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Effect of Temperature on Dynamic Viscosity, Density and Flow Rate of Coconut Oil

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Abstract

This study was conducted to evaluate the correlation between extraction techniques and the oil yield of coconut. Relationship between temperature, dynamic viscosity and flow rate of the extracted oils was determined. Coconut oil Three oil extraction techniques were used namely; solvent extraction (SE), wet mill cold extraction (WMCE) and wet mill hot extraction (WMHE) SE had the highest oil recovery (79.52%). There was no significant difference between the yield of oil from wet mill cold extraction (45.13%) and wet mill hot extraction (42.19%). The dynamic viscosities of the oils extracted from the different techniques were determined at different temperatures (30°C-100°C) and shear rates (6rpm, 12rpm, 30rpm and 60rpm) using NDJ-5S viscometer. The result of analysis of variance showed that the interaction between temperature, dynamic viscosity at different shear rate of the coconut oil was significant (P<0.05). The mean flow rate of coconut oil extracted from the different extraction techniques at different temperatures of 30°C to 100°C ranged from 3.50 ml/s to 6.61 ml/s, 4.16 ml/s to 6.81 ml/s and 3.95 ml/s to 6.64 ml/s for WMCE, WMHE and SE respectively. The correlation between temperature and dynamic viscosity of the extracted oils showed negative non-linear relationship. A positive non-linear relationship was observed between oil flow rate and temperature.
Keywords: Vegetable Oil; Physical properties; Viscometer; Dimension; Solvent extraction; Shear rate.

1. Introduction

Coconut palm (*Cocosnucifera L.*) is a tree belonging to the palm family *Arecaceae*. It is one of the most important tropical palm trees. Coconut trees are typical single trunked palms which can grow to an average height ranging from 50 – 100 ft. They are planted by seed and usually at about 9m apart. Averagely the coconut tree can produce about 70 - 150 nuts annually and each tree can remain productive for about 50- 100 years [1]. Coconut palm (*Cocosnucifera L.*) is widely cultivated to about 12 million hectare across the world [2]. It was also described as multi-use tree with great economic significance and cultural importance providing food, fibre, fuel, medicine, energy, water, nutrition, landscapes and home beautification for about 10 million families from more than 80 countries [3, 4]. Several researches revealed that every part of the coconut tree and its fruit can be used or converted into valuable products [3]. Coconut palm is an all-around crop and incredible tree giving more than 300 products. In addition, for agro-forestry uses, includes coastal stabilization and windbreaks [5].

Coconut oil extracted from coconut fruit is nutritious and has wider applications in pharmaceutical, nutraceutical and cosmoceutical, margarine and soaps in the oleo-chemical and automotive and energy generation as a bio fuel industries [5-9]. Bawalan [3], reported the use of coconut oil as an alternative fuel source to run automobiles, trucks, and buses, and to power generators and also substitute for diesel. In some part of Africa, coconut oil is used to fuel native lamps for lighting in rural communities that are not connected to electricity.

Coconut fruit is rich in major food components such as carbohydrates, proteins, lipids, dietary fiber, vitamins and minerals. Oil is characterized with medicinal values such as alleviating cardiovascular disease, digestive complaints, cancer and prostate problems, food supplement, body moisturizer, aromatherapy, a hair conditioner [6]. Coconut oil contains medium chain fatty acid that burns up immediately after consumption and therefore the body uses it instantly to produce energy instead of being stored as body fat [10]. It enhances healthy heart, source of energy and fat-soluble vitamins in the maintenance of human nutrition [9, 11]. According to Espino [12], virgin coconut oil has been rated as one of the "healthiest oil in the world", owing to its rich amount of medium chain fatty acids particularly 48-53 % of lauric acid (C-12), about 90% saturated fats, with 60% being medium chain triglycerides that could boost the metabolism, immunity, digestibility and guarantee the better serum lipid profile that is causal to the healthy survival [13].

Coconut has a high oil content of 33%, which is a major source of vegetable oil for people in the tropics [6]. Oil yield of 30-40% was reported by Hamid, *et al.* [14]. Coconut oil is a vegetable oil that is extracted from the kernel of coconut [11, 15].

Bawalan [3] and Bawalan [16] reported four processing techniques for coconut oil extraction that is, traditional wet or modified kitchen methods, modified natural fermentation methods, low pressure oil extraction techniques and

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high pressure expeller methods. Solvent extraction is another technique widely used in the extraction of coconut oil as well as several other vegetable oils [17].

Many researchers have worked on extraction oil from different oilseed crops such as coconut, citrus seeds, rapeseed, canola, roselle seeds, palm kernel, soybean, melon, peanut, cotton, rapeseeds, sunflower and jatropha are common commercially-available vegetable oils with considerable high oil content [3, 16, 18-28]. There paucity of information on the effect of temperature on the viscosity and flow rate, at shear rate of 6, 12, 30 and 60 rpm.

2. Materials and Methods

Coconut fruits with the husks of the same batch were purchased from Songhai farms, located at Sapele-Eku Road, Delta State. Solvent (n-hexane) was of analytical grade and was purchased from Yenagoa. Experiment was conducted at Reaction Engineering and Kinetics Laboratory and Reservoir/Production Laboratory of Chemical Engineering Department, Faculty of Engineering, Niger Delta University.

These three techniques were employed for the extraction of oil from coconut fruits this include: Wet mill cold extraction (WMCE), Wet mill hot extraction (WMHE) and Solvent extraction (SE).

2.1. Wet Mill Cold Extraction (WMCE)

Coconut fruits were cracked with a sharp cleaver and dehusked with a sharp knife. The resulting coconut meat was washed with clean water inside a bowl and grated with stainless steel grater. Grated coconut meat was weighed using Golden - Mettler U.S.A electronic balance and 1000g was obtained, which was mixed with clean water at ratio 1:2 and blended using a Binatone blender/food processor. The mixture obtained was strained through cheesecloth to obtain coconut milk. Coconut milk was placed in a transparent bucket with lid and left for 48hrs to naturally separate into different layers. Water settled at the bottom of the bucket, followed by coconut solids (curds), and then the coconut oil with a thin film of coconut cream at the top. Film of coconut cream was scooped out with a table spoon and coconut oil was carefully collected into an aluminum pot with a Pasteur pipette and heated mildly to reduce moisture as well as to enable some coconut solids still present to settle to the bottom. Oil was sieved and collected into an already weighed bottle and weighed to get weight of oil obtained.

2.2. Wet Mill Hot Extraction (WMHE)

Removal of the husk, or outer casing of coconut was manually carried out with a sharp knife. Dehusked coconut was de-shelled carefully without breaking kernel. A thin layer of brownish film that lies between the kernel and the shell was peeled off using sharp knife. Skinned coconut meat kernel was washed with clean water inside a bowl and grated with stainless steel grater. Grated coconut meat was weighed on Golden – Mettler U.S.A Electronic balance. Stainless steel plate mill was used to grind coconut to smaller particle. The mixture obtained was strained through cheesecloth to obtain coconut milk. Coconut milk was poured into a aluminum pot and boiled and continuously stirred until all the water evaporated leaving a mixture of oil and coconut solids, heating continued until the oil completely separated from the coconut solids and turned yellowish. Extracted oil was cool, sieved and weighed.

2.3. Solvent Extraction (SE)

Dehusked and skinning operations of coconut fruits were carried done manually with a sharp knife. The resulting coconut meat was washed with clean water inside a bowl and grated with stainless steel grater. Grated coconut meat was weighed using Golden - Mettler U.S.A Electronic balance and 500g was obtained, which was oven dried using WTB Binder to 7% moisture content. Oil was extracted from the dried coconut by solvent extraction using n-hexane in a Soxhlet apparatus (Electromantle). Thermal cycle was done at 75°C in batches, with every batch running for about 2hours and using 200ml of n-hexane per batch. The mixture of n-hexane and coconut oil obtained from the soxhlet apparatus was transferred to a rotary evaporator where a water bath was used as the source of heat to evaporate the n-hexane leaving the coconut oil which was then allowed to cool, weighed and transferred to a collecting bottle.

Plate-1. Soxhlet Apparatus

Oil Yield

Fife [6] and Davies [29] established that coconut has 33% oil content. Thus oil yield (%) was calculated in comparison with the total oil content of as shown in the expression below.

$$Oil\ yield(\%) = \frac{Weight\ of\ oil\ extracted(g)}{Total\ oil\ content(g)} X\ 100 \quad 1$$

2.4. Determination of Viscosity

Model NDJ-5S Viscometer measured the viscosity by applying a known shear rate. The sp-4 spindle was operated at 6rpm, 12rpm, 30rpm, and 60rpm on the test oil, while temperatures were varied from 30°C - 100°C at a step size of 10°C. The amount of shear transmitted through the oil was displayed as data on the electronic screen of the Viscometer and this reading corresponds to the viscosity of the test oil. The rotor was threaded and could easily be removed and cleaned at Plate 3.2: Soxhlet Apparatus the end of each test. For testing above ambient temperatures, a laboratory thermometer and water bath (Stuart - RE300B) was provided to increase temperatures to as high as 100°C. NDJ-5S Viscometers are designed to measure the viscosity of test fluids by measuring shear stress at specific shear rates.

Plate-2. NDJ-5S Viscometer

2.5. Determination of Flow Rate

Two retort stands, two 250ml beakers, 500ml plastic cup with a hole of 2.5mm radius at the bottom, a stopwatch, a laboratory thermometer, water bath, and a nail were used. The plastic cup was held on one retort stand, a 250ml beaker was placed below the cup to hold the flowing oils, and the stopwatch was used to record the time taken for the oils to flow out of the plastic cup into the beaker. For temperatures above ambient temperature, another retort stand was used to hold a beaker placed in the water bath and the temperature was regulated. The laboratory thermometer was used to check the temperature and the oil from the beaker was poured into the plastic cup when the desired temperature was reached. The nail on the hole of the bottom of the plastic cup was removed and the stopwatch was set to record the time of flow of the oil. A formula derived by Davies [29] was used to calculate the flow rate as follows.

Q = V/t 1

Where:

Q is the flow rate (ml/s)

V is volume of oil (ml)

t is time for oil to flow out of the plastic cup into the beaker (s).

3. Results and Discussion

The result of oil yield from coconut adopting different extraction techniques showed revealed in Fig.1. Oil yield varied significantly with extraction techniques. SE had the highest oil yield (79.52%) and lowest oil yield (42.19%) corresponded to WMHE technique, The ANOVA showed significant difference for the compaction ratio values of the water hyacinth briquette at the different compaction pressure (P<0.001). This observation could be adduced to the use of hexane which is a non-polar solvent capable of dissolving fats and may be the prolonged exposure to heat (75^{o}C).

The viscosity of coconut oil extracted from WMCE, WMHE and SE at different temperatures were determined at different shear rates as shown in Fig.2-4. The viscosity at different temperature interval of 30^{o}C to 100^{o}C ranged between 103.44 and 78.54cP, 49.89 and 43.24 cP, 27.58 and 8.32 cP and 10.99 and 9.69cP for 6rpm, 12rpm, 30rpm and 60rpm respectively for oil extracted from WMCE. The viscosity of oil extracted from WMHE at temperature interval as above ranged from 98.83 to 77.03cP, 47.87 to 39.63cP, 23.20 to 7.24cP and 9.69 to 6.45cP for 6rpm, 12rpm, 30rpm and 60rpm respectively. While the mean viscosity at the different temperature intervals ranged from 101.23 to 79.23cP, 52.11 to 36.50 cP, 14.88 to 7.43 cP and 11.42 to 6.24cP, for 6rpm, 12rpm, 30rpm and 60rpm respectively for oil extracted from SE. It was observed that the dynamic viscosity of the oils decreased with increase in temperature. At a particular shear rate. Similar, trend was reported by Davies [29]. According to Davies [29] revealed that for certain oil, the viscosity with temperature slope change rapidly with temperature for different crude oil fraction from the same natural source. It was observed that the dynamic viscosity of the vegetable decreased with an increased in temperature. It was found that temperature and shear rate have significant effect on viscosity [29, 30]. It was also observed that the dynamic viscosity of the oils decreased with increase in shear rate. Thus shear rate also had a significant effect on the dynamic viscosity of vegetable oils. The flow rate of coconut oil extracted from WMCE, WMHE and SE were determined at different temperatures ranging from 30°C to 100°C. The mean flow rate of coconut oil extracted from the different extraction techniques at different temperatures of 30°C to 100°C ranged from 3.50 ml/s to 6.61 ml/s, 4.16 ml/s to 6.81 ml/s and 3.95 ml/s to 6.64 ml/s for WMCE, WMHE and SE respectively. This signifies that the flow rate of the extracted oils is directly proportional to temperature as increase in temperature results to a correspondent increase in flow rate. This temperature flow rate relationship is shown in Fig.5. The effect of temperature on viscosity of unrefined palm kernel oil, refined palm kernel oil, soybean oil, kulikuli oil, olive oil, sunflower oil, and crude palm oil vegetable oils at seven different temperatures using shear rate of 30 rpm showed strong negative non-linear correlation [29, 30].

Fig-1. Effect of extraction techniques on the yield of coconut oil

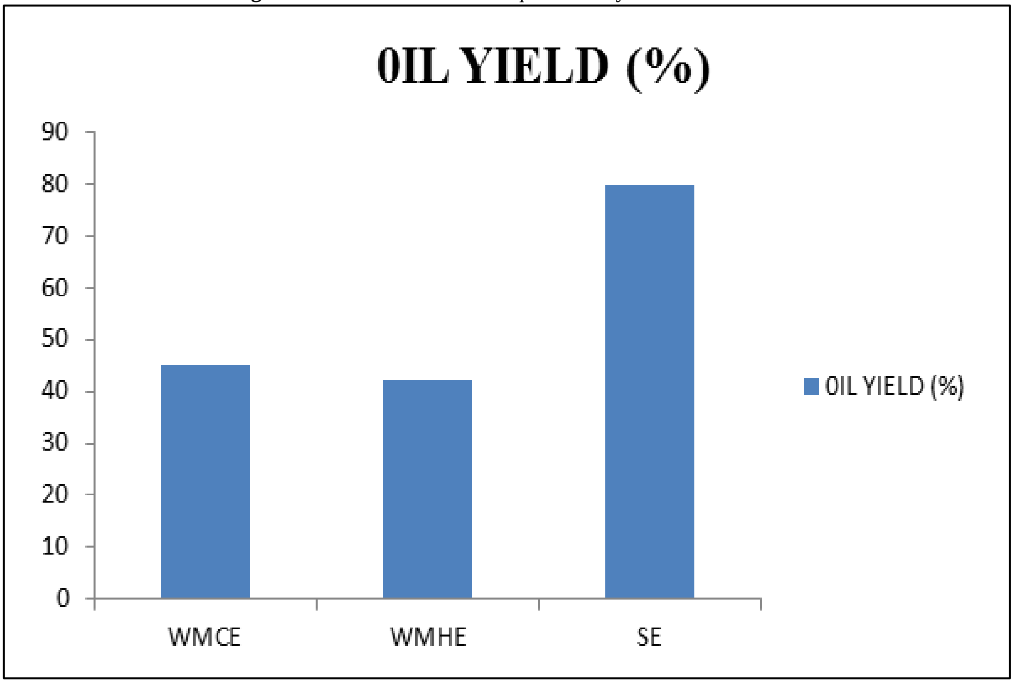


Fig-2. Effect of temperature on the viscosity of coconut oil produced from WMCE at different shear rates

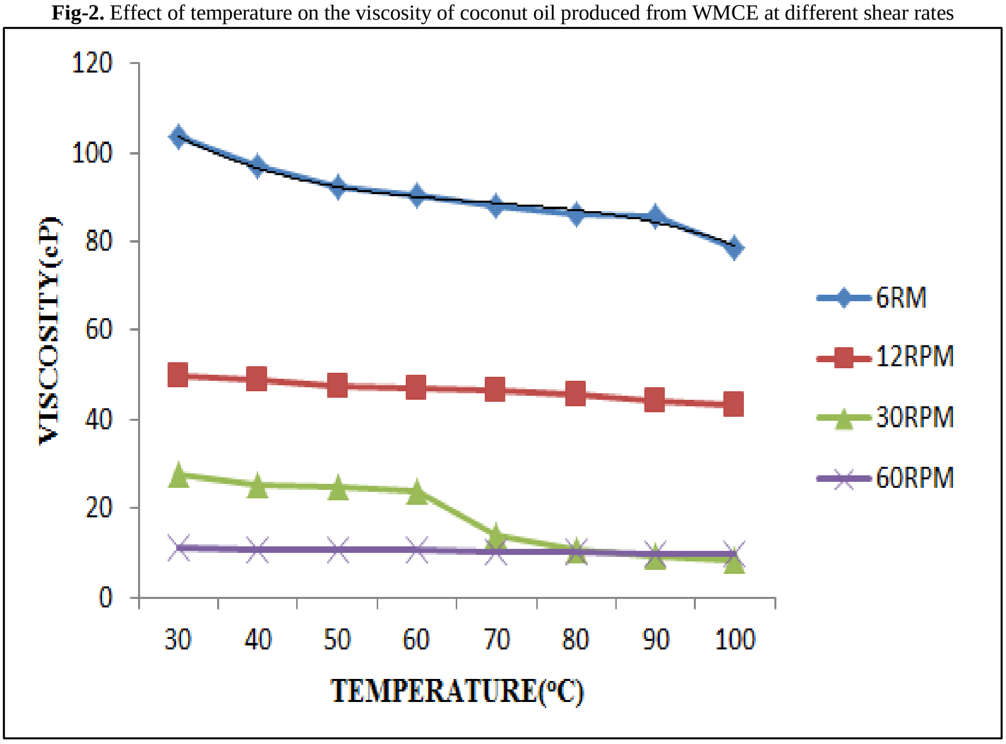


Fig-3. Effect of temperature on the viscosity of coconut oil produced from WMHE at different shear rates

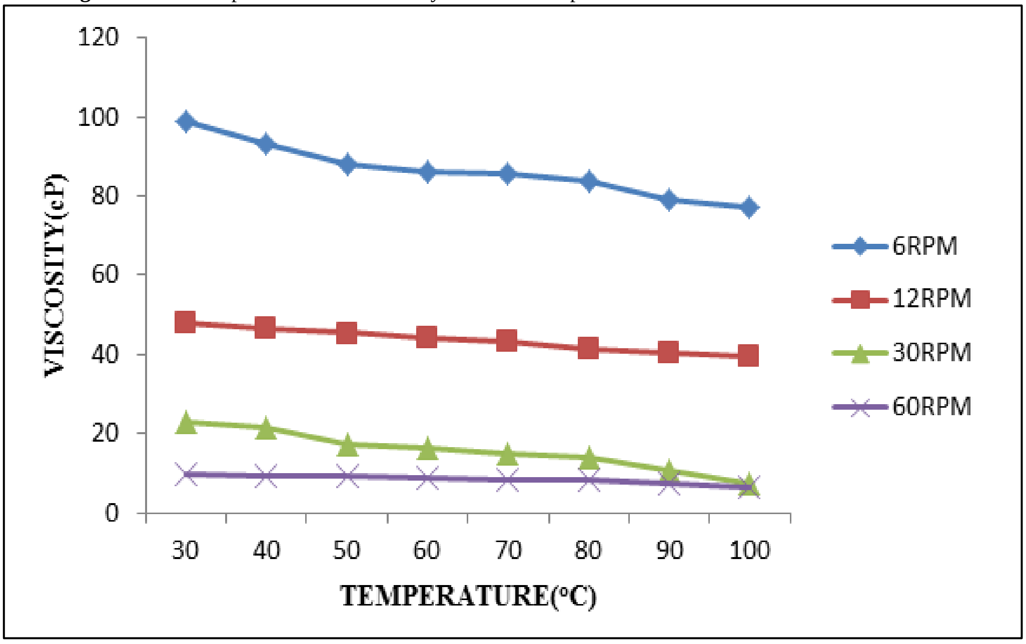


Fig-4. Effect of temperature on the viscosity of coconut oil produced from SE at different shear rates

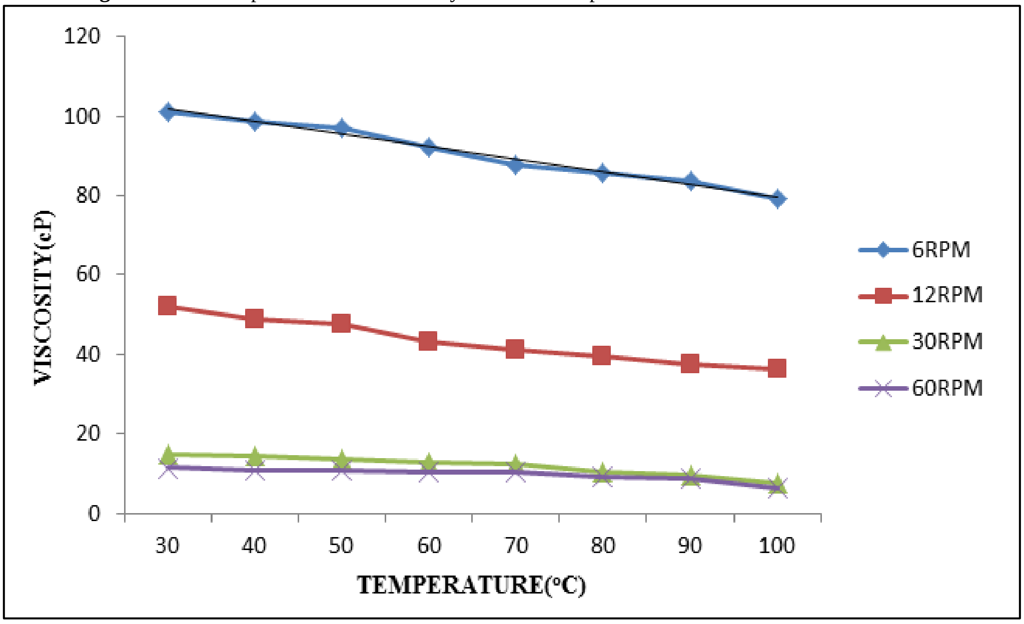
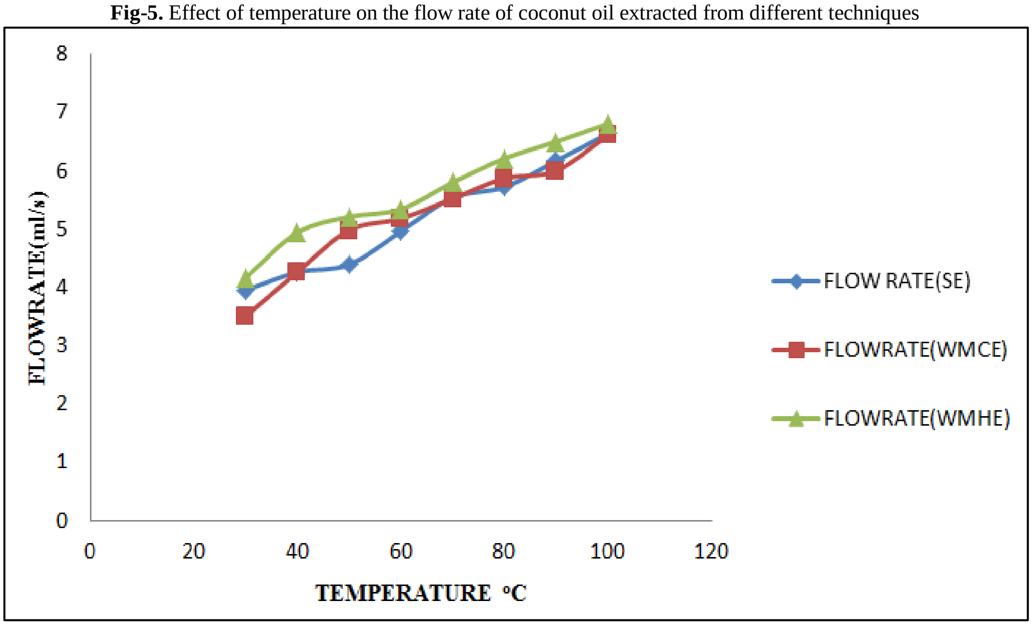


Fig-5. Effect of temperature on the flow rate of coconut oil extracted from different techniques



4. Conclusion

Solvent extraction technique yielded the highest quantity of oil compared to other oil extraction techniques studied. The quantity of oil yield through wet mill cold extraction and wet mill hot extraction showed no significant difference. The effect of temperature on the dynamic viscosity of all the extracted oils revealed a negative non-linear relationship. Conversely, the effect of temperature on the flow rate of the extracted oils demonstrated a positive non-linear relationship. Thus, flow rate of coconut oil is directly proportional to temperature, dynamic viscosity is inversely proportional to temperature.

References

[1] Yeboah, K., 2010. "Coconut the wonderful crop." Available: http://www.blogspot.com

[2] FAO, 2014. *Food and agriculture organization statistics*. ROME.

[3] Bawalan, D. D., 2011. "Processing manual for virgin coconut oil, its products and by-products for pacific island countries and territories." Available: http://www.spc.int

[4] Perera, L., Perera, S. A. C. N., Bandaranayake, C. K., and Harries, H. C., 2009. "Coconut." In *Vollmann, J. and i. Rajcan eds., Oil crop breeding,Handbook of Plant Breeding Series, Springer-Verlag, Chapte.* pp. 369 – 396.

[5] Fife, B., 2005. *Coconut cures*. Piccadilly Books, Ltd, pp. 184-185.

[6] Fife, B., 2004. *The coconut oil miracle*. 4th ed. vol. 7-9. New York: (Piccadilly books Ltd.) Penguin group Inc. pp. 56-143.

[7] Kiran, 2019. *Properties of Coconut Oil*. Organic Facts.

[8] Nevin, K. G. and Rajamohan, T., 2008. "Influence of virgin coconut oil on blood coagulation factors, lipid levels and ldl oxidation in cholesterol fed spragueedawley rats." *The European E- Journal of Clinical Nutrition And Metabolisam,* vol. 3, pp. e1-e8.

[9] O'brien, R. D., 2008. *Fats and oils: formulating and processing for applications*. 3rd ed. Boca Raton, USA: CRC Press.

[10] Enig, M. G., 2010. "Health and nutrition benefits from coconut oil and its advantages over competing oils." *Indian Coconut Jurnal,* vol. 9, pp. 9-15.

[11] Gbasouzor, A. I. and Nwanikezie, M. N., 2016. "Development of an improved motorized nmanuakuoyibo (coconut oil) extracting machine for employment generation in Nigeria." In *Proceedings of the World Congress on Engineering and Computer Science.*

[12] Espino, T. M., 2010. *Product development, challenges and prospects: functional coconut food products*. Improving the Investment Climate in Emerging Nontraditional Coconut Products p. 110.

[13] Nagao, K. and Yanagita, T., 2010. "Medium-chain fatty acids: functional lipids for the prevention and treatment of the metabolic syndrome." *Pharm. Res.,* vol. 61, pp. 208-212.

[14] Hamid, M. M., Sarmidi, M. R., Mokthar, T. H., Sulaiman, W. R. W., and Aziza, R. A., 2011. "Innovative integrated wet process for virgin coconut oil production." *Journal of Applied Sciences,* vol. 11, pp. 2467-2469.

[15] Dayrit, F. M., Dimzon, I. K. D., Valde, M. F., Santos, J. E. R., Garrovillas, M. J. M., and Villarino, B. J., 2011. "Quality characteristics of virgin coconut oil: Comparisons with refined coconut oil." *Pure Appl. Chem.,* vol. 83, pp. 1789-1799.

[16] Bawalan, D. D., 2005. *Final mission report on coconut processing project on pilot production of virgin coconut oil and other products in Thailand*. Thailand: Food and Agriculture Organization (FAO) of the United Nations.

[17] Bawalan, D. D. and Chapman, K. R., 2006. *Virgin Coconut Oil production manual for micro and village-scale processing*. Bangkok: Thammada press co. ltd.

[18] Alamu, O. J., Waheed, M. A., and Jekayinfa, S. O., 2007. "Alkali- catalysed laboratory production and testing of bio diesel from nigerian palm kernel oil." *Agricultural International: CIGR Electonic Journal,* vol. 9, pp. 1-10.

[19] Atta, M. B. and Imaizumi, K., 2002. "Some characteristics of crude oil extracted from Roselle (Hibiscus sabdariffa L.) seeds cultivated in Egypt." *Journal of Oleo Science,* vol. 51, pp. 457-461.

[20] Bamgboye, A. I. and Adejumo, O. I., 2008. "Effects of processing parameters of Roselle seed on its oil yield." *International Journal of Agricultural and Biological Engineering,* vol. 4, pp. 82-86.

[21] Davies, R. M., 2009. "Some physical properties of groundnut grains." *Research Journal of Applied Sciences, Engineering and Technology,* vol. 1, pp. 10-13.

[22] Davies, R. M. and EI-Okene, A. M. I., 2009. "Moisture-dependent physical properties of soybean." *Int. Agrophysics,* vol. 23, pp. 299-303.

[23] Diamante, L. M. and Lan, T., 2014. "Absolute viscosities of vegetable oils at different temperatures and shear rate range of 64.5 to 4835s−1." *Journal of Food Processing,* vol. 2014, pp. 1-6.

[24] Isik, E. and Izli, N., 2007. "Physical properties of sunflower seeds (helianthus annuus l.)." *Internat J Agric. Res.,* vol. 2, pp. 677-686.

[25] Khodabakhshian, R., Emadi, B., Abbaspour, F. M. H., and Saiedirad, 2010. "Mechanical properties of sunflower seeds and its kernel. Azargolvarietyas a case study under compression loading." *Journal of Agric. Science and Technology,* vol. 4, pp. 37-41.

[26] Mehmood, T., Ahmad, A., Ahmed, A., and Khalid, N., 2012. "Quality evaluation and safety assessment of different cooking oils available in Pakistan." *Journal Chemical Society,* vol. 34, pp. 518-25.

[27] Sirisomboon, P., Kitchaiya, P., Pholpho, T., and Mahuttanyavanitch, W., 2007. "Physical and mechanical properties of Jatropha curcasL. fruits, nuts and kernels." *BiosystEng*, vol. 97, pp. 201-207.

[28] Zhang, Y., Dube, M. A., Mclean, D. D., and Kates, M., 2003. "Biodiesel production from waste cooking oil: 1. Process design and technological assessment." *Bioresource Technology*, vol. 1, pp. 1-16.

[29] Davies, R. M., 2016. "Effect of the temperature on the dynamic viscosity, density and flow rate of some vegetable oils." *Journal of Scientific Research in Engineering and Technology*, vol. 1, pp. 15-24.

[30] Yerima, J. B., Madugu, J. S., Timter, P., and David, Y. M., 2012. "Dependence of viscosity and density of nigerian lophiralanceolata oil (ochnaceae) on " *Temperature Physical Review and Research International*, vol. 2, pp. 125-132.