

Hypoglycaemic Activity of Extra Virgin Avocado (*Persea americana*) oil and Extra Virgin Coconut (*Cocos nucifera*) oil on Alloxan-induced Diabetic Rats

ABSTRACT

Diabetes mellitus is a chronic, metabolic disorder characterized by abnormal elevation of blood glucose levels (hyperglycaemia). Despite significant milestones achieved using conventional drugs in managing the disease, there are some drawbacks associated with their use such as drug resistance, adverse drug effects, high cost, and sometimes outright therapeutic failure. The urgent need to bridge this therapeutic lacuna calls for further exploration and investigation of other treatment options. This study therefore aims at evaluating the antidiabetic potentials of virgin avocado oil and virgin coconut oil in alloxan-induced diabetic rats. Animals were divided into 5 groups of five rats each. Group 1 (negative control) received 10ml /kg/day of normal saline, group 2 (diabetic control) -10ml/kg/day of normal saline; group 3 received extra virgin avocado oil (1ml/250g) body weight, group 4 received extra virgin coconut oil (2ml/kg) bodyweight, and group 5 received 10mg/kg/day of metformin. Treatments were administered orally for 15 days. Extra virgin avocado oil and extra virgin coconut oil respectively showed significant antidiabetic activities, and may be beneficial for management of diabetes mellitus.

Keywords: Avocado oil, coconut oil, extra virgin, diabetes, alloxan

1. INTRODUCTION

Diabetes mellitus (DM) is chronic metabolic disorder that is characterized by unusually high blood glucose levels known as hyperglycaemia resulting from disruption in carbohydrate, fat and protein metabolism due to defective insulin action, secretion or both [1-3]. The incidence of this disease has been increasing at an alarming rate [4-5]. The two main types of diabetes are type 1 and type 2. Type 1 diabetes which occurs at early stages of life is caused by an autoimmune disorder where the cells of the immune

system attack the insulin-producing β -cells of the pancreas. Type 2 diabetes on the other hand, develops later later in life, as a result of malfunctions in metabolic homeostasis. Genetic background, unhealthy eating habits, and sedentary life style are predisposing factors in type 2 diabetes [6-7]. Globally, 463 million adults were living with diabetes in 2019, and this resulted in about 4.2 million deaths in that year alone. By the year 2045, the number of patients with diabetes is estimated to reach 700 million [1]. Diabetes treatment includes blood sugar monitoring, physical activity, nutritional intervention, self-management education, use of synthetic oral hypoglycaemic drugs, and insulin therapy [8-10]. Despite the significant progress made in the management of Diabetes mellitus, therapeutic outcomes are still unpredictable due to drug resistance, adverse drug effects, and toxicity [11-12]. Toxicity of oral hypoglycaemic agents differs immensely in clinical manifestations and severity [13].

Many plants have been credited to be useful for the management of diabetes, and a reasonably high population of rural dwellers have been depending on medicinal plants for treatment of diabetes due to their affordability and availability [14]. Virgin coconut oil (VCO) is obtained from the fresh mature kernel of the tropical plant, coconut fruit (*Cocos nucifera* L.), by natural or mechanical method without harsh processing such as chemical bleaching, hydrogenation, deodorization or refining [15-17]. In addition to the above, extra-virgin coconut oil is cold-expressed (extracted under room temperature), hence the natural content of the oil is not altered. It has been reported that coconut oil has antioxidant and anti-inflammatory properties [18-19]. The oil also been reported to have antiviral, antibacterial, antifungal, antiparasitic, antithrombotic, cardioprotective, hepatoprotective, antidote, antidermatophytic, insect repellent, hypolipidaemic, anticholecystitic, anticancer, anticaries, disinfectant, and anti-asthmatic effects [24-25]. Coconut oil contains fatty acids, mostly saturated fatty acid (medium chain fatty acid) and less unsaturated fatty acid. The various fatty acid constituents of coconut oil include lauric acid (50%), myristic acid, caprylic acid, palmitic acid, capric acid, stearic acid, oleic acid, and linoleic acid [17]. The peroxide value of coconut oil was reported to be even lower than that of fresh palm oil, and this was suggested to be the reason for its increased oxidative stability [20]. The peroxide value of an oil is an indication of its

oxidation propensity, and perhaps to serve as a guide on the safety of that particular edible oil [21]. In addition to the peroxide value, high phenolic acid content also contributes to a reduction in the oxidation process [22]. Coconut oil has been reported to contain polyphenols that may significantly reduce lipid peroxidation [23].

Avocado oil is obtained from the pulp of the avocado fruit (*Persea americana* Mill.). It is a fruit that is native to Central America. Today, it is cultivated and harvested worldwide, growing mainly in warm temperate and subtropical climates [26-27]. Extra-virgin avocado oil is obtained from the avocado fruit, mostly by cold pressing, and without undergoing alterations in its nature by the addition of chemicals or subsequent processing [32]. It is viscous and dark green in colour (due to chlorophylls and carotenoids contents), and has a mild taste [32]. Avocado oil is rich in monounsaturated fatty acids with oleic acid content being the highest (50.95 %). Other fatty acid constituent includes palmitic acid (28.21 %), linoleic acid (13.87 %), palmitoleic acid (5.69 %), stearic acid (0.69 %), and linolenic acid (0.58 %) [28]. The oil contains bioactive compounds such as phytosterols (β -sitosterol), carotenoids (e.g., tocopherols, tocotrienols) as well as polyphenols, lecithin, minerals, and vitamins, making it of particular interest for research aimed at the prevention and mitigation of several disease conditions [18, 26]. Avocado oil has been reported to have anti-inflammatory [29], antihypertensive [30], and antioxidant [31] potentials. This study aims at evaluating the hypoglycaemic activity of virgin avocado oil and virgin coconut oil in alloxan-induced diabetic rodent model.

2. METHODS

2.1 Preparation of Extra Virgin Coconut oil

Five (5) mature coconut fruits were cracked and the fleshly edible endosperm removed, chopped into pieces and blended to obtain a milky slurry. The slurry was strained using sieve cloth to obtain coconut milk which was allowed to stand for about 16 hours. The

top paste was skimmed off, and kept frozen in a freezer for 24 hours. Thereafter, it was removed from the refrigerator, allowed to defrost, the oil settling out at the top carefully separated, and filtered into an air-tight container.

2.2. Preparation of Extra Virgin Avocado oil

Ten (10) mature, high-quality avocado fruits were bought from Uyo market, in Uyo Local Government Area of Akwa Ibom State, Nigeria. They were washed and kept until soft. The pulp was removed, mashed and spread on a large surface open container kept under room temperature. During this period, the pulpy mash was turned occasionally for faster drying. After about 4 days, droplets of the oil were seen on the surface (this shows its ready for extraction). The oil was squeezed from the paste using sieve cloth and then filtered to remove unwanted particles.

2.3. Experimental Animals

A total of 25 rats of both sexes, weighing (100-140g) were obtained from the animal house of the Department of Pharmacology and Toxicology, Faculty of Pharmacy, University of Uyo. They were maintained on standard animal pellets and water *ad libitum*, housed in cages to acclimatize to the animal house, and maintained under standard conditions (25- 28 °C) with 12h dark/12h light cycles.

2.4. Induction of Diabetes mellitus

The animals were fasted overnight and experimental diabetes was induced by single intra-peritoneal injection of freshly prepared solution of alloxan (150mg/kg bodyweight) in distilled water. Negative control rats were injected with distilled water alone. After 72 hours, rats with hyperglycaemia (blood glucose level >200mg/dl were considered as

diabetic and used for the treatment [33]. Blood glucose levels were checked using a glucometer (Accu-Chek®, Roche Diagnostics, Germany).

2.5. Experimental Design

Animals were divided into 5 groups consisting of five rats per group. Rats of each group were orally pre-treated as follows:

Group 1 (Negative control): Nondiabetic rats given 10ml /kg/day of normal saline orally for 15 days.

Group 2 (Diabetic control): Diabetic rats given 10ml/kg/day of normal saline orally for 15 days.

Group 3 (Avocado oil): Diabetic rats given extra virgin avocado oil 1ml/250g body weight orally for 15 days [34].

Group 4 (Coconut oil): Diabetic rats given extra virgin coconut oil 2ml/kg bodyweight orally for 15 days [35].

Group 5 (Positive control): Diabetic rats given 10mg/kg/day of metformin orally in aqueous solution for 15 days

Oral administration was carried out with the aid of a rubber cannula attached to a calibrated syringe. Blood glucose level was checked before administration of extracts (0 hour), and at 1hr, 2hrs, 4hrs, 6hrs, 5days, 10days, and 15 days after daily treatments. Blood was obtained from the tail veins of the animals. Animals were weighed using electronic balance on days 0, 5, 10, and 15 of treatment.

2.6 Statistical Analysis

Results were expressed as mean \pm standard error of mean (SEM). Statistical analysis was carried out using SPSS version 23 statistical software. Statistical significance was

determined using one-way Analysis of Variance (ANOVA) followed by Tukey's post hoc test. Values of $p < 0.05$ were considered to be significant.

3. RESULTS

3.1 Effect of Avocado oil and Coconut oil on Body weight of Alloxan-induced Diabetic Rats

The effect of Avocado oil and Coconut oil on body weight of alloxan-induced diabetic rats is shown in table 1. After 5 days of experiment, there was no significant difference ($p > 0.05$) in body weight of rats in all the groups except for rats in the groups treated with coconut oil which showed significant ($p < 0.05$) increase in body weight compared to the diabetic control group. On days 10 and 15, rats in the diabetic control group showed significant ($p < 0.05$) decrease in body weight compared to those in the negative control group. The effects of the two oils and Metformin were comparable to each other as they showed significant ($p < 0.05$) increase in body weight relative to those in the diabetic control group, with avocado oil causing the most improvement in the body weight after 15 days.

Table 1. Effect of avocado oil and coconut oil on body weight of alloxan-induced diabetic rats

Group	Dose	Body weight (g)			
		Day 0	Day 5	Day 10	Day 15
Group 1 (Negative control)	10 ml/kg normal saline	121.80±4.20	124.00±4.12	145.60±3.36	142.00±2.21
Group 2 (Diabetic control)	10 ml/kg normal saline	113.60±4.18	114.00±4.15	115.200±3.84 ^a	115.20±4.34 ^a
Group 3 (Avocado oil)	1ml/250g body weight	112.00±3.87	113.00±4.64	134.20±2.64 ^b	144.20±2.65 ^b
Group 4 (Coconut oil)	2ml/kg body weight	108.00±5.33	134.00±1.55 ^b	132.00±3.29 ^b	138.00±3.11 ^b
Group 5 (Positive control)	Omeprazole 10mg/kg	106.20±3.93	116.60±6.91	134.20±5.00 ^b	135.40±4.54 ^b

Data are expressed as mean ± SEM. Significant at ^ap<0.05 when compared to negative control; ^bp<0.05 when compared to diabetic control (n=5).

3.2 Antidiabetic Effect of Avocado oil and Coconut oil on Alloxan-induced Diabetic Rats in Acute Study

The antidiabetic effect of avocado oil and coconut oil on alloxan-induced diabetic rats in acute study is as shown in table 2, and figure 1. Avocado oil significantly ($p<0.05$) reduced the mean blood glucose level when compared to the diabetic control starting from the 2nd hour and continuing to the 6th. Coconut oil also reduced blood glucose level when compared to the diabetic control but the effect started after 4hours and continued to the 6th hour under evaluation. The antidiabetic effects of the two oils (particularly avocado oil) were comparable to that of the standard drug, Metformin.

Table 2. Antidiabetic effect of avocado oil and coconut oil on alloxan-induced diabetic rats in acute study

Group	Dose	Mean blood glucose level (mg/dl)				
		0hr	1hr	2hr	4hr	6hr
Group 1 (Negative control)	10 ml/kg normal saline	99.40±0.75	97.60±0.	96.40±0.93	95.20±1.07	94.20±1.53
Group 2 (Diabetic control)	10 ml/kg normal saline	326.40±12.97 ^a	374.20±10.59 ^a	374.20±21.78 ^a	395.40±28.90 ^a	417.20±18.39 ^a
Group 3 (Avocado oil)	1ml/250g body weight	344.60±7.97 ^a	312.40±19.28 ^a	284.00±15.24 ^{a, b}	256.20±11.05 ^{a, b}	245.00±7.92 ^{a, b}
Group 4 (Coconut oil)	2ml/kg body weight	355.00±16.79 ^a	359.00±3.79 ^a	340.00±12.72 ^{a, c}	275.00±8.34 ^{a, b}	261.20±8.97 ^{a, b}
Group 5 (Positive control)	omeprazole 10mg/kg	296.28±13.12 ^a	362.40±27.43 ^a	270.60±11.07 ^{a, b}	247.40±2.36 ^{a, b}	233.20±4.32 ^{a, b}

Data are expressed as mean ± SEM. Significant at ^ap<0.05 when compared to negative control; ^bp<0.05 when compared to diabetic control; ^cp<0.05 when compared to metformin (n=5)

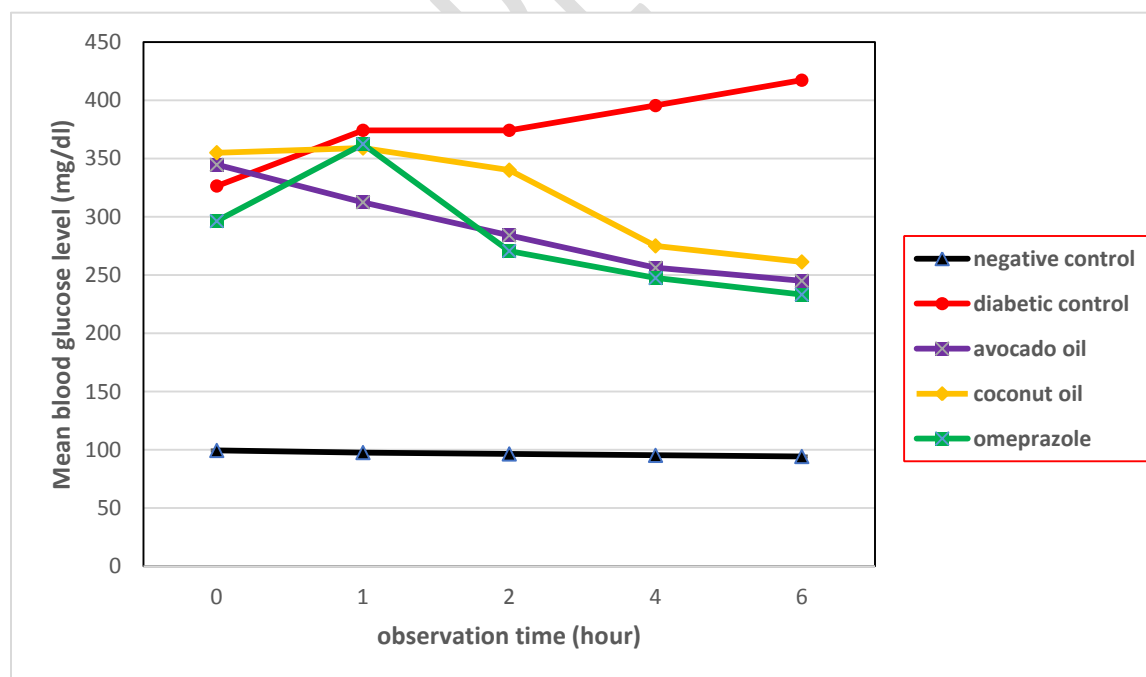


Fig. 1: Antidiabetic effect of avocado oil and coconut oil on alloxan-induced diabetic rats in acute study

3.3 Antidiabetic Effect of Avocado oil and Coconut oil on Alloxan-induced Diabetic Rats in Prolonged Study

The antidiabetic effect of avocado oil and coconut oil on alloxan-induced diabetic rats in prolonged study is as shown in table 3 and figure 2. Avocado oil significantly ($p < 0.05$) sustained the reduction in blood glucose level throughout the 15-day period of the experiment (155.60 ± 9.16 , 110.20 ± 1.83 and 98.60 ± 0.93 for days 5, 10 and 15 respectively) when compared to the diabetic control values of 418.80 ± 2.20 , 404.20 ± 6.15 and 341.20 ± 10.08 for the same period. On its part, coconut oil also significantly ($p < 0.05$) reduced blood glucose level in the prolonged study (174.40 ± 4.18 , 108.60 ± 3.56 and 97.60 ± 0.93 for days 5, 10 and 15 respectively) when compared to the values of diabetic control for the same interval. There were no significant differences between the blood glucose levels of rats treated with avocado oil, coconut oil and Metformin, they were comparable at the respective intervals of 5, 10 and 15 days. It is worthy of note that after 15 days of treatment, blood glucose levels of avocado oil, coconut oil and Metformin-treated rats were respectively reduced to approximately the same level as that of negative control.

Table 3. Antidiabetic effect of avocado oil and coconut oil on alloxan-induced diabetic rats in prolonged study

Group	Dose	Mean blood glucose level (mg/dl)			
		DAY0	DAY5	DAY10	DAY15
Group 1 (Negative control)	10 ml/kg normal saline	99.40 ± 0.75	94.20 ± 1.53	95.20 ± 1.12	95.20 ± 0.86
Group 2 (Diabetic control)	10 ml/kg normal saline	326.40 ± 12.97^a	418.80 ± 2.20^a	404.20 ± 6.15^a	341.20 ± 10.08^a

Group 3 (Avocado oil)	1ml/250g body weight	344.60±7.97 ^a	155.60±9.16 ^b	110.20±1.83 ^b	98.60±0.93 ^b
Group 4 (Coconut oil)	2ml/kg body weight	355.00±16.79 ^a	174.40±4.18 ^b	108.60±3.56 ^b	97.60±0.93 ^b
Group 5 (Positive control)	omeprazole 10mg/kg	296.28±13.12 ^a	160.00±8.1 ^b	106.60±4.08 ^b	96.60±4.40 ^b

Data are expressed as mean ± SEM. Significant at ^ap<0.05 when compared to negative control; ^bp<0.05 when compared to diabetic control (n=5).

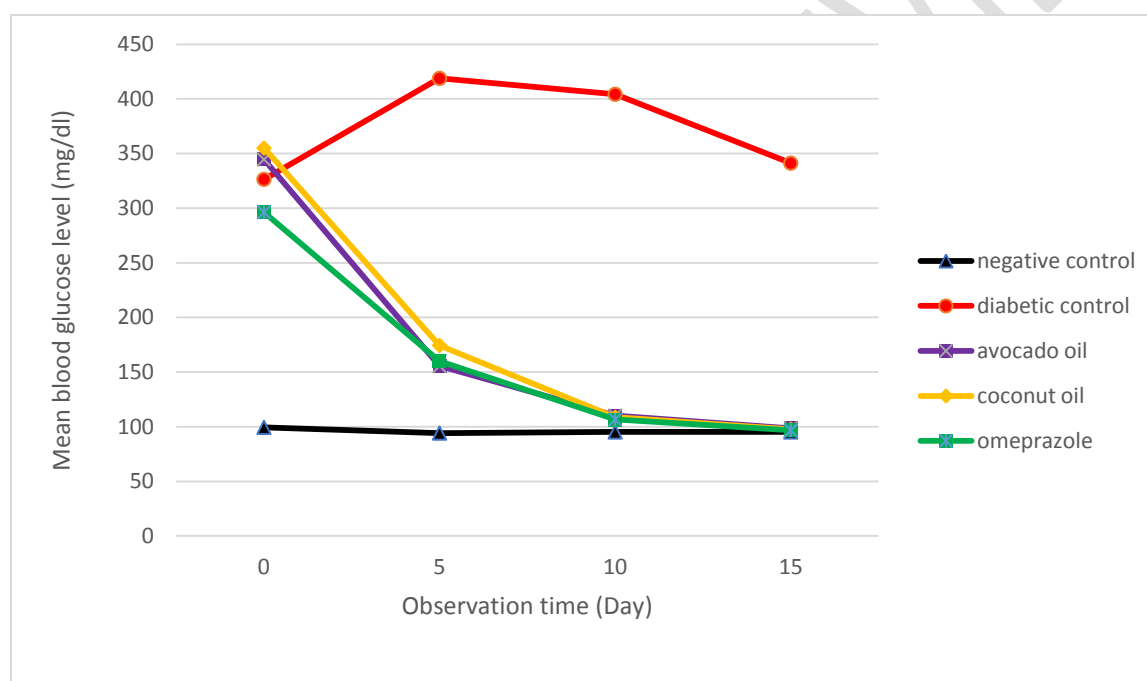


Fig. 2: Antidiabetic effect of avocado oil and coconut oil on alloxan-induced diabetic rats in prolonged study

4. DISCUSSION

Diabetes mellitus is not merely a disease of blood level elevation. In most cases, it involves a plethora of complications in peripheral tissues such as the kidneys, liver, cardiovascular system, retina, and the nervous system. Current therapies are not

always effective in completely combating this malady [1], hence the urgent need to explore alternative treatments such as the use of plant-derived substances. Alloxan (2,4, 5, 6-pyrimidinetetrone) is a popular diabetogenic agent commonly used to induce type 2 Diabetes mellitus in animal models [36]. Alloxan and its reduction product, dialuric acid form superoxide radicals which undergo dismutation to hydrogen peroxide. Simultaneously, there is a massive increase in cytosolic calcium concentration which causes rapid destruction of β cells of the pancreas, resulting in decreased insulin secretion [37]. From the result, administration of alloxan caused hyperglycaemia in the diabetic control group when compared to rats in the negative control group given normal saline instead of alloxan. Generally, body weights are decreased in diabetic animals [38]. In this study, the decrease in body weight was diminished by both avocado and coconut oils, and their effects were comparable to that of the standard drug, metformin. This effect may be beneficial to the diabetic animals. Medium chain fatty acids and triglycerides present in coconut oil metabolizes fast and may help in stimulating weight loss in diabetic patients with obesity [16].

In this research, coconut oil reduced the blood glucose levels of alloxan-induced diabetic rats in both acute and prolonged studies. This may be due to the presence of bioactive constituents present in the oil. Coconut has been reported to contain bioactive, antioxidant constituents which include ferulic, *p*-coumaric, vallinic, and protocatechuic acids suggested to have several beneficial health effects [39-40]. In diabetic patients with hypoglycaemia, antioxidants may play a vital role in enhancing insulin sensitivity, or may reduce insulin resistance and injury to pancreatic beta cells by scavenging reactive oxygen species (ROS) [16]. Lauric acid, present in coconut oil has also been reported to possess insulinotropic properties [41]. Also in this experiment, avocado oil has reduced the blood glucose levels of alloxan-induced diabetic rats in both acute and prolonged studies. Torres and co-workers [42] have reported the presence of phytochemicals such as alkaloids, saponins, unsaturated steroids and triterpenoids (Leucoanthocyanins) in the ethanolic extract of avocado fruit. Tocopherols have also been identified in the acetone extract of avocado [43]. Avocado oil retains most of the bioactive substances and carotenoids present in the fruit [44]. The antidiabetic activity of avocado oil seen in this study may be attributable to these bioactive constituents present in the oil.

5. CONCLUSION

In conclusion, extra virgin avocado oil and extra virgin coconut oil respectively showed significant hypoglycaemic activity, and may be beneficial in management of diabetes mellitus. However, further studies should be carried out at the cellular and molecular levels to unravel the exact mechanism(s) of action.

CONSENT

It is not applicable

ETHICAL APPROVAL

The procedures were performed according to the guidelines on the use of animals, and approved by the Institutional Animal Ethical Committee of the Faculty of Pharmacy, University of Uyo, Nigeria (Ethical Approval No: FPharm/EC/011).

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

1. Demir S, Nawroth PP, Herzig S, Üstüne BE. Emerging Targets in Type 2 Diabetes and Diabetic Complications. *Adv. Sci.* 2021; 8: 2100275
2. Mubayrik AB, Al Mutairi A, Al Mutairi H, Osseil AB, Al Shahwan N, Al Sohaibani H. Public knowledge and awareness of the effect of diabetes mellitus on oral health. *Saudi Dent J.* 2019; 31: S5.

3. Siddiqui R, Rukhsana N, Arif AU, Khan B, Rizwan S, Fahim MF. Assessment of knowledge of diabetes among diabetic and non-diabetic individuals. *Rawal Medical Journal*. 2021; 46(4): 795-98
4. Chupradit S, Widjaja G, Khasanah U, Tondok SB, Samal A, Rahman FF, Aravindhana S. Prevalence of Diabetes and Sedentary Lifestyle: A Review of Diabetes Self-Management Education. *Health Education and Health Promotion*. 2021; 9(4): 309-15
5. Sharifi A, Shafiei E, Hoseinzadeh M. The study of the effectiveness of a mixture of *Arnebia euochroma* and gum extract in animal oils and comparing it with honey in diabetic foot ulcer. *J Chem Health Risks*. 2019; 9(2):167-72.
6. Udler, MS, Mccarthy MI, Florez JC, Mahajan A. Genetic Risk Scores for Diabetes Diagnosis and Precision Medicine. *Endocr. Rev*. 2019; 40:1500.
7. Zheng Y, Ley SH, Hu FB. *Nat. Rev. Endocrinol*. 2018, 14, 88. Global aetiology and epidemiology of type 2 diabetes mellitus and its complications. *Nat. Rev. Endocrinol*. 2018; 14: 88.
8. Greenwood DA, Gee PM, Fatkin KJ, Peeples M. A systematic review of reviews evaluating technology-enabled diabetes self-management education and support. *J Diabetes Sci Technol*. 2017; 11(5): 1015-27.
9. Cappon G, Acciaroli G, Vettoretti M, Facchinetti A, Sparacino G. Wearable continuous glucose monitoring sensors: a revolution in diabetes treatment. *Electronics*. 2017; 6(3): 65.
10. Powers MA, Bardsley JK, Cypress M, Funnell MM, Harms D, Hess-Fischl A, et al. Diabetes self-management education and support in adults with type 2 diabetes: A consensus report of the American diabetes association, the association of diabetes care & education specialists, the academy of nutrition and dietetics, the American academy of family physicians, the American academy of PAs, the American association of nurse practitioners, and the American Pharmacists association. *J Acad Nutr Diet*. 2021; 121(4): 773-88.
11. Hui H, Zhao X, Perfetti R. Structure and function studies of glucagon-like peptide-1 (GLP1): the designing of a novel pharmacological agent for the treatment of diabetes. *Diabetes Metab Res Rev*. 2005; 21: 313-31.

12. Umoh IO, Samuel OO, Kureh TB, Davies KG. Antidiabetic and hypolipidaemic potentials of ethanol fruit pulp extract of *Persea americana* (avocado pear) in rats. *J. Afr. Ass. Physiol. Sci.* 2019; 7(1): 59-63.
13. Kumar S, Kuma V, Prakash O. Antidiabetic, hypolipidemic and histopathological analysis of *Dillenia indica* (L.) leaves extract on alloxan induced diabetic rats. *Asian Pacific Journal of Tropical Medicine.* 2011; 4(5): 347–52.
14. Girija K, Lakshman K, Udaya C, Sabhya SG, Divya T. Anti-diabetic and anticholesterolemic activity of methanol extracts of three species of *Amaranthus*. *Asian Pacific Journal of Tropical Biomedicine.* 2011; 2(1): 133–38.
15. Jaarin K, Norliana M, Kamisah Y, Nursyafiza M, Qodriyah HMS. Potential role of virgin coconut oil in reducing cardiovascular risk factors. *Exp Clin Cardiol.* 2014; 20:3399–410
16. Siddalingaswamy M, Rayaorth A, Khanum F. Anti-diabetic effects of cold and hot extracted virgin coconut oil. *Journal of Diabetes Mellitus.* 2011; 1: 118-123
17. Salian V, Shetty P. Coconut Oil and Virgin Coconut Oil: An Insight into its Oral and Overall Health Benefits. *Journal of Clinical and Diagnostic Research.* 2018; 12(1): ZE01-03
18. Famurewa AC, Aja PM, Nwankwo OE, Awoke JN, Maduagwuna EK, Alope C. *Moringa oleifera* seed oil or virgin coconut oil supplementation abrogates cerebral neurotoxicity induced by antineoplastic agent methotrexate by suppression of oxidative stress and neuro-inflammation in rats. *J Food Biochem.* 2019; 43(3): e12748.
19. Famurewa AC, Aja PM, Maduagwuna EK, Ekeleme-Egedigwe CA, Ufebe OG, Azubuike-Osu SO. Antioxidant and anti-inflammatory effects of virgin coconut oil supplementation abrogate acute chemotherapy oxidative nephrotoxicity induced by anticancer drug methotrexate in rats. *Biomed Pharmacother.* 2017; 96: 905–11.
20. Jaarin K, Yusof K. Repeatedly heated vegetable oils and lipid peroxidation, in *Open Access, INTECH*, ch. 10. 2012; 211-28.
21. Subermaniam K, Saad QHM, Das S, Othman F. Virgin Coconut Oil (VCO) Decreases the Level of Malondialdehyde (MDA) in the Cardiac Tissue of

- Experimental Sprague-Dawley Rats Fed with Heated Palm Oil. *Journal of Medical and Bioengineering*. 2014; 3(2): 102-6
22. Marina AM, Che Man YB, Nazimah SAH, Amin I. Antioxidant capacity and phenolic acids of virgin coconut oil. *International Journal of Food Sciences and Nutrition*. 2009; 60(S2): 114-23.
23. Nevin KG, Rajamohan T. Virgin coconut oil supplemented diet increases the antioxidant status in rats. *Journal of Clinical Food Chemistry*. 2006; 99: 260-66.
24. DebMandal M, Mandal S. Coconut (*Cocos nucifera* L: Arecaceae): In health promotion and disease prevention. *Asian Pac J Trop Med*. 2011; 4(3): 241-47
25. Tomar P, Hongal, Jain M, Rana K, Saxena V. Oil pulling and oral health: a review. *IJSS Case Reports & Reviews*. 2014;1(3):33-37
26. Ranade SS, Thiagarajan P. A review on *Persea americana* Mill. (Avocado)- Its fruit and oil. *International Journal of PharmTech Research*. 2015; 8(6): 72-77.
27. Flores M, Saravia C, Vergara CE, Avila F, Valdés H, Ortiz-Viedma J. Avocado Oil: Characteristics, Properties, and Applications. *Molecules*. 2019; 24(11): 2172.
28. Akpabio UD, Akpakpan AE, Matthew IE, Akpan AU. Extraction and characterization of oil from Avocado pear (*Persea americana*) and native pear (*Dacryodes edulis*) fruits. *World Journal of Applied Science and Technology*. 2011; 3: 27-34.
29. Furlan CPB, Valle SC, Östman E, Maróstica MR, Tovar J. Inclusion of Hass avocado-oil improves postprandial metabolic responses to a hypercaloric-hyperlipidic meal in overweight subjects. *J. Funct. Foods*. 2017; 38: 349–54.
30. Márquez-Ramírez C, Hernández de la Paz J, Ortiz-Avila O, Raya-Farias A, González-Hernández J, Rodríguez-Orozco A, Salgado-Garciglia R, Saavedra-Molina A, Godínez-Hernández D, Cortés-Rojo C. Comparative effects of avocado oil and losartan on blood pressure, renal vascular function, and mitochondrial oxidative stress in hypertensive rats. *Nutrition*. 2018; 54: 60–67.
31. Ortiz-Avila O, Gallegos-Corona M, Sánchez-Briones L, Calderón-Cortés E, Montoya-Pérez R, Rodríguez-Orozco A, Campos-García J, Saavedra-Molina A, Mejía-Zepeda R, Cortés-Rojo C. Protective effects of dietary avocado oil on impaired electron transport chain function and exacerbated oxidative stress in liver mitochondria from diabetic rats. *J. Bioenerg. Biomembr*. 2015; 47: 337–53

32. Wang M, Yu P, Chittiboyina AG, Chen D, Zhao J, Avula B, Wang YH, Khan IA. Characterization, quantification and quality assessment of avocado (*Persea americana* Mill.) oils. *Molecules*. 2020; 25(6): 1453
33. Yanarday R, Colac H. Effect of chard (*Beta vulgaris* L. var. *varicla*) on blood glucose level in normal and alloxan-induced diabetic rabbit. *J. Ethnopham*. 1998; 4: 309-11.
34. Abozaid, OAR, Aziza SAH, Moawed FSM, Kasseb SG. Avocado oil attenuates Diethyl nitrosamine-induced hepatic carcinogenesis. *Bahama Veterinary Medical Journal*. 2018; 3(2): 344-53
35. Meng J, Chen T, Zhao Y, Lu S, Yu Y, Chang Y, Chen D. Study of the mechanism of antiulcer effects of virgin coconut oil on gastric ulcer-induced rat model. *Arch Med Sci*. 2017; 15(5): 1329-35
36. Lenzen S. The mechanisms of alloxan- and streptozotocin-induced diabetes. *Diabetologia*. 2008; 51(2): 216-26
37. Szuldeski T. The mechanism of alloxan and streptozotocin action in β cells of the rat pancreas. *Physiology Research*. 2001; 50: 536-46
38. Kamboj A, Kumar S, Kumar V. Evaluation of antidiabetic activity of hydroalcoholic extract of *Cestrum nocturnum* leaves in streptozotocin-induced diabetic rats. *Advances in Pharmacological Sciences (Hindawi)*. 2013. Article ID 150401. <http://dx.doi.org/10.1155/2013/150401>
39. Marina AM, Chem-Man YB, Amin I. Virgin coconut oil: emerging functional food oil. *Trends Food Sci Tech*. 2009; 20:481–87
40. Famurewa AC, Akunna GG, Nwafor J, Chukwu OC, Ekeleme-Egedigwe CA, Oluniran JN. Nephroprotective activity of virgin coconut oil on diclofenac-induced oxidative nephrotoxicity is associated with antioxidant and anti-inflammatory effects in rats. *Avicenna J Phytomed*. 2020;10(3):316-24.
41. Girotti AW, Thomas IP. Damage effects of oxygen radicals on resealed erythrocyte ghosts. *The Journal of Biological Chemistry*. 1984; 259: 1744-52.
42. Torres RC, Garbo AG, Walde RZML. Larvicidal activity of *Persea americana* Mill. against *Aedes aegypti*. *Asian Pacific Journal of Tropical Medicine*. 2014; 7S1: S167-70
43. Corral-Aguayo RD, Yahia EM, Carrillo-Lopez A, Gonzalez-Aguilar G. Correlation between some nutritional components and the total antioxidant capacity measured

with six different assays in eight horticultural crops. J Agric Food Chem. 2008; 56: 10498-504.

44. Ranade SS, Thiagarajan P. A review on *Persea americana* Mill. (Avocado)- Its fruit and oil," International Journal of PharmTech Research. 2015; 8(6):72-77.

UNDER PEER REVIEW