table 2 Effect of extraction method on the microbial count of coconut oil

Method	Fungal (cfu × 10^3 g^{-1})	Bacterial (cfu g^{-1})	Total microbial count (cfu × 10^2 mL^{-1})
Traditional method	13±0.03[a]	1 ±0.01[a]	6.19 ± 0.03[a]
Soxhlet extraction method	6±0.01[b]	1 ±0.01[a]	5.07 ± 0.04 [b]
Hydraulic press method	6±0.02[b]	2 ±0.02[b]	6.02 ±0.02[a]

Note: Values are means while ± are standard deviation values; column with different superscripts are significantly different (p=0.05)

The microbial test showed that traditional method has the highest fungal count with soxhlet extraction and hydraulic press method having the same number of fungal infection. A higher bacterial infection was observed in hydraulic press method while soxhlet extraction and traditional method have the same number of bacterial infection. The fluctuations in fungal and bacterial infection may be due to the resident moisture content in the kernels during the oil extraction. The total microbial count of the oil samples ranged from 5.07 to 6.19 × 10^2 cfu mL^{-1}. The highest microbial load (6.19 × 10^2 cfu mL^{-1}) was in the traditional oil extraction method while the least microbial count occurred in the solvent oil. The Values obtained are within acceptable range of APCC (2009). Bacteria (Acetobacter, Streptococcus, Staphylococcus sp.) and fungi species (Saccharomyces, Candida, and Rhizopus) have been implicated in coconut oils spoilage (Okechalu et al., 2011). Their presence could be attributed to the fermentation process, contamination from the environment and humans during production, storage and handling. It is therefore necessary to adopt good manufacturer practices (GMP) during production (Villarino et al., 2003; Okechalu et al., 2011; Ndife et al., 2019).

Influence of extraction method on some physical properties of coconut oil: The effect of extraction method on flashpoint, specific gravity, boiling and melting points of coconut oil is presented in Table 3. The flash point ranged from 131°C to 124°C the results showed that there was no significant difference in the flash point of the coconut oil produced from the three extraction methods. The specific gravity of the three extraction methods was obtained to be 0.94, this signified that the oil is less dense than water and therefore would be useful in cream production as it will make the oils flow and spread easily on the skin (Oyeleke et al., 2012). Yahaya et al. (2012) reported that specific gravity was commonly used in conjunction with other parameters in assessing the purity of oil. The higher specific gravity of 0.93 observed in the solvent oil can be attributed to the higher content of linoleic acid (Ackman and Easton, 1997). The boiling point results showed that there were significant differences between the soxhlet extraction, traditional, and mechanical expression methods, the boiling point obtained ranged from 196.33°C to 204°C. The melting point ranged from 41°C to 45°C; the results obtained showed that there was no significant difference between traditional method and soxhlet extractions.

Table 3 Effect of physical analysis on some coconut oil extracted from three methods

Methods	Flashpoint (°C)	Specific gravity	Boiling point (°C)	Melting point (°C)
Traditional method	124.00±1.00^{a}	0.94±0.01^{b}	204.00±1.00^{a}	42.00±1.00^{b}
Soxhlet extraction	131.00±1.00^{a}	0.94±0.01^{a}	196.33±1.53^{b}	41.00±1.00^{b}
Hydraulic method	130.67±1.16^{a}	0.94±0.02a^{b}	201.33±1.53^{a}	45.00±1.00^{a}

Note: Values are mean ± SD of triplicate determination. Physical parameter with the same superscripts within the same column were not significantly ($p<0.05$) different.

4 Conclusion

Vegetable oil was extracted from coconut kernels using traditional, chemical and mechanical extraction methods and the quality of the oil produced was analyzed and compared using the proximate and chemical content, microbial content and physical properties. The chemical extraction method using soxhlet extractor has the highest oil recovery followed by mechanical expression while traditional method of extraction has the lowest oil recovery rate. The oil yield ranged from 72.9% to 82.7% for traditional and chemical methods respectively. The study showed that the quality attributes of coconut were within the standard range of vegetable oils and the oil was free from cholesterol; it was obtained that extraction method had a significant impact on the quantity and quality attributes of coconut oil. This study will solve the problem of underutilization of coconut oil amidst consumers and improve the economic value of the oil.

References

Ackman, G. C., and M. J. Eaton. 1997. Physical and chemical properties of coconut oil. *Journal of Stored Product and Postharvest Research*, 5: 62-70.

Agarwal, R. K., and S. J. D. Bosco. 2017. Extraction processes of virgin coconut oil. *MOJ Food Processing & Technology*, 4(2): 00087.

Ahuja, S. C., S. Ahuja, and U. Ahuja. 2014. Coconut – history, uses, and folklore. *Asian Agri-History*, 18(3): 221-248.

Ajiwe, V. I. E., C. A. Okeke, B. Nnabuike, G. A. Ogunleye, and E. Elebo. 1997. Application of oils extracted from African star apple (*Chysoplyllum africanum*), horse eye bean (*Mucuna sloanei*) and African pear (*Dacrydes edulis*). *Bioresource Technology*, (59): 259-261.

Anyasi, T. A., A. I. O. Jideani, and G. A. Mchau. 2014. Morphological, physicochemical and antioxidant profile of noncommercial banana cultivars. *Food Science and Nutrition*, 3(3): 221-232.

Anyasor, G. N., K. O. Ogunwenmo, A. O. Oyelana, D. Ajayi, and J. Dangana. 2009. Chemical analyses of groundnut (*Arachis hypogaea*) oil. *Pakistan Journal of Nutrition*, 8(3): 269-272.

AOAC. 2005. Official Methods of Analysis of AOAC International. 18th ed. Gaithersburg, MD, USA: AOAC.

APCC. 2009. Asian and pacific coconut community. Available at: http://www.apccsec.org. Accessed 2 November, 2018.

APHA. 1992. Compendium of methods for the microbiological examination of foods. 4th ed. Washington, D.C., USA: American Public Health Association.

Aremu, A. K., and C. A. Ogunlade. 2016a. Effect of operating parameters on mechanical oil expression from African oil bean seeds. *Global Journal of Science Frontier Research: D, Agriculture and Veterinary*, 16(1): 19-26.

Aremu, A. K., and C. A. Ogunlade. 2016b. Influence of moisture content and seed dimension on mechanical oil expression from African oil bean (*Pentaclethra macrophylla*) seeds. *Journal of Biosystems Engineering*, 41(3): 193-200.

Aremu, M. O., H. Ibrahim, and T. O. Bamidele. 2015. Physicochemical characteristics of the oils extracted from some Nigerian plant foods – a review. *Chemical Process Engineering Research*, 32: 36-52.

Ashaye, O. A., and O. C. Olusoji. 2006. Evaluation of some quality attributes of soybean oils in Ibadan. *African Journal of Agricultural Research*, 1(1): 017-019.

Bamgboye, A. I., and A. O. D. Adejumo. 2007. Development of a sunflower oil expeller. *CIGR Journal*, IX: Manuscript EE 06 015.

Bargale, P. C. 1997. Mechanical oil expression from selected under oilseeds under uniaxial compression. Ph.D. Diss., Department of Agricultural and Bioresource Engineering, University of Saskatchewan, Saskatoon, Canada.

Dagnachew, Y., Y. Asteraye, T. Mensigitu, and M. Anza. 2015. Extraction and physico-chemical characterization of cordia africana lam seed oil. *Journal of Advanced Botany and Zoology*, 3(4): 1-5.

Deepika, D., V. R. Vegneshwaran, P. Julia, K. C. Sukhinder, T. Sheila, M. Heather, and M. Wade. 2014. Investigation on oil extraction methods and its influence on omega-3 content from cultured salmon. *Journal of Food Processing and Technology*, 5(12): 1-13.

FAO. 2009. Codex Alimentarius Stan 201. Standard for Named Vegetable Oils. Availabe at: http://www.fao.org/fao-whocodexalimentarius/en/. Accessed 20 June 2019.

Ghani, N. A. A., A. A. Channip, P. Chok Hwee Hwa, F. Ja'afar, H. M. Yasin, and A. Usman. 2018. Physicochemical properties, antioxidant capacities, and metal contents of virgin coconut oil produced by wet and dry processes. *Food Science and Nutrition*, 6(5): 1298-1306.

Hamid, M. A., M. R. Sarmidi, T. H. Mokhtar, W. R. W. Sulaiman, and R. A. Aziz. 2011. Innovative integrated wet process for virgin coconut oil production. *Journal of Applied Sciences*, 11(13): 2467-2469.

Hernandez, E. M., and A. Kamal-Eldin. 2013. *Processing and Nutrition of Fats and Oils*. The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ: John Wiley & Sons, Ltd.

Ibrahim, A., and A. P. Onwualu. 2005. Technologies for extraction of oil from oil-bearing agricultural products. *Journal of Agricultural Engineering and Technology*, 13(1): 58-70.

Ibrahim, A. I., S. Nurjanah, A. M. Kramadibrata, R. Naufalin, and H. Dwiyanti. 2019. Influence of different extraction methods on physic-chemical characteristics and chemical composition of coconut oil (*Cocos nucifera* L). *IOP Conference Series: Earth and Environmental Science*, 250(1): 012102.

Islam, M. D., M. Z. H. Khan, M. A. R. Sarkar, N. Absar, and S. K. Sarkar. 2013. Changes in acidity, TSS, and sugar content at different storage periods of the postharvest mango (*Mangifera indica* L.) influenced by Bavistin DF. *International Journal of Food Science*, 2013: ID 939385.

Kate, A. E., U. C. Lohani, J. P. Pandey, N. C. Shahi, and A. Sarkar. 2014. Traditional and mechanical method of the oil extraction from wild apricot kernel: a comparative study. *Research Journal of Chemistry and Environmental Science*, 2(2): 54-60.

Kothalawala, S., U. Dahanayake, and J. Jayasinghe. 2018. Identification of the contributing factors that affect the rise of the acidity in milk extracted from Sri Lankan Coconut (*Cocos nucifera*). *International Journal of Food Science and Nutrition*, 3(5): 47-51.

Krishna, A. G., R. Gaurav, B. A. Singh, P. P. Kumar, and C. Preeti. 2010. Coconut oil: chemistry, production and its applications - a review. *Indian Coconut Journal*, 53(3): 15-27.

Lisa, N. 2019. Water, sand and oil baths. Available at https://chem.libretexts.org/Bookshelves/Organic_Chemistry/Book%3A_Organic_Chemistry_Lab_Techniques_(Nichols)/01%3A_General_Techniques/1.04%3A_Heating_and_Cooling_Methods /1.4H%3A_Water_Sand_and_Oil_Baths. Accessed 20 June 2019.

Mansor, T. S. T., Y. B. Che Man, M. Shuhaimi, M. J. Abdul Afiq, and F. K. M. Ku Nurul. 2012. Physicochemical properties of virgin coconut oil extracted from different processing methods. *International Food Research Journal*, 19(3): 837-845.

Mohammed, M. I., and Z. U. Hamza. 2008. Physicochemical properties of oil extracts from *Sesamum Indicum* L. seeds grown in Jigawa State – Nigeria. *Journal of Applied Science and Environmental Management*, 12(2): 99-101.

Narayanankutty, A., R. K. Mukesh, S. K. Ayoob, S. K. Ramavarma, I. M. Suseela, J. J. Manalil, B. T. Kuzhivelil, and A. C. Raghavamenon. 2016. Virgin coconut oil maintains redox status and improves glycemic conditions in high fructose fed rats. *Journal of Food Science and Technology*, 53(1): 895-901.

Ndife, J., D. Obot, and K. Abasiekong. 2019. Quality evaluation of coconut (*Cocos nucifera* L) oils produced by different extraction methods. *Asian Food Science Journal*, 8(4): 1-10.

Neelakantan, N., J. Y. H. Seah, and R. M. van Dam. 2020. The effect of coconut oil consumption on cardiovascular risk factors a systematic review and meta-analysis of clinical trials. *Circulation*, 141(10): 803-814.

Ngassapa, F. N., and O. C. Othman. 2001. Physicochemical characteristics of some locally manufactured edible vegetable oils marketed in Dar Es Salaam. *Tanzania Journal of Science*, 27(1): 49-58.

Ogunlade, C. A., and A. K. Aremu. 2019. Influence of processing conditions on yield and quality of mechanically expressed african oil bean (*Pentaclethra macrophylla* Benth) kernels: a response surface approach. *Journal of Food Process Engineering*, 42(2): 1-9.

Ogunlade, C. A., and A. K. Aremu. 2020. Modeling and optimisation of oil recovery and throughput capacity in mechanically expressing oil from African oil bean (*Pentaclethra macrophylla* Benth) kernels. *Journal of Food Science and Technology*, 57(11): 4022-4031.

Okechalu, J. N., M. M. Dashen, P. M. Lar, B. Okechalu, and T. Gushop. 2011. Microbiological quality and chemical characteristics of palm oil sold within Jos Metropolis, Plateau State, Nigeria. *Journal of Microbiology and Biotechnology Research*, 1(2): 107-112.

Oseni, N. T., W. M. A. D. B. Fernando, R. Coorey, I. Gold, and V. Jayasena. 2017. Effect of extraction techniques on the quality of coconut oil. *African Journal of Food Science*, 11(3): 58-66.

Ouilly, J. T., P. Bazongo, A. Bougma, N. Kaboré, A. M. Lykke, A. Ouédraogo and I. H. N. Bassolé. 2017. Chemical composition, physicochemical characteristics, and nutritional value of *Lannea kerstingii* seeds and seed oil. *Journal of Analytical Methods in Chemistry*, 2017: Article ID 2840718.

Oyeleke, G. O., E. O. Olagunju, and A. Ojo. 2012. Functional physicochemical properties of watermelon (*Citrullus lanatus*) seed and seed-oil. *Journal of Applied Chemistry,* 2(2): 29-31.

PAES 230 – 231. 2005. Coconut Oil Expeller. Philippine Agricultural Engineering Standard. Available at: https://www.brainscape.com/flashcards/coconut-oil-expeller-paes-230-231-2005-8007545/packs/13322174. Accessed 10 July, 2017

Passera, L. S. 1981. Oxidation of lipids. *Plant Food Human Nutrition*, 31: 77-83.

Peng, L., S. Men, Z. Liu, N. Tong, M. Imran, and Q. Shu. 2019. Fatty acid composition, phytochemistry, antioxidant activity on seed coat and kernel of *Paeonia ostii* from main geographic production areas. *Foods*, 9(30): 1-20.

Seneviratne, K. N., and D. M. S. Dissanayake. 2005. Effect of method of extraction on the quality of coconut oil. *Journal of Science of the University of Kelaniya Sri Lanka*, 2: 63-72.

Seweh, E. A., P. A. Asagadunga, S. Apuri, and G. Owusu. 2016. Effects of extraction method and geographical location on the physico-chemical properties of shea (Vitellaria paradoxa) butter. *Asian Research Journal of Agriculture*, 1(1): 27513.

Sulieman, A. M. E., M. B. Mohammed, and O. A. Ali. 2013. Physicochemical and sensory properties of traditionally and laboratory made Ghee (*Samin*) of the Sudan. *International Journal of Food Science and Nutrition Engineering,* 3(1): 7-11.

Targais, K., T. Stobdan, A. Yadav, and S. B. Singh. 2011. Extraction of apricot kernel oil in cold desert Ladakh, India. *Indian Journal of Traditional Knowledge*, 10(2): 304-306.

Villarino, B. J., L. M. Dy, and C. C. Lizada. 2003. Descriptive sensory evaluation of virgin coconut oil and refined, bleached and deodorized coconut oil. *LWT - Food Science and Technology*, 40(2): 193-199.

WiredChemist. 2019. Determination of Melting Point. Available at http://www.wiredchemist.com/chemistry/instructional/laboratory-tutorials/determination-of-melting-point. Accessed 20 June 2019.

Yahaya, A. T., O. Taiwo, T. R. Shittu, L. E. Yahaya, and C. O. Jayeola. 2012. Investment in cashew kernel oil production; cost and return analysis of three processing methods. *American Journal of Economics*, 2(3): 45-49.