Quality Evaluation of Coconut (Cocos nucifera L) Oils Produced by Different Extraction Methods

Abstract:

Background: Despite the health benefits of coconut oil and its potential for economic development, the availability remain scarce and the cost very high. This is mainly due to poor extraction methods that in turn affect the yield and quality.
Aims: To produce coconut oil using different extraction protocols and to compare the quality of the different oil samples**.**
Study Design: The experimental set-up was of a completely randomized design**.**
Place and Duration of Study: Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Nigeria, between August and October 2018.
Methodology: Coconut oils produced by natural fermentation, centrifugation, freeze-thaw and solvent extraction protocols were analyzed for physical, chemical, sensory, microbial sensory properties.
Results: The solvent extracted oil had the highest oil yield (23.12 %) whereas fermentation oil, the lowest (14.19 %). The smoke and fire points had 173.75 -176.60 ^{0}C and 262.45 - 266.65 ^{0}C respectively. Solvent oil had the highest saponification (261.33 mgKOH/g) and acid values (0.77 mgKOH/g). The oils generally contained more lauric (46.22-48.16 %) and myristic (18.03-19.83 %) acids. They were also richer in vitamins A (6.22-18.65 ug/g) and E (2.92-4.28 mg/100g) than D and K. Fermentation oil had the highest microbial count (12.93×0^2 cfu/ml) whereas solvent oil had the lowest (5.05×0^2 cfu/ml).
Conclusion: The methods used for the coconut oil extraction had significant impact on the quality of the oils. The highest oil yield was the centrifugation oil obtained from Centrifugation Method. The physico-chemical properties and fatty acid compositions of the coconut oils were comparable to international standards. Coconut oil extracted by freezing and thawing was the most preferred in sensory attributes.

Key-words: Coconut, oil, fatty acid, oil yield, quality, extraction

1. INTRODUCTION

Coconut (*Cocos nucifera* L) is a staple in the diet of many islands of the world, which supplies nutritious meat, juice, milk and oil for nourishment [1,2]. Coconut oil or copra oil, is the edible oil extracted from the kernel or meat of mature coconuts harvested from the coconut palm [1,2]. Studies have shown that coconut oil is used by the food and pharmaceutical industries [2].

Coconut oil is one of the earliest oil to be consumed as food and for medicinal purposes. Studies have shown that people whose diets are high in coconut oil are healthier and have fewer incidences of cardiovascular diseases, digestive complaints, cancer and prostrate problems [3,4]. Nutritional and clinical observations have shown that coconut oil contains 64% medium chain fatty acid (MCFA) which can prevent and treat a wide range of diseases [4]. The MCFA when broken down is used for energy production and thus seldom end up as body fat or deposit in arteries which does not adversely affect cholesterol levels [5,6].

The varieties of coconut oils include: pure, refined, virgin, organic, organic-virgin and extra virgin. Virgin coconut oil (VCO) is defined as the oil resulting from the fresh and mature kernel of the coconut through mechanical and natural means, either with the use of heat or not, provided it does not lead to alteration or transformation of the oil [2,7].

There are no specific processing prerequisites that are established for coconut oil production [4]. However, several methods to produce Virgin coconut oil are found to measure up with the definition of the

Virgin coconut oil [4,8]. Since high temperature and chemical solvent are not used, the oil retains its naturally occurring phyto-chemicals with distinctive coconut taste and smell.

Despite the health benefits of coconut oil and its potentials for economic development, the availability remains scarce and the cost very high [1]. The low availability of coconut oil is not due to limitation of coconuts but rather, due to poor extraction methods that in turn affect the yield, quality and shelf life [4}. Therefore, there is need to research into coconut oil extraction in order to identify the optimal extraction procedure, which will enhance the consumption and future development in the industry. The main objective of this research therefore was to produce coconut oil using different extraction protocols and to compare the quality of the different oil samples.

2. Materials and Methods

2.1 Sourcing of the materials

The fresh and mature coconut fruits were obtained from Ikot Anwana, Ikono Local Government Area of Akwa Ibom State. The analysis was carried out at Central Laboratory of National Root Crop Research Institute (NRCRI) Umudike, Nigeria. The laboratory equipment and reagents that were used for the experiment were of analytical grades and standards.

2.2 Sample preparation and production

The fresh and mature coconut fruits were dehusked and shelled with machete. The coconut meat was peeled, washed, size reduced and crushed using a Q-link China Model blender. The varieties of coconut oils were produced using different oil extraction protocols, viz:

Natural Fermented Virgin Coconut Oil (NFVCO): Mashed coconut meat (500 g) and water were blended at 70 ^oC at a ratio of 1:2 and kneaded by hand for 5 min. The mixture was strained through cheese cloth to obtain coconut milk, which was allowed to ferment naturally for 72 h at 40 ^oC. The oil was decanted from the fermented curd by centrifuging at 4000.

Centrifugation method: The mashed coconut meat (500 g) was blended with H2O (1:1) and filtered to extract the coconut milk. Centrifugation was carried out twice (4000 rpm) to destabilize the oil water emulsion for 30 min at room temperature. Initial centrifugation was done to obtain the cream and the second centrifugation, to separate the cream into two layers (oil-cream and aqueous). The top oil layer was decanted to get the virgin coconut oil.

Freezing and thawing method: The mashed coconut meat (500 g) was blended with H2O (1:1), hand kneaded for 5min, pressed and filtered to extract coconut milk. The Coconut milk was centrifuged (4000 rpm/10 min). The upper layer of the cream was removed and chilled (-5 ^oC/6h). The chilled cream was thawed slowly at room temperature to extract the oil. Centrifugation was applied (4000 rpm) for 30 min at room temperature to obtain coconut cream. The process was done repeatedly to produce chill-thawed virgin coconut oil.

Solvent extraction method: The coconut meat was washed, sliced and oven dried using contherm thermoset 2200 at 75 ℃ to obtain copra with moisture content of (7 %). The copra (500 g) was then mashed, soaked overnight and blended in n-hexane solvent. The oil was extracted from the dried coconut by solvent extraction using soxhlet apparatus.

The oils obtained by natural-fermentation, centrifugation, freezing-thaw and solvent extraction methods were analyzed thereof.

2.3 Methods of analysis

2.3.1 Determination of physical properties

The oil yield (%) was calculated relative to the total weight. Other physical properties of smoke, flash, fire, melting and cloud points, as well as refractive index, specific gravity, impurities and moisture contents of oil samples were determined by the methods described by Onwuka [9].

2.3.2 Evaluation of chemical characteristics

The oil quality characteristics such as acid value, iodine value, free fatty acid, thiobarbituric acid number and saponification value, were evaluated according to the methods described by AOAC [10].

2.3.3 Analysis of fatty acid composition

Fatty acid composition was examined using the Gas Chromatography (GC) protocol [10]. The oils were converted to their fatty acid methyl esters (FAMEs) and were identified with the pure standards. The results were expressed as % of individual fatty acids.

2.3.4 Determination of Zinc and Iron contents

The Zn and Fe were determined according to the method described by Nielsen [11]. 5g of the sample was weighed in a crucible and then placed in a muffle furnace for ashing at a temperature of 500oC for two hours. 10cm3 of 6M Nitric acid (HNO3) was added and agitated until a uniform solution was obtained. The digests were analysed using Atomic Absorption Spectrophotometer (AAS).

2.3.5 Vitamin assay

The fat soluble vitamins A (carotenoid), E (tocopherol), D and K contents of the palm oil samples were determined by the method described by Nielsen [11] with some modifications. The vitamins were quantified using their respective standards with a UV-VIS spectrophotometer.

2.3.6 Microbiological assay

The determination of the total aerobic count of the palm oil was performed by the method outlined in the compendium of methods for the microbiological examination of foods, with some modifications [12].

2.3.7 Sensory evaluation

The protocol described by Iwe [13] was used. The organoleptic properties of coconut oil samples were evaluated by 20-member semi-trained panellists, randomly selected from the staff and students of the university. The sensory attributes of appearance, taste, aroma and general acceptability were assessed using the 9-point Hedonic scale, with 9 as dislike extremely and 1 as like extremely.

2.4 Experimental design and statistical analysis

The experimental set-up was of a completely randomized design. All determinations were done in triplicates and their mean values were reported with standard deviations. The data obtained from the various analyses were subjected to analysis of variances using the statistical package for social sciences (SPSS), version 16.0 for windows. One-way Analysis of Variance (ANOVA) was used for comparison of the means. Differences between means were considered to be significant at $p<0.05$ using the Duncan multiple range test.

3 RESULTS AND DISCUSSION

3.1 Physical properties

The result of the physical characteristics of Virgin Coconut Oil (VCO) samples by different extraction methods are presented in Table 1 along with the Asian and Pacific Coconut Community (APCC) standard [7]. The moisture content of the extracted coconut oils ranged from 0.17 to 0.41% [14]. It is desirable to keep the moisture content low to increase the shelf life by preventing oxidation and rancidity processes. High moisture content promotes hydrolytic rancidity of fats and oils [8]. There was a significant ($p<0.05$) difference in the moisture content of the coconut oils. The fermentation, centrifugation and freezing oils had moisture content of 0.39, 0.25 and 0.41 respectively which were all above the APCC [7] standard of <0.2%.

The percentage impurity refers to extraneous substances which remain insoluble after the oil is dissolved in a specific solvent [15]. The solvent coconut oil had the lowest insoluble impurity of 0.11 % while the highest impurity of 0.42 % occurred in the fermentation oil. The insoluble impurities of the oils ranged from 0.11 to 0.42% which was higher than the maximum limit (0.05 %) stated by CODEX [16]. The amount of insoluble impurities is reflecting the efficiency of clarification during extraction of oil [17]. It was observed that different processing methods resulted in a significant variation ($p<0.05$) in purity of the resulting oil.

The specific gravity value of the coconut oils ranged from 0.91 to 0.93, which were all above APCC standard of 0.915 to 0.920. The highest value (0.93) of specific gravity occurred in the solvent oil while the fermentation oil had the lowest specific gravity (0.91). There were no significant differences ($p<0.05$) between the specific gravity of the oil samples. The higher specific gravity of 0.93 observed in the solvent oil can be attributed to the higher content of linoleic acid [18].

The refractive index is the degree of refraction of a beam of light that occurs when it passes from one transparent medium to another. The refractive index value obtained in this study ranged from 1.44 to 1.45. There was no significant ($p>0.05$) difference in the refractive index of the oil samples. The refractive index is unique for coconut oil and can therefore be used to check adulteration and purity of oil [9].

The oil yield of the different techniques of extractions revealed the differences in the quantity of oil extracted. Significant ($p<0.05$) higher oil yield (23.12 %) was obtained from the solvent oil followed by the centrifugation oil (19.84 %) which may be attributed to the frequency and high speed of centrifugal force used [19]. The extraction yield (14.19%) could be increased in the fermentation oil by prolonging fermentation time by lactic acid bacteria [8,20].

The ranges of the smoke (170.50 - 176.60 %), flash (202.75 - 208.55 ^{o}C) and fire points (262.45 - 266.65 ^{o}C) were all lower than the APCC (2009) set standards. The centrifugation oil had the highest flash point (208.55 ^{0}C) while the lowest fire point (262.45 ^{0}C) occurred in the solvent oil. The lower the FFA, the higher the smoke point [9]. The more FFA oil contains, the quicker it will break down and start smoking [21]. The flash point is used to assess the safety hazards with regard to its flammability [22]. Fire point is important as they show the degree to which oil or fat may be heated without undergoing undue breakdown and ignition [23,5]. The melting points (23.05 ^{o}C - 24.05 ^{o}C) of the coconut oil samples were comparable to the APCC standard (24 ^{o}C).

Table 1: Physical properties of oil samples

Coconut Oil	Moisture Content (%)	Impurity (%)	Specific Gravity	Refractive Index	Oil Yield (%)	Flash Point (^{O}C)	Fire Point (^{O}C)	Smoke Point (ºC)	Melting Point (^{O}C)
Fermentation	$0.39^{a}\pm0.01$	$0.42^{c}\pm0.01$	$0.91^{a}\pm0.00$	$1.44^{a}\pm0.00$	$23.12^{c}\pm0.03$	$204.20^{a}\pm0.14$	$264.10^{b}\pm0.14$	$175.30^{b}\pm0.28$	$24.05^{a}\pm0.07$
Centrifugation	$0.25^{b}\pm0.01$	$0.20^{d}\pm0.01$	$0.91^{a}\pm0.00$	$1.44^{a}\pm0.00$	$19.84^{a}\pm0.03$	$208.55^{a}\pm0.21$	$266.65^{a}\pm0.21$	$176.60^{a}\pm0.28$	$23.45^{b}\pm0.21$
Freezing	$0.41^{a}\pm0.01$	$0.36^{b}\pm0.01$	$0.92^{a}\pm0.00$	$1.44^{a}\pm0.00$	$19.04^{c}\pm0.01$	$202.75^{d}\pm0.14$	$264.50^{b}\pm0.17$	$173.75^{d}\pm0.21$	$23.05^{c}\pm0.07$
Solvent	$0.17^{c}\pm0.01$	$0.11^{a}\pm0.02$	$0.93^{a}\pm0.00$	$1.45^{a}\pm0.00$	$14.19^{d}\pm0.02$	$205.35^{c}\pm0.07$	$262.45^{c}\pm0.35$	$170.50^{c}\pm0.28$	$23.65^{b}\pm0.07$
ASCC	<0.2	<0.05	0.91-0.92	1.44±1.450	--	<295	<330	<177	<24

Values are means $\pm$ standard deviation; Column with different superscript are significantly different ($p<0.05$). APCC-Asian and Pacific Coconut Community Standard.

3.2 Chemical characteristics

The chemical properties of the extracted coconut oils are shown in Table 2. The saponification value (SV) of the oils ranged from 248.12 to 261.33 mgKOH/g. There was significant difference ($P<0.05$) in the SV of the oil samples which could be attributed to the different extraction processes used [4]. Coconut oil has a relatively high saponification value due to its high content of short and medium chain triglycerides [24]. All the oils had SV which compared well with CODEX [16] standard of 248 to 265 mgKOH/g of oil.

The acid value of the oil samples ranged from 0.39 to 0.77 mg/KOH/g. The Solvent oil had the highest acid value (0.77 mg/KOH/g) followed by the fermentation oil (0.71 mgKOH/g). The acid value indicates the level to which the glycerides in the oil had been decomposed by lipase action [9]. According to CODEX [16], the acid value must be lower than 0.6 mgKOH/g for good quality coconut oil.

The Iodine value is used to determine the amount of unsaturation in an oil, by the addition of iodine to double bonds [15,17]. The iodine value range of the coconut oils (7.52 -11.15 g/100g) were above CODEX [16] set standard of 6.3-10.6 g/100g. Vegetable oils can be differentiated by the amount of iodine that is absorbed [11,9].

The Free Fatty Acid values of the oil samples ranged from 0.19 to 0.39 %. There was a significant difference ($p<0.05$) among the samples. The solvent oil had the highest FFA (0.39 %) while the centrifugation oil had the lowest (0.19 %). The heat used during the solvent extraction must have contributed to the increase of FFA in the solvent oil. During extraction and storage, additional FFAs may be formed by reactions with residual water and lipase enzyme in the oil [14,8].

Table 2: Chemical properties of oil samples

Coconut Oil	Saponification Value (mgKOH/g)	Peroxide Value (mEq/kg)	Acid Value (mgKOH/g)	Iodine Value (g/100g)	Free Fatty Acid (%)
Fermentation	$259.17^b \pm 0.02$	$7.42^c \pm 0.01$	$0.71^b \pm 0.01$	$10.41^c \pm 0.01$	$0.36^b \pm 0.01$
Centrifugation	$248.12^d \pm 0.02$	$9.63^a \pm 0.01$	$0.39^c \pm 0.01$	$7.52^d \pm 0.01$	$0.19^d \pm 0.00$
Freezing	$258.86^c \pm 0.02$	$7.81^b \pm 0.01$	$0.68^b \pm 0.01$	$10.96^b \pm 0.28$	$0.34^c \pm 0.01$
Solvent	$261.33^a \pm 0.02$	$6.13^d \pm 0.01$	$0.77^a \pm 0.01$	$11.15^a \pm 0.02$	$0.39^a \pm 0.01$
CODEX	248-265	<15	<0.6	6.3-10.6	<0.5

Values are means $\pm$ standard deviation; Column with different superscript are significantly different ($p<0.05$); CODEX - Codex oil standard.

3.3 Fatty acids composition

Tables 3 show the fatty acid profiles of the extracted coconut oils along with the CODEX standard. The Caproic acid (C_6) content of the coconut oils ranged from 0.54 to 0.59 % with no significant difference ($p>0.05$) observed among them. Caproic acid (C_6) was the least fatty acid in all the coconut oils. However, the value was close to the CODEX [16] standard (0.7%).

The Caprylic acid (C8) of the coconut oils (6.28 - 7.46%) was within the CODEX standard (4.6 - 10.0 %). There was no significant difference ($p>0.05$) in the Caprylic acid (C8) of the oil implying non-effect of extraction method on the caprylic acid content. These values were lower than 8.22 - 9.02% reported in an earlier study [25] for extracted coconut oils. The Caprylic acid (C10) value of the oils which ranged from 5.51 to 6.17 % was comparable to the CODEX [16] standard (5.0 - 8.0 %).

The Lauric acid (C12) values of the oils (46.22 - 48.40 %) was within the standard range (45.1 -53.2 %). Coconut oil is predominated by medium chain saturated fatty acids (MCFA) [25]. Myristic acid (C14) was the highest MCFA (18.03 - 19.83 %) after Lauric acid. These values were similar to those reported by Mansor et al. [26] and Marina et al. [4] for virgin coconut oils (18.01 - 20.00 %).

The Palmitic acid (8.90 – 9.43 %) and Stearic acid (2.90 – 3.18%) values also concurred with the stated standard (7.5 – 10.2 %). The solvent (9.43 %) and centrifugation (3.18%) oils had the highest Palmitic acid and Stearic acids respectively while the centrifugation (9.02 %) and solvent (2.90 %) oils had the least for same. These ranges were higher than 8.02 - 8.88 % reported for Palmitic acid [22] and 2.00 - 2.18 % for stearic acids [25] in coconut oil recovered by different techniques and fruit maturities.

The Oleic acid (C18:1) of the coconut oils ranged from 6.17 to 6.54% and the Linoleic acid (C18:2) ranged from 1.30 to 1.51 %. The highest Oleic (6.54 %) and Linoleic acid (1.51 %) values were found in the centrifugation oil. The values of Oleic acid (C18:1) in this study was higher than 1.50 - 2.30 % reported by Dayrit *et al.* (2011) for VCO. The Oleic and Linoleic acids values were within the stated range for good oil quality [27,8].

Table 3: Fatty Acid Profile of Oil Samples

Coconut Oil	Caproic (C_6)	Caprylic (C_8)	Capric (C_{10})	Lauric (C_{12})	Myristic (C_{14})	Palmitic (C_{16})	Stearic (C_{18})	Oleic ($C_{18:1}$)	Linoleic ($C_{18:2}$)
Fermentation	0.54^{a}±0.00	6.94^{a}±0.00	5.86^{a}±0.00	48.04^{a}±0.00	18.17^{a}±0.00	9.12^{a}±0.00	3.18^{a}±0.00	6.36^{a}±0.00	1.42^{a}±0.00
Centrifugation	0.54^{a}±0.00	6.28^{a}±0.00	5.51^{a}±0.00	46.22^{a}±0.00	19.83^{a}±0.00	9.02^{a}±0.00	3.40^{a}±0.00	6.54^{a}±0.00	1.51^{a}±0.00
Freezing	0.57^{a}±0.00	7.34^{a}±0.00	6.10^{a}±0.00	48.16^{a}±0.00	18.34^{a}±0.00	8.90^{a}±0.00	2.94^{a}±0.00	6.17^{a}±0.00	1.30^{a}±0.00
Solvent	0.59^{a}±0.00	7.46^{a}±0.00	6.17^{a}±0.00	48.40^{a}±0.00	18.03^{a}±0.00	9.43^{a}±0.00	2.90^{a}±0.00	6.22^{a}±0.00	1.40^{a}±0.00
CODEX	ND-0.7	4.6-10.0	5.0-8.0	45.1-53.2	16.8-21.0	7.5-10.2	2.0-4.0	5.0-10.0	1.0-2.5

Values are means ± standard deviation; Column with different superscript are significantly different ($p<0.05$); CODEX - Codex oil standard.

3.4 Vitamin and mineral contents

The Vitamin and Mineral composition of the oil samples are presented in Table 4. Vitamins A, D, E, and K in consideration, are fat soluble vitamins which are important to the nutritional value of oil foods. Vitamin A is a group of unsaturated compounds that include retinol, retinal, retinoic acid and several pro-vitamin A carotenoids [6,28]. The vitamin A content ranged from 6.22 to 18.65 µg/g. The Solvent oil had the lowest Vitamin A content (6.22 µg/g).

Vitamin D is a group of fat soluble secosteroid responsible for increasing intestinal absorption of calcium, magnesium, phosphate and has multiple other biological effects in the body [29]. The vitamin D content of the oils ranged from 1.01 to 1.62 µg/g. The freezing coconut oil had the highest Vitamin A (1.62 µg/g). There was a significant difference ($p<0.05$) in the vitamin D content of the oil samples. Dietary recommendation typically assumes that a person's entire vitamin D is taken by mouth, as sun exposure in the population is variable [5].

Vitamin E (Tocopherol) is an enzyme activity regulator for protein kinase C (PKC) which plays a role in smooth muscle growth [5]. Within the Vitamin E range (2.92 - 4.28 mg/100g), the freezing oil had the highest value (4.28 mg/100g). This could be attributed to the low temperature used in the extraction which retained the vitamin content. There was significant difference ($p<0.05$) in the vitamin E content of the oil samples. VCO produced naturally without or with mild heating help preserve the tocopherol and other antioxidants [3]. Vitamin K is required by the human body for blood coagulations and for controlling binding of calcium in bones and body tissues [29]. The vitamin K value of the coconut oils ranged from 0.61mg to 1.03 mg/100g. The low vitamin values of the solvent oil could be attributed to the heat treatment and leaching of the vitamins, due to the use of hexane in the extraction process.

The Iron and Zinc contents of the coconut extracted oils (Table 4) ranged from 0.41 to 0.53mg/100g and 0.62 to 1.21mg/100g respectively. Zinc was generally higher than the Iron values. This might be connected to the Zinc -rich mineral of the soil [25]. The solvent oil had the lowest Iron (0.41mg/100g) and Zinc values (0.62mg/100g). There were significant differences ($p<0.05$) in the Iron and Zinc content of the oils. Zinc and Iron are essential elements required in very small amounts that are necessary for human health. Iron is a constituent of haemoglobin, myoglobin and a number of enzymes; it is therefore an essential nutrient for body function [5,6].

Table 4: Vitamin and Mineral composition of oil samples

Coconut Oil	Vitamin A (µg/g)	Vitamin D (µg /g)	Vitamin E (mg/100g)	Vitamin K (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)
Fermentation	$12.33^{c}\pm0.02$	$1.41^{b}\pm0.01$	$3.05^{c}\pm0.01$	$0.77^{b}\pm0.00$	$0.47^{b}\pm0.01$	$1.10^{c}\pm0.00$
Centrifugation	$16.77^{b}\pm0.01$	$1.38^{b}\pm0.01$	$4.12^{b}\pm0.01$	$0.73^{c}\pm0.01$	$0.48^{b}\pm0.00$	$1.21^{a}\pm0.01$
Freezing	$18.65^{a}\pm0.03$	$1.62^{a}\pm0.02$	$4.28^{a}\pm0.01$	$1.03^{a}\pm0.01$	$0.53^{a}\pm0.01$	$1.16^{b}\pm0.02$
Solvent	$6.22^{d}\pm0.02$	$1.01^{c}\pm0.01$	$2.92^{d}\pm0.02$	$0.61^{d}\pm0.01$	$0.41^{d}\pm0.01$	$0.62^{d}\pm0.02$
CODEX	NA	NA	ND-17	NA	NA	NA

Values are means $\pm$ standard deviation; Column with different superscript are significantly different ($p<0.05$). CODEX - Codex oil Standard.

3.5 Total microbial count

The results of total microbial count of the coconut oils are presented in Table 5. The total microbial count of the oil samples ranged from 5.05 to 12.93×10^{2} cfu/ml. The highest microbial load (12.93×10^{2} cfu/ml) was in the fermentation oil while the least microbial count occurred in the solvent oil. The centrifugation, freezing and solvent oils were all within the APCC [7] standards ($<10 \times 10^{3}$ cfu/ml), while the fermentation oil was beyond.

The high microbial count in of the fermentation oil could be attributed to the fermentation process which involved microorganisms. Failure to meet specified standards indicates that the product is of poor quality with potential health hazard and short shelf life [12].

Bacteria (*Acetobacter, Streptococcus, Staphylococcus* sp.) and fungi species (*Saccharomyces, Candida*, and *Rhizopus*) have been implicated in coconut oils spoilage [30]. 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 [30,31].

Coconut Oil	Total Microbial Count (Cfu/ml $\times 10^{2}$)
Fermentation	$12.93^{a}\pm0.02$
Centrifugation	$9.54^{b}\pm0.03$
Freezing	$6.17^{c}\pm0.02$
Solvent	$5.05^{d}\pm0.03$
CODEX	$<10 \times 10^{2}$

Table 5: Total microbial count of oil samples

Values are means ± standard deviation; Column with different superscript are significantly different ($p<0.05$).

APCC (Asian Pacific Coconut Community Standards, 2009).

3.6 Sensory evaluation of oil samples

The result of sensory evaluation of the oil samples is shown in Table 6. There were significant differences ($p<0.05$) in all the sensory attributes assessed exception of consistency. The appearance score of the oils ranged from 6.65 to 7.95. The oil samples were almost colourless, except for the solvent oil. The freezing oil had the highest score (7.95) while the solvent oil had the least (6.65).

In the taste score, the freezing oil had 7.75 followed by centrifugation oil with 7.70, and solvent oil with 6.55. A close range of 6.30 to 8.30 was reported in previous works on the descriptive sensory evaluation of virgin, refined, bleached and deodorized coconut oils [32]. The fermentation oil had the least score (4.00) while the freezing oil had the highest score (7.50) in aroma. The fermentation oil was observed as having rancid aroma. Since no heat was applied to this sample, it is possible moisture and microflora may have facilitated hydrolytic rancidity [31,33].

The consistency (smoothness) score of the oil samples ranged from 6.25 to 6.85. There was no significant difference ($p>0.05$) in the consistency score of the oil samples. The fermentation oil had the least score (6.25) and the freezing oil had the most (6.85). This implied that various extraction methods did not affect the consistency of the oil samples.

In the general acceptability score (6.40 – 7.90), the freezing oil was the most acceptable (7.90), followed by centrifugation and Solvent oils with 7.00. The fermentation oil was the least acceptable (6.40), probably due to the poor aroma and appearance. There was significant difference ($p>0.05$) in the general acceptability of the coconut oils. The coconut oil produced by freezing and thawing method was the most preferred in all attributes evaluated. Freezing methods of processing had been reported not to alter the organoleptic and nutritional quality of foods [33].

Table 6: Sensory Evaluation of Oil Samples

Coconut Oil	Appearance	Taste	Aroma	Consistency	Acceptability
Fermentation	7.20^{ab}±1.19	5.75^{b}±1.80	4.00^{b}±2.70	6.25^{a}±1.33	6.40^{b}±1.64
Centrifugation	7.70^{a}±0.86	6.55^{b}±1.15	6.90^{a}±1.17	6.60^{a}±0.99	7.00^{b}±0.80
Freezing	7.95^{a}±1.10	7.75^{a}±1.02	7.50^{a}±1.00	6.85^{a}±1.39	7.90^{a}±1.37
Solvent	6.65^{b}±1.70	6.55^{b}±1.15	6.35^{a}±1.60	6.35^{a}±1.50	7.00^{b}±1.30

Values are means ± standard deviation: Column with different superscript are significantly different ($p<0.05$).

4. CONCLUSION

The methods used for the coconut oil extraction had significant impact on the quality of the oils. The highest oil yield was the centrifugation oil obtained from Centrifugation Method. The physico-chemical properties and fatty acid compositions of the coconut oils were comparable to international standards for oil quality. The high microbial count in the fermentation oil could be attributed to the fermentation process which involved microorganisms, which failed to meet reference international standard. Coconut oil extracted by freezing and thawing (freezing oil) was the most preferred in most sensory attributes evaluated. Further research work should be focused on the shelf stability of these oils. Public enlightenment on the nutritional and health benefits of coconut oils as well as the best extraction protocol should be done as this would to help improve its utilization and develop the industry.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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