ANTIDIABETIC EFFECTS OF WATER MELON AND PAWPAW SEED POWDERS AND OILS IN ALLOXAN- INDUCED DIABETIC RATS

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MINNA

AUGUST, 2023

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTERS OF TECHNOLOGY IN BIOCHEMISTRY

AUGUST, 2023

DECLARATION

I hereby declare that this thesis title: **"Antidiabetic effects of Water melon and Pawpaw seed powders and oils in Alloxan- induced Diabetic rats"** is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

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SIGNATURE AND DATE

CERTIFICATION

The thesis title: **"Antidiabetic effects of Water melon and Pawpaw seed powders and oils in Alloxan- induced Diabetic rats"** by OAIKHENAN, Lydia Obehioye (MTech/SLS/2018/8650) meets the regulations governing the award of the degree of Master of Technology of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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(DEAN, POSTGRADUATE SCHOOL) ______________________ SIGNATURE AND DATE

DEDICATION

This project is dedicated to the Almighty God, the source of my strength, for seeing me through this program regardless of the hurdles encountered.

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My utmost gratitude goes to the almighty God, for His steadfast love towards me.

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ABSTRACT

Diabetes mellitus is a common metabolic disorder with increasing morbidity and mortality across the globe. The use of synthetic drugs in the treatment of diabetes mellitus is associated with side effects such as cancer, diarrhea, and weight gain, hence the need for nutraceuticals that are safe, affordable, readily available and without side effects. In this present study, the antidiabetic effect of watermelon and pawpaw seeds powders and oils were investigated. The proximate composition of the seeds powders and the fatty acid profile of the seeds oils were conducted using standard methods and gas chromatography respectively while the histological examination of the kidney and liver tissues of the untreated diabetic rats as well as those treated with watermelon seed oil and metformin was assessed using the hematoxlin and eosin staining method. Thirty rats were divided into six groups (n= 5) and diabetes was induced in all the rats using alloxan monohydrate (130 mg/kg body weight). They were treated orally with 100 ml/kg of the seed oil and feeds formulated from the seed powders, 50 mg/kg body weight metformin and 20 ml/kg body weight normal saline for 28 days. The results showed that the watermelon seed oil was richer in linoleic acid (60.0) while the pawpaw seed oil was richer in oleic acid (70.0). The treatments produced a significant ($P \leq 0.05$) antidiabetic effect with maximum activities observed with watermelon seed oil which are a percentage reduction in the fasting blood glucose levels of 50.5 % comparable to 71.67 % of metformin, reduced LDL-cholesterol level from 90.20 ± 4.35 mg/dL to 60.90 ± 1.93 mg/dL, increased HDL-cholesterol from 20.60 ± 1.20 mg/dL to 33.20 ± 0.55 mg/dL, reduced creatinine level from 90.00 ± 1.23 µmol/L to 25.33 ± 1.83 µmol/L, AST from 52.88 ± 0.61 Iµ/L to 34.00 ± 0.29 Iµ/L, ALT from 54.40 ± 0.15 Iµ/L to 39.73 ± 0.60 Iµ/L, ALP from 177.80 ± 2.13 Iµ/L to 135.00 ± 1.53 Iµ/L, increased PCV level from 34.51 ± 1.29 % to 41.63 ± 0.44 % and hemoglobin level from 11.07 ± 0.73 g/dL to 13.37 ± 0.11 g/dL. There was also a significant ($P \leq 0.05$) reduction on body weight as the treatment progressed. The histological examination showed that the watermelon seed oil ameliorated the adverse effect of diabetes mellitus in these tissues. Therefore, watermelon and pawpaw seeds powders and oils may be of high importance as nutraceuticals because they have the ability to lower blood sugar and maintain a stable lipid profile.

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ABBREVIATIONS

WMSO	Watermelon Seed Oil
WMSP	Watermelon Seed Powder
PSO	Pawpaw Seed Oil
PSP	Pawpaw Seed Powder
NC	Negative Control
PC	Positive Control

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Diabetes is a chronic metabolic disorder that progresses gradually, usually due to heredity, lifestyle, or a combination of both. It is characterized by higher levels of blood glucose than the normal range of 70 – 110 mg/dL, with distortions in the carbohydrate, protein and fat metabolisms which are highly intertwined metabolic activities (Vieira *et al.,* 2019). The main causes of diabetes mellitus are either less production of insulin by the islet of Langerhans in the pancreas or a reduction in the response of cellular insulin receptors (Udler *et al.,* 2018; Ahlquist *et al*., 2018). Diabetes mellitus affects many people in the 21st century, and alongside its debilitating complications, it is considered one of the leading causes of death across the globe (Cho *et al*., 2018). Statistically, about 463 million people within the age range of 20 – 79 years are diabetic, and this value is expected to rise to 578 million by 2030 (IDF, 2019). Diabetes mellitus increases the chances of obesity, aging, genetic mutilation of β-cell function/insulin receptor and infections. It develops with time from certain health-related issues or from some environmental factors which alone or in concert aggravates the complications which include retinopathy with a potential loss of vision, nephropathy resulting in renal failure, peripheral neuropathy with the risk of foot ulcer. However, much of the medical and economic burden arise from the complications associated with the disease (American Diabetes Association, 2018).

The initial treatment option for several diseases including diabetes mellitus are the synthetic drugs. However, due to the adverse effects associated with the long or even short term intake of these drugs, studies aimed at finding alternative options for treating and preventing diseases is considerably on the increase. Studies have shown that diabetes mellitus can be prevented or their onset delayed by lifestyle interventions and thus it is expedient to promote changes in dietary intake that will reduce the incidence of diabetes mellitus (Telle-Hansen *et al*., 2019). Plant parts such as their leaves, rinds, fruits, stems and seeds have been used in traditional medicine since remote times due to their ability to heal and are therefore considered folk therapeutic options with health benefits (Alquathama *et al*., 2019). These plants are reportedly less toxic, readily available, free from the adverse effects associated with the synthetic drugs and cost effective. Among such plants with these beneficial properties are *Carica papaya* (pawpaw) and *Citrullus lanatus* (watermelon). There is rapidly increasing evidence that supports the assertion that consuming watermelon and pawpaw seeds have a robust capacity to reduce cardiovascular diseases and lower the risk of diabetes (Cena and Calder, 2020). Watermelon and pawpaw seeds are rich sources of nutrients and bioactive constituents that can impact on the health of human beings and can be explored in combating non- communicable diseases (Patra *et al.,* 2022). Unfortunately, these have not been given much attention and are usually discarded after the fruits have been consumed, thereby adding to the environmental solid wastes and contributing to pollution.

Carica papaya Linn (*Caricaceae*), commonly known as Pawpaw or Papaya, is a popular fruit with its largest production in tropical and subtropical regions. It is an herbaceous plant that has a thick stem with few or no branches, and has a height of up to 10 meters (Verma *et al.*, 2017). Pawpaw tree produces separate male and female flowers on the same plant (Saba and Pattan, 2022). It is consumed either in natural or processed form worldwide (Jiao *et al.,* 2022).

Citrullus lanatus is a fruit belonging to the family *Cucurbitaceae* (Nkoana *et al.,* 2022) and distributed majorly in the tropical regions. The plant is a crawling annual plant that has several non woody, firm and stout stems up to 3 meters long (Ngwepe *et al.*, 2019). The watermelon fruit has a thick rind and a fleshy center with high water content and serves as a thirst quencher. Reports shows that watermelon seed is high in protein, oil, citrulline, carotenoids, lycopene, vitamin B, niacin and dietary fibre thus having high nutritional value (Lakhe *et al.,* 2022).

1.2 Statement of the Research Problem

Diabetes mellitus has attained epidemic proportion worldwide and constitutes a major problem across the globe, affecting all ages through impairment of normal development with wide social and economic burdens (Cho *et al*., 2018). The global estimate of adults within the age range of 20 – 79 years being diabetic rising to about 578 million by 2030 corresponds to about 80 % rise on the statistics obtained in 2019 (International Diabetes Foundation, 2019). The high prevalence of diabetes mellitus makes it a dreaded metabolic disorder among the populace. The use of synthetic drugs have been the most common approach in managing this disorder which have known side effects such as weigh gain, cancer, diarrhea, dyspepsia (Lebovitz, 2019). Watermelon and pawpaw seeds are underutilized sources of nutraceuticals due to lack of significant information on their therapeutic use (Esparza *et al*., 2020). These seeds have been shown to possess nutritional values comparable to other edible seeds such as olive, soybean, pumpkin and melon seeds (Esparza *et al*., 2020). These seeds have been evaluated for their antidiabetic properties (Ediangbe *et al*., 2010), however watermelon and pawpaw seeds have not been given much attention.

1.3 Justification for the Study

The prevalence of diabetes mellitus globally, the estimated rise in the statistics of individuals with or at risk of diabetes mellitus and the adverse effects associated with the consumption of synthetic antidiabetic drugs require alternative, readily available, economic and effective sources of therapy (Saeedi *et al*., 2019). Nutraceuticals which are defined as nutritions with pharmaceutical benefits have gained attention as alternatives to synthetic drugs because they can serves as antioxidants, anti-inflammatory and anti- cholesterol agents and increase insulin sensitivity (Alkhatib *et al*., 2017; Durazzo *et al*., 2019). Watermelon and pawpaw seeds are good sources of bioactive agents which can serve as nutraceuticals (Saba and Pattan, 2022), but are usually discarded after consumption and are often waste products of fruit processing (Esparza *et al*., 2020). Utilization of these seeds is correlated to their widespread availability, relative safety, cheapness and effectiveness (Lakhe *et al*, 2022). Food processing methods involve steps that affect the quality of the various constituents in seed samples. Seed oils obtained by cold pressing method can be of a major advantage over other extraction methods because it is an environmental friendly process that does not require organic solvents and therefore eradicates the cost and time of solvent removal (Rezig *et al.*, 2019). Also, low pressure will yield high quality oils using cold press method (Lakhe *et al*., 2022).

1.4 Aim and Objectives of the Study

The aim of this study was to evaluate the antidiabetic effects of watermelon and pawpaw seed powders and oils in alloxan- induced diabetic rats.

The objectives of the study were to determine the:

i. proximate composition of the powder from *Citrullus lanatus* and *Carica papaya* seeds.

ii. fatty acid profile of the oil from *Citrullus lanatus* and *Carica papaya* seeds.
iii. toxicity of the oil from *Citrullus lanatus* and *Carica papaya* seed
iv. effects of the oil and powder from *Citrullus lanatus* and *Carica papaya* seeds on the fasting blood glucose and biochemical parameters in the alloxan- induced diabetic animals.
v. effect of the oil and powder from *Citrullus lanatus* and *Carica papaya* seeds on the hematological and biochemical parameters in the alloxan- induced diabetic rats.
vi. histological changes in the liver and kidney of the alloxan-induced diabetic rats.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Diabetes Mellitus

2.1.1 Background

The recent changes in lifestyle and food habits has made human beings addicted to unhealthy food choices which is the major reason for many chronic health diseases including diabetes mellitus which has also increased with rapid cultural and social changes. Diabetes mellitus is a major disease of the endocrine system in humans with multiple clinical manifestations (Cho *et al.*, 2018). The International Diabetes Foundation (IDF) gave a statistical report in 2019 that about 463 million adults whose ages were within the range of 20 – 79 years would be diabetic. This value was estimated to increase by 80 % to 578 million by 2030 (IDF, 2019).

Also, diabetes mellitus has been reported to kill one patient every six second at a rate higher than human immunodeficiency virus (HIV), tuberculosis, malaria, and also known to reduce life expectancy (Alqathama *et al.*, 2019; Lin *et al.*, 2020). Diabetes mellitus is a metabolic disorder often caused by the combination of hereditary and environmental factors resulting in hyperglycemia due to either a defect in insulin secretion or its action in the body (Viera *et al.,* 2019). Hyperglycemia is a condition associated with alteration in glucose metabolism, raising the production of reactive oxygen species (ROS) and chemical modifications of fats, DNA and proteins in various organ systems including the brain (Abdel- Moneim *et al.,* 2017; Osawa and Kato, 2005). Diabetes deregulation leads to other complications involving various organs of the body such as the brain, kidney, liver, and digestive system. The human brain is a finely calibrated organ of the body but the deregulation in lipid metabolism and the presence of high amounts of glucose or hyperglycemia associated with diabetes mellitus can cause injury to the central nervous system leading to severe complications such as disturbances in peroxisome proliferator-activated receptors (PPARs). These receptors are one of the chief regulators of lipid metabolism and glucose homeostasis and are therefore involved in the activities that are linked in curing this metabolic disorder (Campos *et al.*, 2019). There are also emerging complications associated with diabetes mellitus which have increased the morbidity and mortality rates of individuals with this disease (Pearson- Stuttard *et al*., 2021). These emerging complications include cancer, infections, liver disease, functional disability, cognitive disability, and affective disorders (Tomic *et al*., 2022). Studies have also revealed an association between diabetes mellitus and anxiety, eating disorders and depression (Tomic *et al*., 2022).

2.1.2 Classification of diabetes mellitus

Diabetes mellitus can be classified as type 1, type 2, gestational, and other rarer inherited and syndromic forms such as monogenic diabetes of the youth (MODY) or neonatal diabetes, as well as latent autoimmune diabetes in adults (Cole and Florez., 2020). All these classes of diabetes mellitus have been known to have a genetic base (Udler, 2018).

Type 1 diabetes mellitus (T1DM), formerly known as Insulin Dependent Diabetes Mellitus (IDDM), is a condition of insulin deficiency related to autoimmune-mediated loss of beta-cell function. It is typically diagnosed in childhood or early adulthood, although it can also present later in life (latent autoimmune disease of the adult or LADA). It is usually characterized by the presence of one or more of these antibodies: Glutamic acid decarboxylase-65 (GAD-65), anti-insulin, islet cell, or zinc transporter. The level of the fasting C-peptide (a product of the cleavage of proinsulin) is mostly undetectable in these individuals reflecting in insulin deficiency. The common symptom of type 1 diabetes is severe hyperglycemia with progressive weight loss, polydipsia (frequent thirst), and polyuria (frequent urination) culminating in diabetic ketoacidosis. The onset of this presentation could be sudden or gradual (Syed, 2022).

Type 2 diabetes mellitus (T2DM), formerly known as Non-Insulin Dependent Diabetes Mellitus (NIDDM), is typically diagnosed in adulthood, although cases among children have increased recently in the United States, such that in 2009, approximately 30 % of children with diabetes were estimated to have T2DM (Dabelea *et al.*, 2009). This form of diabetes mellitus accounts for about 90 – 95 % of all diabetic cases and is characterized by hyperglycemia due to the loss of the beta cell function of the pancreas, related to progressive resistance to the action of insulin in the muscle, fat and liver (Almanza-Aguilera *et al*., 2020; Chatterjee *et al*., 2017). The global prevalence of type 2 diabetes mellitus is estimated to rise from about 171 million people in 2000 to about 366 million people by 2030, thus having a serious devastating effect on overall health (Chen *et al*., 2017; Golpour *et al*., 2020).

Type 2 diabetes is associated with poor metabolic regulation due to lower levels of glucokinase (an enzyme in human beings that is involved in the phosphorylation of glucose to glucose-6-phosphate (G6P) in the parenchymal hepatocytes of the liver) and a reduction in its activity, thus resulting in decreased hepatic glucose disposal. Excessive dietary consumption of sugars in form of sucrose and fructose results in insulin resistance, higher lipid levels in the blood, nonalcoholic fatty liver disease (NAFLD) and type 2 diabetes (Haeusler *et al.,* 2015; Peter *et al.,* 2011). The disease however, is very versatile with varied expression and progression which makes its control very difficult. Hence, management of type 2 diabetes mellitus with lifestyle changes and oral drugs may not be sufficient to control hyperglycemia, and insulin may be required. Recently there has been an increasing appreciation for the role that other hormones/ receptors play in the origin of T2DM, particularly “the incretin effect.”

When carbohydrates are ingested, incretins such as glucagon-like peptide-1 and glucose-dependent insulinotropic polypeptide are released which elicit an enhanced secretion of insulin by the pancreatic beta cells (Tasyurek *et al.*, 2014; Vilsboll *et al.*, 2004).

Gestational diabetes mellitus (GDM) is a form of diabetes mellitus associated with pregnancy period. It is characterized by a high blood glucose levels first identified during pregnancy (Adam *et al*., 2023). Although, it is known to resolve immediately after birth, it still carries long term risk. Statistically, gestational diabetes mellitus affects about 13.4 % of pregnant women worldwide, with both mother and child pre-disposed to developing type 2 diabetes mellitus and other related health complications and a fewer a percentage of them developing type 1 diabetes mellitus (Adam *et al*., 2023).

2.1.3 Dangerous metabolic route of diabetes mellitus

Reactive oxygen species (ROS) are used to assist normal cellular processes in normal metabolic conditions such as the proliferation and differentiation of cells, signal transduction and apoptosis (Kowluru and Chan, 2007). The levels of these reactive oxygen species increases in hyperglycemic conditions thereby compromising the cell's structure and function through the degradation of fats, proteins and deoxyribonucleic acids (DNA) (Calderon *et al*., 2017). Hyperglycemia triggers the accumulation of advanced glycagon end- products (AGEs), the activation of protein kinase C (PKC) and an increased flux in the polyol and hexoamine pathways, which provoke oxidative stress (Maria and Giovanni, 2019).

An increase in reactive oxygen species is also likely to result in DNA fragmentation which in turn inhibits glyceraldehyde-3-phosphate dehydrogenase and activates poly-

ADP ribose polymerase. This leads to an accumulation of metabolites of the glycolytic pathway thus contributing to the complications of diabetes mellitus (Wang and Lo, 2018). Raised levels of reactive oxygen species is also likely to promote the activation of an oxidant-sensitive factor (NF-kB) and a crosslink between inflammation and oxidative stress (Forrester *et al*., 2018).

2.1.4 Economic burden of diabetes mellitus

Diabetes is associated with higher management costs due to the need for continuous medical attention, reduced labor force participation and productivity, and early death rate rising from complications caused by insufficient blood glucose control (Dall *et al.*, 2012). Diabetes mellitus poses serious economic burden to individuals and nations, with both the low and high income nations having an increasing prevalence of diabetes (Shaw *et al.*, 2010; Whiting *et al.*, 2011). There is also an increased rate of disability among diabetic patients as a result of the complications that accompany the disease, thus affecting the economy of these nations negatively. According to Oyagbemi *et al.*, (2014), the sub- Saharan Africa spends over US$ 3.4 billion annually in the treatment and management of this metabolic disorder. Poorer developing countries spend lowest on diabetes and are more negatively affected. The complications associated with diabetes mellitus has a vast range of reported side effects on various body organs and failure of existing treatments to confer a permanent solution has led to the need to come up with a budget friendly, easily accessible, long-term and sustainable solution for its management.

2.1.5 Management of diabetes mellitus

The three possible remedies for the management of diabetes mellitus include medications, diet modulations and exercises. The synthetic drugs used in the management of diabetes mellitus are in six main classes viz: biguanides (metformin), sulfonulureas, meglitinides, glitazones, α-glucosidase inhibitors and dipeptidyl peptidase IV, while the injections usually administered to diabetic subjects are incretin mimics and insulin (Lebovitz, 2019). Though effective, these drugs have notable side effects such as diarrhea, dyspepsia, nausea, weight gain, retention of body fluids resulting in cardiac failure, and can also increase the chances of bladder cancer; characteristic of intake of pioglitazone (Lebovitz, 2019). The use of medication under the strict supervision of a physician has been the top priority for the treatment of diabetes mellitus, however, diet modulation and exercise seem to be the new wave for the prevention and management of diabetic conditions (Neunschwander *et al*., 2020).

2.2 Nutraceuticals

Nutraceutical is a word coined from "nutrition" necessary for healthy living and "pharmaceuticals" essential for remedying sicknesses or injuries. They are foods (of vegetal or animal origin) providing medicinal benefits such as preventing and treating diseases (Daliu *et al*., 2018). They are also referred to as naturally occurring medical foods with bioactive ingredients for promoting health. These nutraceuticals usually contain the essential amount of vitamins, lipids, proteins, carbohydrates, minerals and other required nutrients (Whitman, 2001).

Nutraceuticals can be used as dietary supplements and are not likely to cause any known side effects (Chauhan *et al*., 2013). Regular intake of nutraceuticals could help improve pancreatic β- cell function, enhance insulin secretion, regulate lipid metabolism, manage body weight and control hyperglycemia (Anthony and Vijayan, 2021). Dietary fibres, prebiotics, polyunsaturated fatty acids, spices, polyphenols, probiotics, vitamins and probiotics are some of the needed nutraceuticals for diabetic patients (Saurabh and Vrish, 2018).

2.2.1 Classification of nutraceuticals

Nutraceuticals can be classified based on their sources, nature and applications (AlAli *et al*., 2021). They can be classified as nutrients (substances such as vitamins, minerals, amino acids and fatty acids, known to have nutritional functions), herbals (extracts of herbs) or dietary supplements (reagents from other sources with specific functions) (Saurabh and Vrish, 2018).

2.3 *Citrullus lanatus* (Watermelon)

2.3.1 Taxonomy of watermelon

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnolipsida

Order: *Cucurbitales*

Family: *Cucurbitaceae*

Genus: *Citrullus*

Specie: *Citrullus lanatus*

(Renner *et al*., 2017)

2.3.2 Description of *Citrullus lanatus*

Plate I: Watermelon seeds

Citrullus lanatus (water melon) is a fruit belonging to the genus *Citrullus* and the family *Cucurbitaceae* (Renner *et al*., 2017). It contains about 90 % water, hence the name "water" melon. The "melon" is a result of its large and round fruit that has a sweet, pulpy flesh (Baker *et al.,* 2012). It is an annual, climbing plant with several herbaceous, firm and stout stems up to 3 meters long (Zhan *et al*., 2016). The shape of the fruit is usually globose, oblong, ellipsoid and sometimes ovoid. The flesh of watermelon fruit comprises of 40 % of its total weight while the remaining 60 % is made up of its seeds and rinds (Chakrabarty *et al*., 2020; Zamuz *et al*., 2021). The pulp of watermelon has various colors including red, yellow, salmon or orange (Bang *et al.,* 2007), owing to different carotenoids content which in turn depend on its origin and climate of cultivation. This predicts that watermelon is a potent source of carotenoids (Yoo *et al.*, 2012). Watermelon contains 8 % sugar and 92 % water by weight. The pulp serves as a thirst- quencher and a very good source of minerals such as Vitamin A and C (Egbuonu *et al*., 2015). It is an excellent source of natural antioxidants such as lycopene (Mandel *et al.,* 2005) and citrulline (a precursor of arginine and nitric oxide) (Azizi *et al*., 2020; Becraft *et al*., 2020, which are carotenoids with beneficial effects against diabetes mellitus, anemia, and cardiovascular diseases (Mehra *et al*., 2015). Tabiri *et al*., 2016 reported that these seeds possess a high nutritional value because they are rich in protein, oil, citrulline, carotenoids, lycopene, niacin, folate, vitamin B and dietary fibres (Ejikeme *et al.,* 2010; Enemor *et al*., 2019). They have much higher food values than the flesh and can be dried, roasted or consumed fresh (Essien and Edduok, 2013). They are abundant in lipids and proteins (Angelova- Romova *et al*., 2019), an excellent source of carbohydrate (Karrar *et al*., 2019), and contain no hydrocyanic acid, making them suitable as a livestock feed. Furthermore, these seeds are rich in minerals such as calcium, phosphorus, magnesium, potassium, zinc and sodium (Enemor *et al*., 2019). They are also known to contain phytochemical constituents such as alkaloids, flavonoids, tannins, terpenoids and a considerable high amount of oil (Alemika *et al*., 2017; Johnson *et al.,* 2012; Raziq *et al.,* 2012). The content of unsaponifiable matters in watermelon seed oils ranges from 0.56 % to 0.80 % depending on the specie of watermelon melon fruit (Mariod *et al.,* 2009; Raziq *et al.,* 2012).

Report by Taiwo *et al.,* 2008 showed that watermelon seed oil is an easily absorbing and highly wholesome oil, suspected to be high in lycopene and good as an anti- aging agent hence, could be ideal for dry and damaged skin, as a humectant or skin moisturizer. Other studies have shown that the oil from watermelon can act as an antiseptic, antihelmintic, anti- inflammatory, anti- pyretic, anti- tumor, anti- ulcer, hypotensive, diuretic and febrifuge agent (Taiwo *et al.,* 2008; Kolawole *et al*., 2016;

Dammak *et al*., 2019). Studies in animal models have also revealed that consumption of watermelon rind and flesh reduced blood glucose levels and can bring about a regeneration of the beta cells of the pancreas (Chatterjee *et al*., 2017; Rezq, 2017). Water melon oil consists majorly of linoleic acid, followed by oleic acid, palmitic acid and stearic acid (BhanuTeja *et al.,* 2020). It comprises of about 23.3 % of saturated fatty acids and 78.4 % unsaturated fatty acids (Pannerselvam *et al.,* 2016; Autherson *et al.,* 2021).

Polyunsaturated fatty acids are lipid molecules having two or more double bonds in between their carbon chains and are categorized into n-9, n-6 and n-3 fats (Abdelhamid *et al.,* 2018). Linoleic acid (most abundant in watermelon seed oil) is an essential fatty acid that makes for about 85-90 % of the dietary n-6 polyunsaturated fatty acids. It is gotten mainly from the nuts and oils of plants (Russo, 2009). Linoleic acid has been reported to reduce total cholesterol, low density lipoprotein (LDL-cholesterol), very low density lipoprotein (VLDL-Cholesterol), and serum triglyceride and increases the high density lipoprotein (HDL-Cholesterol) levels (Mensink *et al.,* 2003). Linoleic acids have also been known to improve the uptake of insulin and glycemic conditions (Imamura *et al.,* 2016).

According to Marklund *et al.,* 2019, linoleic acids have an inverse proportion to diabetic conditions (particularly type 2 diabetes mellitus). Dietary consumption of linoleic acids and its biomarkers reduces the risk of coronary heart diseases and strokes. Other studies showed that consumption of linoleic acids largely contributes to a lower risk of all-cause and death rates associated with cancer (Li *et al.,* 2020). However, the magnitude of association between linoleic acids and diabetic states have a shown a dose-response relationship. Various studies have shown that dietary inclusion and uptake of linoleic acids mitigates diabetic conditions in the cell membrane by increasing cell fluidity and functions like glucose transporters (GLUT) translocation, cell signaling, the binding and affinity of insulin to its receptor and ion permeability. These mechanisms result in an increased insulin sensitivity (Jacobson, 2009). As a suggested mechanism for reducing hepatic fat contents, linoleic acids can also play a role in the regulation of sterol regulatory element binding transcription factor- 1 (SREBP1), which balances fatty acid synthesis and oxidation (Clarke, 2004). It has been shown that substituting fatty acids or carbohydrates with polyunsaturated fatty acids lowers the risk of type 2 diabetes mellitus, further buttressing the importance of the quality of dietary fats in the management/ prevention of diabetic mellitus. However, watermelon seeds are usually discarded indiscriminately into the environment, thereby constituting environmental challenges though they are edible (Esparza *et al*., 2020).

2.4 *Carica papaya* (Pawpaw)

2.4.1 Taxonomy of pawpaw

Kingdom: Plantae

Division: Magnoliophyta

Class: Magnoliopsida

Order: *Brassicales*

Family: *Caricaceae*

Genus: *Carica*

Specie: *Carica papaya*

(Yanty *et al*., 2014)

2.4.2 Description of pawpaw

Figure I: Pawpaw seeds
Source: Yanty *et al*. (2014)

Carica papaya (pawpaw) is a precious plant prevalent throughout tropical Africa with Nigeria as the third largest producer globally (Oseni *et al.*, 2018). It is a member of the *Caricaceae*, available in the tropical and sub- tropical regions of the world (Yanty *et al.*, 2014). It is green in colour when harvested and turns yellow to orange upon ripening (Barosso *et al.*, 2016). It is a diploid, dicotyledonous specie known to produce fruits all through the year. It is known for its weak and unbranched soft stem, crowded with a terminal cluster of large leaves with stalks (Owoyele *et al.*, 2008). The fruit is rich in folates, vitamins (A, C and E), magnesium, potassium and pantothenic acid which boosts the immune system (Aravind *et al.*, 2013).

Pawpaw fruit has a large number of seeds that are embedded in the interior of the fruits in a row (Noorzianna *et al.*, 2014), white at the immature stage and darkish in color upon full maturation of the fruit. The seeds and leaves of *Carica papaya* contain significant amounts of proteins which could be harnessed for feed formulation and supplementation (Feng, 2022). These seeds are also known to contain fatty acids, crude protein, crude fibre, oil, carpaine, benzyl glucosinolates, benzyl isothiocyanate, βsitrosol, myrosin, caricin and benzyl thiourea (Kumar and Devi, 2017). Aravind *et al.,* (2013) reported that the seeds of pawpaw have the ability to detoxify the liver, protect the kidneys from failure, and also cure piles and typhoid. Afolabi and Ofobrukweta (2011) reported that regardless of the stage of maturity of pawpaw fruits, its seeds have the ability to alter the activity of gram positive and negative bacteria which makes it useful in the treatment of skin diseases. Other medicinal applications of pawpaw seeds, as claimed by folk medicine, include serving as an anti-fertility agent in males, treatment of ringworms, vermifuge and liver cirrhosis (Kumar and Devi, 2017). Makanjuola and Makanjuola (2018) reported that the seeds of pawpaw contains essential nutrients that are of great importance to the sustenance of life in humans and animals. Pawpaw seeds contain several phytonutrients such as phenolics, carotenoids, tocopherols contributes to the many benefits of pawpaw (Tarun and Yash, 2015). Besides its nutritional properties, it is also an important medical plant due to its specific enzymes and bioactive constituents (Mello *et al.,* 2008).

The oil from pawpaw seeds have a characteristic aroma, enriched with lipophilic phytochemicals (Briones-Labarca *et al*., 2015), and also possess nutritional and functional properties similar to that of olive oil thus can be used as the feedstock for synthesizing biodiesel (Mohammad *et al.,* 2019). This oil is rich in oleic acid and can serve as an alternative for other unsaturated oils (Parni and Verma, 2014). Due to the presence of high oleic acid in pawpaw seed oils, the oil has a high oxidation stability (Dangarembizi *et al.,* 2015). Studies by Afolabi *et al.,* (2011) revealed that these seeds are undervalued and a waste product often discarded after consuming the fruit because of limited knowledge resulting in its very inadequate use up to date.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials Required

3.1.1 Reagents and apparatus

Reagents used for this research work include petroleum ether, sulphuric acid, distilled water and hydrochloric acid. They were purchased from SIM BEST Scientific Chemicals at Bosso Local Government, Minna, Niger state. Apparatus and equipment used include: oven (PBSH8SE, GENLAB, WIDNES, ENGLAND), locally fabricated oil extractor made of stainless steel from the department of Agricultural Bioresources Engineering of the Federal University of Technology, Minna, Niger state, digital weighing balance (F-METTLER, USA), Accu-check glucometer (ACCU-CHECK Active, Mannheim, Germany).

3.1.2 Sample collection

Watermelon fruits (*Citrullus lanatus*) were obtained from Kure market, in Niger state while the pawpaw seeds were harvested from a domestic farm in Bosso Local Government Area of Niger state. The watermelon fruits were cut into slices, the seeds were manually collected and washed with clean water and then air dried. These seeds were identified at the National Institute for Pharmaceutical Research and Development (NIPRD), Idu in Abuja with voucher number NIPRD/H/7216.

3.2 Methods

3.2.1 Sample processing

The seeds were air dried under shade and de-hulled manually to remove the kernels and pounded to powder manually (Aladekoyi *et al.,* 2016; Elvianto and Erni, 2017). The water melon and pawpaw seeds were grinded manually using a mortar and pestle, the powders obtained were stored in an air tight container until they were needed for analysis.

3.2.2 Extraction of water melon and pawpaw seed oil

Extraction of seed oil was done using the cold pressing methods (Rezig *et al.*, 2019) which does not involve chemical treatment. The oils were obtained by pressing the dried powder on a continuous screw press oil extractor (Rabrenovic *et al.*, 2014).

3.2.3 Determination of percentage oil yield

The percentage oil yield of the seeds were determined and calculated using the formula below according to Galit *et al*., 2020:

$$\%\ oil\ yield = \frac{Weight\ of\ extracted\ oil}{Weight\ of\ seed} \times 100 \qquad (3.1)$$

3.2.4 Fatty acid composition of water melon and pawpaw seed oil samples

The fatty acid composition was determined using gas chromatography- mass spectroscopy (GC- MS) (Angelova- Romova *et al*., 2019).

3.3 Proximate composition analysis of water melon and pawpaw seed powder samples

The proximate compositions of the seeds powder samples were determined using standard analytical methods and values were presented in percentages.

3.3.1 Determination of moisture content of the water melon and pawpaw seed powder samples

Moisture content was determined by the method of Association of analytical chemists (AOAC, 1990). Two grams of the water melon and pawpaw seed powder samples were weighed in a dry crucible and their initial weight noted as W_1. The crucible was placed in the oven at 100 ^{0}C overnight until a constant weight was reached. The crucible was removed and cooled in a desiccator for 30 minutes and the final weight was taken as W_2. Percentage loss in weight was expressed as the percentage moisture content.

$$\% \text{ moisture} = \frac{W_2 - W_3 \times 100}{W_2 - W_1} \quad (3.2)$$

Where W_1 = initial weight of the empty crucible, W_2 = weight of the crucible and seed powder before oven drying and W_3 = weight of the crucible and seed powder after oven drying.

3.3.2 Determination of ash content of the water melon and pawpaw seed powder samples

Two grams of the water melon and pawpaw seed powder samples were placed in a crucible and ashed. The ashing was done in a muffle furnace at a temperature of 550 ^{0}C for 6 hours and then cooled in a desiccator. The residue left was weighed and expressed in percentage as the ash content. (AOAC, 1990).

3.3.3 Determination of crude lipid content of the water melon and pawpaw seed powder samples

The crude lipid content was determined by the method reported by Gabriel *et al.*, 2018. This method involved the use of petroleum ether in a soxhlet extractor. The percentage fat was calculated by the formula below:

$$\% \text{ Fat} = \frac{C - A \times 100\%}{B} \quad (3.3)$$

Where A = weight of empty flask, B = Weight of sample and C = Weight of oil after drying.

3.3.4 Determination of crude protein content of the water melon and pawpaw seed powder samples

Kjeldahl (1883) method as reported by Gabriel *et al*., (2018) was used to determine the crude protein content. One gram of the seed powder sample was put into a filter paper and placed in a Kjeldahl flask. Ten milliliters (10 ml) of concentrated H_2SO_4 was added and digested in a fume cupboard until a colorless solution was obtained. Distillation was done with 15 ml of 50 % NaOH. The tip of the condenser was dipped into a conical flask containing boric acid in a mixed indicator until a green color was observed. Titration was done in a receiver flask with 0.01 M HCl until the color of the solution changed from green to red. The Nitrogen content of the seed powder were obtained and then multiplied by a factor (6.25) to obtain the crude protein content of the sample (Nwosu *et al.,* 2014).

3.3.5 Determination of crude fibre content of the water melon and pawpaw seed powder sample

This was done by acid and alkaline digestion methods. Two gram of each powder sample was used with H_2SO_4 and NaOH solution (Darmanto *et al*., 2022).

3.3.6 Determination of carbohydrate content of the water melon and pawpaw seed powder sample

The carbohydrate content of the seeds powder was determined by estimation using the arithmetic difference as described by Nwosu *et al.,* (2014).

% carbohydrate = 100 – (% Fat + % Ash + % Fibre + % Moisture + % Protein). (3.4)

3.4 Experimental Animals

Thirty female albino rats were obtained from a domestic farm in Minna, Niger state with an average weight of 100 g. The animals were maintained under standard laboratory conditions of 25 ^{0}C temperature, humidity and light (average of 12 hours per day). The handling of the animals and the experimentations were done in compliance with the principles governing the use of laboratory animals as laid down by the Federal University of Technology, Minna committee on Ethics for Medical and Scientific Research as contained in the Animal Care Guidelines and Protocol Review of National

Institutes of Health Guide for the Care and Use of Laboratory Animals (NIH Publication Number 85-23, 1985). They were allowed to acclimatize for two weeks, fed and given water *ad libitum*.

3.5 Preparation of Animal Feed

Animal diets were prepared in the laboratory. The control diet contained seeds powder (50 %) mixed with the basal diet (50 %). After mixing, the final batter was formed into pellets, air- dried and stored until when needed.

3.6 Induction of Diabetes

Diabetes mellitus was induced by a single intraperitoneal injection of alloxan dissolved in normal saline at a dose of 130 mg/kg body weight. There initial drug-induced hypoglycemia was overcome by giving the animals glucose solution. The rats were observed over a period of 72 hours and their blood glucose level was monitored using glucose strips with ACCU-CHECK glucometer to ensure their diabetic state was sustained. Rats whose blood glucose levels were above 150 mg/dL were considered diabetic (Adefolalu *et al*., 2019).

3.7 Acute Toxicity and Safe Dose Determination

The lethal dose (LD_{50}) of the oil samples was carried out using Lorke's method (Lorke, 1983) as reported by Francis *et al*., (2019). A total of 14 rats were used for the acute toxicity test; the rats were randomly divided into 7 groups consisting of 2 rats each. All rats were made to fast for 12 hours before and 8 hours after the administration of the watermelon and pawpaw oil extracts. In phase 1, the oil samples were administered at doses of 10 ml/kg, 50 ml/kg and 100 ml/kg orally to three groups of rats respectively. In phase 2, oil samples at doses of 200 ml/kg, 300 ml/kg and 500 ml/kg were administered orally to another three groups of rats respectively. The last group of rats served as the control group which was given normal saline (0.9 % w/v NaCl) at 20 ml/kg body weight. The rats were observed for behavioral changes such as decreased activities, licking of paw, body weakness, sleeping and mortality within 24 hours.

3.8 Experimental Animal Design

The rats were divided into six groups of five animals each according to their body weight, after the period of acclimatization of two weeks and the subsequent induction of diabetes mellitus, and kept in different cages. The experiment was carried out for a period of 28 days.

3.9. Animal Grouping and Feed Formulation

The watermelon and pawpaw seed oils were administered orally daily while the seed powders was used in the feed formulation (ratio of 50 % powder and 50 % basal diet) and given to the rats *ad libitum*.

The experimental animals were divided into 6 groups of five rats (n = 5) as follows:

Group 1: Animals induced with alloxan + 100 ml/kg watermelon seeds oil (WMSO)

Group 2: Animals induced with alloxan + 100 ml/kg pawpaw seeds oil (PSO)

Group 3: Animals induced with alloxan + 1200 mg/kg watermelon seed powder (WMSP)

Group 4: Animals induced with alloxan + 1200 mg/kg pawpaw seed powder (PSP)

Group 5: Animals induced with alloxan + 20 ml/kg NaCl (negative control; NC)

Group 6: Animals induced with alloxan + 50 mg/kg metformin (positive control; PC).

3.10 Collection of Blood Sample

After every week of administration of treatments, rats were fasted overnight, blood was collected from their tails (by cutting the tip of their tails), and their blood glucose levels were determined using Accu-check glucometer. The results of the blood glucose levels were expressed in mg/dl.

3.11 Determination of Body Weight

The body weights of the rats were determined using a sensitive digital weighing balance. The mean body weight was calculated using the equation below:

$$\textit{Mean Body Weight} = \frac{Total\ weight\ of\ rats\ in\ a\ group}{Total\ number\ of\ rats\ in\ that\ group} \qquad (3.5)$$

3.12 Analysis of Biochemical Parameters

After 28 days of treatment with the powders and oils from watermelon and pawpaw seeds samples respectively, the rats were sacrificed and their blood collected. The blood glucose levels in the rats were determined using an “Accu-check” glucometer (ACCU-CHECK Active, Mannheim, Germany). The packed cell volume (PCV) and hemoglobin level were determine using the method of Hoffbrand and Moss (2011), after which the blood samples were centrifuged for the serum estimation of biochemical parameters.

3.12.1 The estimation of some serum lipoprotein

Low Density Lipoprotein (LDL) and High Density Lipoprotein (HDL) was done according to the method described by Jacob *et al.,* 2015.

3.12.2 Estimation of creatinine level

The serum creatinine level was analyzed using Randox test kits using the method described by the manufacturer on the kit (RANDOX Laboratories Ltd., UK).

3.12.3 Liver function test

Aspartate aminotransferase (AST), alanine aminotransferase (ALT) and alkaline phosphatase (ALP) activities in the serum were determined using Randox diagnostic kits according to the manufacturer’s instruction (RANDOX Laboratories Ltd., UK).

3.13 Histopathological Examination

The liver and kidney specimens were dissected out and immediately rinsed with normal saline solution. These tissues were fixed in 10 % formalin and subsequently sliced into segments and embedded in paraffin wax. Their sections were stained with hematoxlin and eosin (H& E) and examined under a light microscope. Histological examination for liver injury was assessed by grading of hepatocyte architecture and grading of inflammatory infiltrate while the histological assessment for kidney injury was conducted as grading of architecture, grading of glomerular damage, grading of tubular necrosis, and grading of tubulointerstitial nephritis (Eke *et al*., 2021).

3.14 Data Analysis

All numeric data generated were analyzed by one- way analysis of variance (ANOVA) using SPSS version 20.0. The results were expressed as the mean ± standard error of mean (SEM). The significant difference between the animal groups were compared using the Duncan's posthoc test and a probability level of $P \leq 0.05$ was considered significant.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Percentage yield of oil from water melon and pawpaw seeds samples

The percentage yield of oil obtained from water melon and pawpaw seeds is presented in table 4.1. The watermelon presented a higher oil yield of 38.92 %

Table 4.1: Percentage Yield of Oil Extracted from Water melon and Pawpaw Seeds Samples

Seed sample	% Oil Yield	Colour
Watermelon	38.92	Golden- yellow
Pawpaw	19.72	Dark- yellow

4.1.2 Proximate composition of water melon and pawpaw seeds powder samples

The proximate composition of the water melon and pawpaw seed powder is presented in table 4.2. The watermelon seed powder samples has a higher carbohydrate, fibre, ash and moisture content than pawpaw seed powder samples.

Table 4.2: Proximate Composition of Water melon and Pawpaw Seeds Powder Samples

Parameters	% concentration in powder	
	Water melon	Pawpaw
Crude protein	20.64 ± 0.90^{ab}	17.65 ± 0.87^{a}
Crude fibre	23.70 ± 2.91^{a}	25.82 ± 0.98^{a}
Crude lipid	25.94 ± 1.66^{b}	31.58 ± 3.48^{a}
Ash	3.09 ± 0.71^{ab}	3.32 ± 0.82^{ab}
Moisture content	3.00 ± 0.58^{a}	4.33 ± 0.01^{a}
Crude carbohydrate	23.67 ± 0.87^{a}	17.30 ± 0.69^{a}

Data are mean ± standard error of mean (SEM) of triplicate.
Values within rows bearing the same superscript are not significantly different at the 5 % significance level ($P \leq 0.05$).

4.1.3 Fatty acid composition of water melon and pawpaw seeds oil samples

The composition of fatty acid in the oil extracted from samples of water melon and pawpaw seeds is presented in table 4.3. Watermelon oil is higher in linoleic acid while pawpaw oil has more oleic acid content.

Table 4.3: Fatty Acid Composition of Water melon and Pawpaw Seeds oil Samples

Fatty acids	% Composition in oils	
	Water melon	Pawpaw
Linoleic acid	60.0	3.24
Linolenic acid	Trace (< 0.2)	Trace
Oleic acid	14.0	70.0
Palmitic	9.88	16.20
Palmitoleic	Trace	0.23

4.1.4 Acute toxicity of the oil samples of watermelon and pawpaw seed oil samples

The acute toxicity test of orally administered oils extracted from watermelon and pawpaw seeds in albino rats is shown in tables 4.4a and b. No mortality was recorded as the doses increased but there was visible effect on their physiological behavior which was reflected by muscular weakness.

Table 4.4a: Acute Toxicity Study of the Watermelon Seeds Oil Samples.

Groups	Dose (ml/ kg)	No of death	% mortality	Remarks
A	10 ml/ kg	0	0	Normal
B	50 ml/ kg	0	0	Normal
C	100 ml/ kg	0	0	Normal
D	200 ml/ kg	0	0	slightly weak
E	300 ml/ kg	0	0	weak
F	500 ml/ kg	0	0	weak
G	20 ml/ kg NaCl	0	0	Normal

Table 4.4b: Acute Toxicity Study of the Pawpaw Seeds Oil Samples.

Groups	Dose (ml/kg)	No of death	% mortality	Remarks
A	10 ml/ kg	0	0	Normal
B	50 ml/ kg	0	0	Normal
C	100 ml/ kg	0	0	Normal
D	200 ml/ kg	0	0	slightly weak
E	300 ml/ kg	0	0	slightly weak
F	500 ml/ kg	0	0	weak
G	20 ml/ kg NaCl	0	0	Normal

4.1.5 Fasting blood glucose profiles of diabetic rats treated with watermelon and pawpaw seeds oil and powder samples

The treatment of the diabetic rats with oil extracts and powder of watermelon and pawpaw seeds is shown in table 4.5. A reduction in blood glucose level was observed with the administration of the seed oils and powder. However, it was observed that the group receiving watermelon seed oil had a significant reduction percentage compared to the group given metformin.

Table 4.5: **Mean Fasting Blood Glucose Profile of the Animals Treated with Watermelon and Pawpaw Seed Oil Samples**

Days	Blood Glucose levels (mg/dL)					
	WMSO	PSO	WMSP	PSP	NC	PC
	72.7	71.5	74.8	73.7	72.3	71.8
0	233.5±6.20^{c}	213.5±0.48^{a}	198.8±1.06^{b}	200.8±0.78^{a}	196.8±0.38^{a}	227.0±0.61^{c}
4	215.7±0.52^{f}	209.2±0.18^{b}	184.4±0.32^{e}	198.8±0.77^{c}	202.5±0.19^{d}	178.9±0.58^{a}
8	205.2±0.16^{e}	198.6±0.41^{b}	173.0±0.76^{d}	190.1±0.60^{c}	214.0±0.40^{f}	132.0±1.03^{a}
12	186.7±0.68^{cd}	187.9±1.55^{b}	161.7±0.57^{d}	183.2±0.24^{c}	204.4±2.08^{e}	102.9±0.94^{a}
16	164.6±0.65^{c}	174.9±0.14^{b}	148.8±0.41^{d}	177.1±0.08^{d}	198.8±1.14^{e}	95.6±2.50^{a}
20	143.9±1.35^{c}	162.2±1.43^{b}	133.7±0.85^{d}	162.8±1.84^{d}	186.9±2.15^{e}	72.0±1.27^{a}
24	129.1±0.55^{b}	152.9±1.89^{b}	128.9±1.21^{c}	151.0±0.60^{c}	183.5±0.42^{d}	71.1±1.02^{a}
28	117.6±0.86^{b}	147.8±0.72^{b}	125.1±0.95^{e}	144.1±0.77^{d}	174.1±1.98^{f}	65.0±0.18^{a}
% reduction	50.5	37.23	30.29	30.17	6.3	71.67

KEY: WMSO: Watermelon seed oil; PSO: Pawpaw seed oil; WMSP: Watermelon seed powder; PSP: Pawpaw seed powder; NC: Negative control; PC: Positive control
Values are in ± mean S. E. M (S. E. M = Standard error of Mean)
Values on the same row bearing the same superscript are not significantly different at the 5 % significance level ($P \leq 0.05$).

4.1.6. Effect of watermelon and pawpaw seeds oils and powders on some serum lipoproteins on the Alloxan – induced diabetic rats

The effect of treatment on the serum lipoprotein (High density Lipoprotein – HDL and Low Density Lipoprotein – LDL) is shown in table 4.6. The treatments significantly reduced the level of LDL and increased the HDL level in the rats. However, watermelon seed oil gave a significant result than the other treatments which is comparable to that obtained from the use of metformin.

Table 4.6: Some Serum Lipoprotein of the Alloxan Induced Diabetic Rats Treated with Watermelon and Pawpaw Seeds Oil and Powder Samples

Treatments	HDL (mg/dL)	LDL (mg/dL)
WMSO	33.20 ± 0.58^{b}	60.90 ± 1.93^{a}
PSO	29.70 ± 1.70^{ab}	73.62 ± 0.20^{a}
WMSP	23.40 ± 2.50^{a}	64.40 ± 0.30^{b}
PSP	21.20 ± 1.50^{a}	79.10 ± 0.66^{c}
NC	20.60 ± 1.20^{a}	90.20 ± 4.35^{d}
PC	35.30 ± 1.25^{c}	61.20 ± 0.47^{a}

KEY: WMSO: Watermelon seed oil; PSO: Pawpaw seed oil; WMSP: Watermelon seed powder; PSP: Pawpaw seed powder; NC: Negative control; PC: Positive control
HDL: High density lipoprotein; LDL: Low density lipoprotein
Values are in mean ± S.E.M (S.E.M = Standard error of Mean)
Values within rows bearing the same superscript are not significantly different at the 5 % significance level ($P \leq 0.05$).

4.1.7. Effect of watermelon and pawpaw seeds oil and powder on creatinine level of Alloxan induced diabetic rats

The effect of treatment on the creatinine level is shown in table 4.7. The treatments decreased the level of creatinine in the rats. However, watermelon seed oil, among the treatment options significantly reduced the creatinine level in the diabetic rats.

Table 4.7: Creatinine level of the Alloxan Induced Diabetic Rats Treated with Watermelon and Pawpaw Seeds Oil and Powder Samples

Treatment	Creatinine level (μmol/L)
WMSO	25.33 ± 1.83^{b}
PSO	29.00 ± 2.30^{bc}
WMSP	35.67 ± 0.98^{c}
PSP	32.67 ± 1.45^{d}
NC	90.00 ± 1.23^{a}
PC	20.69 ± 2.09^{b}

KEY: WMSO: Watermelon seed oil; PSO: Pawpaw seed oil; WMSP: Watermelon seed powder; PSP: Pawpaw seed powder; NC: Negative control; PC: Positive control
Values are in Mean ± S. E. M (S.E.M = Standard error of Mean)
Values within columns bearing the same superscript are not significantly different at the 5 % significance level ($P \leq 0.05$).

4.1.8 Effect of watermelon and pawpaw seeds oil and powder on the hematological parameters (Packed Cell Volume- PCV and Hemoglobin level- Hb) of the experimental animals

The effect of the watermelon and pawpaw seeds oil and powder on the hematological parameters (PCV and Hb levels) is shown in table 4.8. Diabetes mellitus is usually associated with a decrease in packed cell volume and hemoglobin levels. However, watermelon seed oil significantly reduced the elevated levels of these parameters than the other treatment options.

Table 4.8: **Hematological Parameters of the Alloxan Induced Diabetic Rats Treated with Watermelon and Pawpaw Seeds Oil and Powder Samples**

Treatment	PCV %	Hb (g/dL)
WMSO	41.63 ± 0.44^{c}	13.37 ± 0.11^{c}
PSO	38.83 ± 0.69^{bc}	11.80 ± 0.57^{bc}
WMSP	39.24 ± 1.07^{ab}	12.30 ± 0.19^{ab}
PSP	36.97 ± 1.99^{bc}	12.50 ± 0.41^{bc}
NC	34.51 ± 1.29^{a}	11.07 ± 0.23^{a}
PC	40.89 ± 0.22^{c}	13.00 ± 0.29^{c}

KEY: WMSO: Watermelon seed oil; PSO: Pawpaw seed oil; WMSP: Watermelon seed powder; PSP: Pawpaw seed powder; NC: Negative control; PC: Positive control PCV: Packed cell volume; Hb: Hemoglobin level
Values are in ± mean S.E.M (S.E.M = Standard error of Mean)
Values within column bearing the same superscript are not significantly different at the 5 % significance level ($P \leq 0.05$).

4.1.9 Effect of watermelon and pawpaw seeds oil and powder on liver function indices in Diabetic Rats

The effect of treatment on the liver function indices: serum aspartate transferase, alanine transferase and alkaline phosphatase) is shown in table 4.9. There was a significant reduction in the elevated level of these enzymes upon treatment with watermelon seed oil.

Table 4.9: **Liver Function Indices of the Experimental Animals Treated with Watermelon and Pawpaw Seeds Oil and Powder Samples**

Treatments	AST (Iµ/L)	ALT (Iµ/L)	ALP (Iµ/L)
WMSO	34.00 ± 0.29^{b}	39.73 ± 0.60^{a}	135.00 ± 1.53^{a}
PSO	34.95 ± 0.29^{c}	47.38 ± 0.95^{d}	145.00 ± 1.15^{b}
WMSP	42.94 ± 0.65^{b}	48.90 ± 0.23^{c}	141.00 ± 2.08^{b}
PSP	45.70 ± 1.37^{d}	50.40 ± 0.31^{e}	150.00 ± 0.14^{c}
NC	52.88 ± 0.61^{e}	54.40 ± 0.15^{f}	177.80 ± 2.13^{d}
PC	30.56 ± 0.18^{a}	30.23 ± 0.15^{a}	133.00 ± 1.61^{a}

KEY: WMSO: Watermelon seed oil; PSO: Pawpaw seed oil; WMSP: Watermelon seed powder; PSP: Pawpaw seed powder; NC: Negative control; PC: Positive control
AST: Aspartate transferase; ALT: Alanine transferase; ALP: Alkaline phosphatase
Values are in ± mean S. E. M (S.E.M = Standard error of Mean)
Values within rows bearing the same superscript are not significantly different at the 5 % significance level ($P \leq 0.05$).

4.1.10 Effect of watermelon and pawpaw seeds oil and powder samples on the body weight of Alloxan – induced diabetic rats

There was a significant increase in body weight gain upon administration of treatment which was consistent as the weeks progressed compared to the diabetic untreated group.

Table 4.10: **Weekly Weight of Alloxan Induced Diabetes Rats Treated with Watermelon and Pawpaw Seeds Oil and Powder Samples**

		Weight (grams)			
Treatments	Week 0	Week 1	Week 2	Week 3	Week 4
WMSO	102.45±14.83^{b}	100.52± 0.15^{b}	121.86±1.55^{c}	126.21±1.49^{d}	128.17±0.71^{d}
PSO	106.21± 6.56^{c}	105.62± 0.87^{c}	106.26±0.50^{e}	118.17± 0.30^{e}	126.20± 0.20^{f}
WMSP	103.26± 6.31^{c}	103.22± 0.24^{c}	105.86±2.04^{b}	112.26±1.70^{b}	117.59± 1.48^{c}
PSP	123.40± 15.3^{e}	118.24± 1.93^{e}	95.22± 0.21^{d}	96.51± 0.40^{c}	99.31± 1.19^{e}
NC	113.52±17.09^{d}	108.21± 0.87^{d}	94.62± 0.88^{a}	92.54± 2.40^{a}	89.83± 0.51^{b}
PC	100.25± 9.23^{a}	98.53± 0.47^{b}	125.63±2.99^{a}	130.35± 0.58^{a}	130.63± 1.31^{a}

KEY: WMSO: Watermelon seed oil; PSO: Pawpaw seed oil; WMSP: Watermelon seed powder; PSP: Pawpaw seed powder; NC: Negative control; PC: Positive control
Values are in ± mean S.E. M (S.E. M = Standard error of Mean)
Values within columns bearing the same superscript are not significantly different at the 5 % significance level ($P \leq 0.05$).

4.1.11 Histological examination

The histology result of the kidney of the diabetic rats revealed that the renal tissue had distorted glomeruli and capsular space, alongside necrosis of the nephrocytes (plate B). On the other hand, the liver tissue of the diabetic rat had a preserved architecture composed of normal portal tracts and central vein but with inflamed hepatocytes. When watermelon seed oil was used in treating the animals, the section of renal tissue showed a preserved architecture composed of normal glomeruli, tubules and interstitium. There were no features of acute or chronic damage to the nephrocytes. The hepatic tissue also had a preserved architecture composed of cords of normal hepatocytes, normal portal tracts and central vein.

4.2 Discussion of Results

4.2.1 Percentage yield of watermelon and pawpaw seed oils

The value for the percentage oil yield of the watermelon seed (38.92 %) falls within the range of 37.8 – 45.4 % reported by Ziyada and Elhussien, (2008). It is however higher than other values such as 24.1 % (Morais *et al.*, 2017), 23.1 % (Nehdi *et al.*, 2013), 27.1

% (Gornas and Rudzinska, 2016) and 28.5 % (Mariod *et al.,* 2009). Oil yield from water melon seeds using the cold press method was first reported by De Conto *et al.,* 2011 to be 21.6 %. The variations observed in the percentage oil yields may be due to differences in plant variety, climate of cultivation, stage of ripening, the time of harvesting of the fruits, collection of seed samples, and the extraction method employed (Nyam *et al.*, 2009). The percentage oil yield from the pawpaw seed (19.72 %) was lower than (27.0 %) reported by Yanty *et al.* (2014), which is possibly due to differences in the moisture content of the seed (dry seeds produce more oils), the variety of cultivar of the fruit and also the method of extraction of the seed oil.

4.2.2 Proximate composition of watermelon and pawpaw seed powders

The carbohydrate content of the watermelon seed powder obtained in this study is closely related with those reported by Egbuonu *et al*., (2015) and Eke *et al*., (2021) as 28.05 ± 0.06 % and 25.91 ± 2.15 % respectively. Tabiri *et al*., (2016) reported a range of 9.55 – 15.32 % as the carbohydrate content of watermelon seeds. The moisture content of the watermelon seed powder is affected by storage as reported by Gabriel *et al.,* (2017). It was found to be closely related to the result of Eke *et al*., 2021 (3.47 ± 1.15 %), Mogotlane *et al*., (2018) (3.16 %), and Egbuonu *et al*., (2015) (3.81 ± 0.00 %); the crude fibre content was close to the findings of Mogotlane *et al*., 2018 (23.1 %) but different from those reported by Tabiri *et al*., 2016 (39.09 – 43.28 %), Egbuonu *et al*., 2015 (2.37 ± 0.00 %), Eke *et al*., 2021 (4.65 ± 0.01 %) and Rezig *et al*., (2019) (48.26 %), however, it fell within the World Health Organization acceptable range of less than 10 %. Seeds moisture content is closely associated with seed quality. Low moisture content prevents seed germination, fungal (mould) growth, inhibits insect development in seeds as well as determines the quality of seeds. Hence, the low moisture content obtained in this study implies that the watermelon and pawpaw seed powders can be stored for a long time and still retain their quality. Therefore, watermelon seed powder can be recommended for the lowering of cholesterol levels in the blood and reduced risk of various cancers. An appreciable amount of crude protein content was obtained in this study. This could imply that watermelon seed powder can be a good source of supplementary protein for man and livestock feeds. The result is comparable to the findings of Tabiri *et al.*, 2016 (16.33 – 17.75 %), Eke *et al*., 2021 (19.02 ± 2.01 %), Mogotlane *et al*., 2018 (16.5 %) and Egbuonu, 2015 (21.46 ± 0.04 %). Seeds, such as watermelon seeds, with a high crude lipid content can be utilized for the production of oil to substitute and substantiate that of palm oil, coconut oil and others.

The crude lipid content was close to the range reported by Tabiri *et al*., 2016 (26.50 – 27.83. This value is however lower than 44.00 ± 0.04 % (Matthew *et al*., 2014), 43.51 ± 3.15 % (Eke *et al*., 2021), 34.4 % (Mogotlane *et al*., 2018) and 41.84 ± 0.04 % (Egbuonu *et al*., 2015), which can also be attributed to differences in varieties and climate. The amount of ash present in a seed sample is a suitable parameter to determine the organic mineral composition in seeds. The ash content in the watermelon seed differs from other studies such as 3.97 ± 1.01 % (Eke *et al*., 2021), 2.00 – 3.00 % (Tabiri *et al*., 2016), 2.48 ± 0.01 % (Egbuonu *et al.*, 2015), and 3.99 % (Mogotlane *et al*., 2018). The pawpaw seeds used in this study has a moisture content close to the range reported by Adesuyi and Ipinmoroti, 2011 (7.55 – 8.13 %), Syed *et al.*, 2012 (7.3 %), and Yanty *et al.*, 2014 (6.2 ± 0.10 %). The ash content of a seed makes it suitable to serve as an alternative source of mineral content in diets. This ash content was however lower than the values obtained by other researchers (9.94 – 11.5 %, Adesuyi and Ipinmoroti, 2011; 7.85 – 11.6 %, Jacob *et al*., 2015; 8.2 %; Syed *et al*., 2012). The crude protein content from this study differed from 28.2 ± 0.00 % reported by Yanty *et al.*, 2014. Seeds having such high crude protein could be harnessed in the formulation and supplementation of feed (Kadiri *et al.,* 2016). The crude lipid content in the pawpaw fruit was higher than 14.01 ± 0.20 % reported by Matthew *et al.,* (2014) but close to 29.4 – 31.6 % reported by Adesuyi and Ipinmoroti, (2011). Fats are important for cellular fluidity and functioning, maintaining homeostasis of the body and necessary for cell signaling (Matthew *et al.,* 2014). It is necessary in reducing the level of cholesterol and risk of cancers in humans (Jacob *et al.,* 2015). The crude fibre determination showed that the fibre content in the pawpaw seed is close to 21.8 ± 0.50 % by Yanty *et al.*, 2014 and 26.01 ± 0.00 % by Matthew *et al.*, 2014. The carbohydrate content of the pawpaw seed corroborates the findings of Yanty *et al*., 2014 (14.4 ± 1.70 %), Adesuyi and Ipinmoroti, 2011 (8.4 – 12.13 %), but lower than 36.25 ± 0.01 % (Matthew *et al*., 2014) and 25.6 % (Syed *et al*., 2012). Comparing this result with the crude carbohydrate content obtained for the watermelon seed, the pawpaw seed contained less carbohydrate. However, this result contradicted the comparison between the crude carbohydrate content of pawpaw seeds and watermelon seeds reported by Jacob *et al.*, (2015) and Oyeleke *et al.,* (2012). The variances in the proximate compositions could be attributed to differences in climatic conditions, specie types and soil factors.

4.2.3 Fatty acid composition of watermelon and pawpaw seed oils

Watermelon seed oil contains fatty acids that impacts on insulin secretion based on their degree of saturation and chain length (Poitout and Robertson, 2008). Unsaturated fatty acids provide first line protection especially against cardiovascular diseases and strengthen the immune system of the human body. The percentage composition of linoleic acid in the oil obtained from the watermelon seed is comparable to 65.85 % reported by Okunrobo *et al.,* 2012. This result correlated with the report of Atolani *et al.,* (2012) who reported linoleic acid as the major fatty acid in watermelon seed oil but contradicted the report of Ariyike *et al.,* (2019), who reported myristic acid as the major fatty acid in watermelon seed oil. Linoleic acid is a polyunsaturated fatty acid known to form an integral component of neuronal membrane phospholipids and has been described in several studies to be involved in modulatory pancreatic β-cell function (Francis *et al.,* 2019), reduction in voltage- gated K^+ channels in rat cells through cAMP-protein kinase resulting in an increase in the secretion of insulin and Ca^{2+}. Therefore, linoleic acid is largely involved in reversing the pathogenesis of diabetic neuropathy (Francis *et al*., 2019). Pawpaw seed oil is rich in oleic acid. Oils with high oleic acid content implies a high oxidation stability. According to Win (2005), oleic acids helps in the prevention of cancer, reducing the risk of artherosclerosis and cardiovascular diseases (Perdomo *et al.*, 2015). Part of the effects resulting from the dietary intake of oleic acid may be due to its derived endogenous lipid mediator; oleoylethanolamide (OEA).

Dietary intake of oleic acid elevates the levels of OEA by increasing substrate availability for its biosynthesis from membrane glycerophospholipids (Bowen *et al.*, 2017). OEA decreases food intake and body weight gain through the activation PPARα. PPARα is a ligand-activated transcription factor expressed predominantly in tissues that are involved in the metabolism of fats like the liver, muscles, tissue and also in the heart. It plays an important role in lipid and glucose metabolism and can serve as a potential therapeutic target. The activation of PPARα reduces the level of triglycerides, increases beta oxidation of fatty acids, inhibits lipoprotein lipase as well as increases HDL levels and activity (Goya *et al*., 2004), improves insulin secretion and insulin sensitivity, thereby reducing blood glucose levels (Ye *et al*., 2001; Ravnskjaer *et al*., 2005) The reduction in body weight caused by OEA has been attributed to its ability to reduce appetite, increase lipid breakdown in adipocytes and the subsequent stimulation of fatty acid oxidation in skeletal muscle (Bowen *et al.*, 2017). It also has the ability to reduce the damaging effect of long chain saturated fatty acids in the aortic endothelial cells of human (Carrillo *et al.,* 2012), and can be used as food emulsifiers to make baked foods and cheeses. Hence, pawpaw seed oil could also be used in pharmaceutical and nutritional industries. This high percentage of oleic acid could be the basis for the hypoglycemic and hypolipidemic effect associated with dietary intake of pawpaw seed oil.

4.2.4 Acute toxicity of the watermelon and pawpaw seed oil

There was no death or behavioral change from the acute toxicity study of the oil extracted from watermelon and pawpaw seed at a dose up to 100 ml/kg. Therefore, the lethal dose (LD_{50}) could be greater than or equal to 100 ml/kg body weight. These values can serve as a guideline in the selection of doses for experimental animals. This result contradicts the result of 2500 ml/kg reported by Madhavi *et al.,* 2012 when female wistar rats were treated with seed oil extracted from India's watermelon. The variance in the doses can be attributed to variations in chemical constituents from fruit specie, season of planting and geographical location (Eke *et al*., 2021).

4.2.5 Fasting blood glucose of the animals treated with watermelon and pawpaw seed oil and powder

Alloxan generates reactive oxygen species that damage the β-cells of the pancreas where insulin is produced, resulting in decreased levels of insulin. This process occurs in a very short time leading to diabetes (Martinez and Milagro, 2000). The mechanism of action of nutraceuticals on diabetes include releasing the bound insulin, increasing the secretion of insulin by the pancreas (Pari and Amarnath, 2004), inhibiting liver gluconeogenesis (Eddouks *et al.,* 2003), inhibiting glucose absorption in the intestines (Youn *et al.,* 2004) and correcting insulin resistance (Hu and Ao, 2003). The significant increase in the level of plasma glucose in the diabetic rats were significantly reduced upon treatment with watermelon and pawpaw seed oils and powders. However, the rats that were administered the watermelon seed oil presented a more significant reduction in the blood glucose level ($P \leq 0.05$). The percentage reduction obtained with treatment with watermelon seed oil (50.5 %) was second to the percentage reduction observed with metformin; a standard drug for treatment of diabetes mellitus (71.67 %). Hence, watermelon seed oil has a potential to control postprandial glucose rise in diabetic subject than the other oil and powders used in this study, possibly due to its richness in linoleic acid.

4.2.6 Serum lipoprotein of the animals treated with watermelon and pawpaw seed oil and powder

The liver is an insulin-dependent tissue that functions in glucose and lipid metabolism. An increase in the serum levels of lipids indicates a dysfunction in the liver. Abnormalities in lipids and lipoproteins play a significant role in the pathogenesis and progression of cardiovascular diseases (Chrysohoou *et al.*, 2004). Alloxan- induced diabetes increases triglycerides and LDL-cholesterol in the plasma (Pari and Saravanan, 2002). In insulin- deficient diabetes, the concentration of serum free fatty acids is elevated due to the outflow of fats from fat depots and is then converted into phospholipids and cholesterol in the liver. The diabetic untreated rats had a significantly elevated LDL level and a low HDL level ($P \leq 0.05$). The HDL level in the experimental animals treated with watermelon seed oil was significantly higher ($P \leq 0.05$) than what was observed the other experimental groups. This study showed that watermelon seed oil has more effect than other treatments on the lipid profiles of the rats by lowering the LDL-cholesterol and increasing the HDL-cholesterol, thus reducing liver damage induced by diabetes mellitus which correlates with the report of Altas *et al.,* 2011. The significant reduction in the level of these lipoproteins could imply that repeatedly consuming watermelon seed oil could reduce 3-hydroxyl-3-methylglutaryl coA (HMG CoA) reductase; a rate-limiting enzyme in the biosynthesis of cholesterol (Okediran *et al.,* 2015). These findings are in concert with those reported by Francis *et al.,* (2019) from experimental animals fed with a diet supplemented with melon seed oil. Random clinical trials have shown that substituting saturated fats with linoleic acids reduces the amount of LDL-cholesterol. This implies that watermelon seed oil (having a high amount of linoleic acid) plays a significant role in reducing bad cholesterol levels. Hence, watermelon seed oil might be considered as a substitute to drugs in combating complications arising from diabetes mellitus.

4.2.7 Creatinine level of the animals treated with watermelon and pawpaw seed oil and powder

The kidney is one of the organs affected by diabetes mellitus, rendering it ineffective in clearing creatinine and thus elevating the level of creatinine in the blood (Harita *et al*., 2009; Traynor *et al*., 2006). The findings of this study revealed that the creatinine level in the negative control diabetic rats was higher than the other treatment groups. Upon treatment, the level of creatinine reduced significantly at $P \leq 0.05$. The reduction was most significant with watermelon seed oil, which is comparable to that observed when metformin was used. This could imply that the seed oil improved the rate of glomerular filtration by the kidney.

4.2.8 Hematological parameters of the animals treated with watermelon and pawpaw seed oil and powder

Low concentrations of hemoglobin in diabetic patients is associated with a more rapid decrease in glomerular filtration, while the reduction in packed cell volume (PCV) could be due to an increase in the enzymatic glycosylation of the red blood cell proteins, thus disrupting the integrity of the red blood cell membrane thereby resulting in the hemolysis of the red blood cells. The treatment options, particularly watermelon seed oil significantly increased the levels of these hematological parameters at $P \leq 0.05$.

4.2.9 Liver function indices of the animals treated with watermelon and pawpaw seed oil and powder

Alanine transferase (ALT) is a liver- specific enzyme than aspartate transferase (AST), but the latter is more particular about the integrity of the hepatocytes (Thapa and Anuj, 2007). The concentration of these enzymes in the blood is an indicator of hepatocellular damage which is a characteristic of diabetes mellitus. The level of alkaline phosphatase did not increase significantly in the treatment groups which implied that there was no liver damage. In contrast, ALT and AST significantly decreased ($P \leq 0.05$) in the watermelon seed oil group compared with other groups. This result contradicts the findings of Temitope *et al*., (2017) who reported that the oral administration of watermelon seed did not alter liver function indices. It is therefore safe to say that watermelon seed oil should be subjected to further toxicological studies for its use and safety for human consumption.

4.2.10 Body weight of the animals treated with watermelon and pawpaw seed oil and powder

Animals that are diabetic are known to undergo a significant decrease in body weight which is also part of the clinical features of diabetes (Abou- seif and Youssef, 2004). The result obtained showed that there was a significant increase in weight of the diabetic rats as treatment commenced ($P \leq 0.05$). Ediangbe *et al*., (2010) demonstrated a similar pattern in rats orally administered with melon seed oil. This study therefore implies that consuming these seed oils can be used to effectively utilize blood glucose.

4.2.11 Histological examination of the kidney and liver of the animals treated with watermelon seed oil

The process of inducing diabetes through alloxan results in the development of high levels of reactive oxygen species (ROS) that destroy the pancreatic β- cells. It accumulates after administration in the beta cells, where it is selectively transported intracellularly by the type 2 glucose transporter (GLUT 2) resulting in DNA alkylation and loss of cellular functions (Szkudelski, 2001). Several studies have reported that increased blood glucose levels elicits the production of proinflammatory cytokines that contribute to considerable pathology associated with diabetes mellitus and cell death (Adam *et al*., 2016).

Inflammation and oxidation both form a malicious series of biological events that lead to tissue damage. Signs of tissue oxidative injuries and inflammation were observed when the liver and kidney of the diabetic animals were examined. Plate II to VII below show the photomicrograph of the liver and kidney tissue of the untreated diabetic control group, positive control group and the group given watermelon seed oil. It showed that the liver tissue of the untreated diabetic rats has a preserved architecture composed of normal portal tracts and central vein, which confirms the result of the alkaline phosphatase (ALP) that indicated that there was no liver damage. However, inflamed hepatocytes was observed. The animal group treated with watermelon seed oil attenuated the hepatic inflammation similar to the group treated with metformin, the standard drug for treating diabetes mellitus. The kidney tissues of the untreated rat showed renal tissue with distorted glomeruli and capsular space, as well as necrosis of the nephrocytes. The positive control group (treated with metformin) and those treated with watermelon seed oil showed renal tissues with preserved architecture composed of normal glomeruli, tubules and interstitium. There were no features of acute or chronic damage to the renal tissues.

It is reasonable that the process of improving pancreatic β- cell function with watermelon seed oil might have occurred through increased free radical scavenging. This could also have been accomplished by the increased presence of unsaturated fatty acid in the sarcolemma following supplementation with polyunsaturated fatty acid (Carrasquilla *et al*., 2019). These fatty acids are known to be able to reduce blood glucose levels by delaying the absorption of glucose. Water melon seed oil is a highly unsaturated oil (having a high level of linoleic acid) hence, capable of regulating glucose levels (Tortosa- Caparros *et al*., 2017)

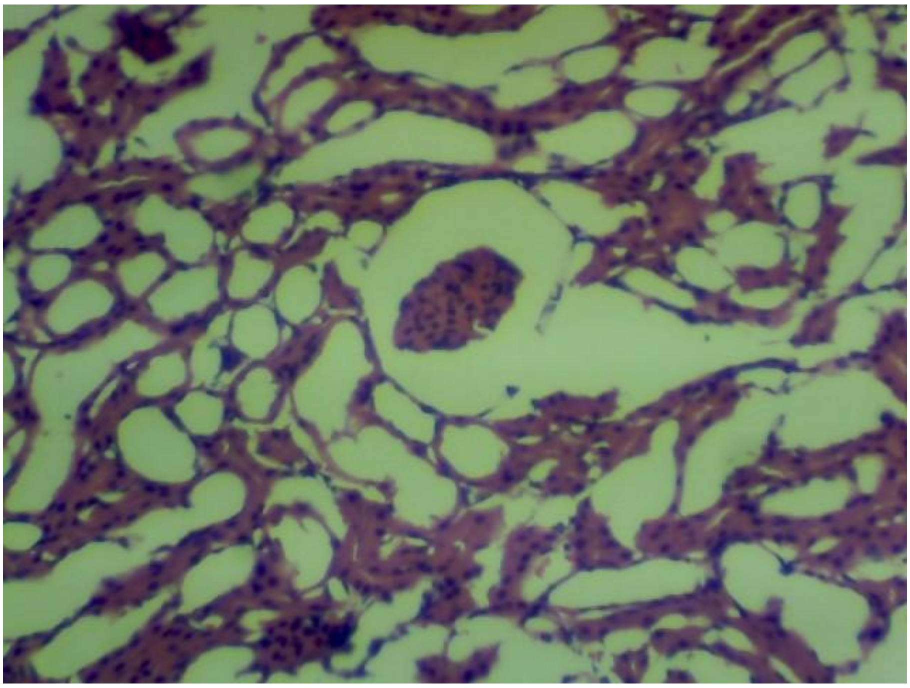

Plate II: Kidney of the rat treated with metformin (positive control)

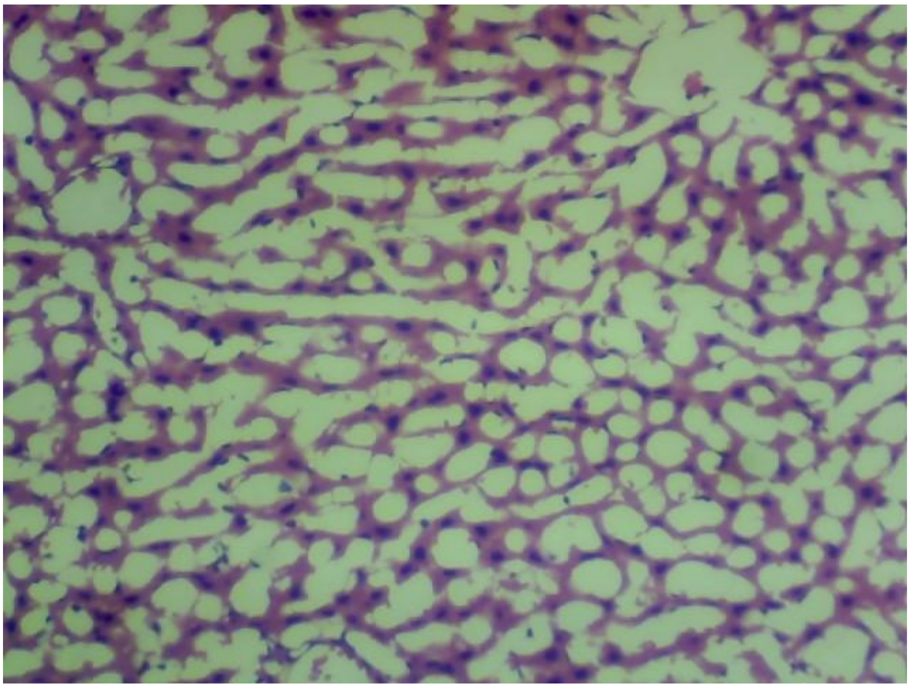

Plate III: Liver tissue of rats treated with metformin (positive control)

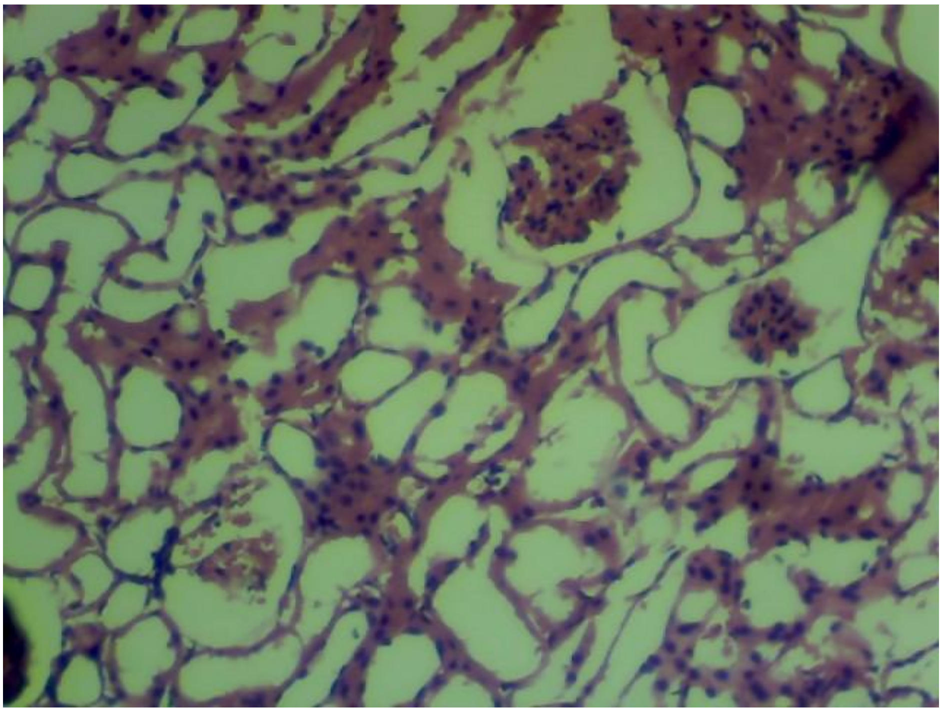

Plate IV: Kidney tissue of rats treated with watermelon seed oil

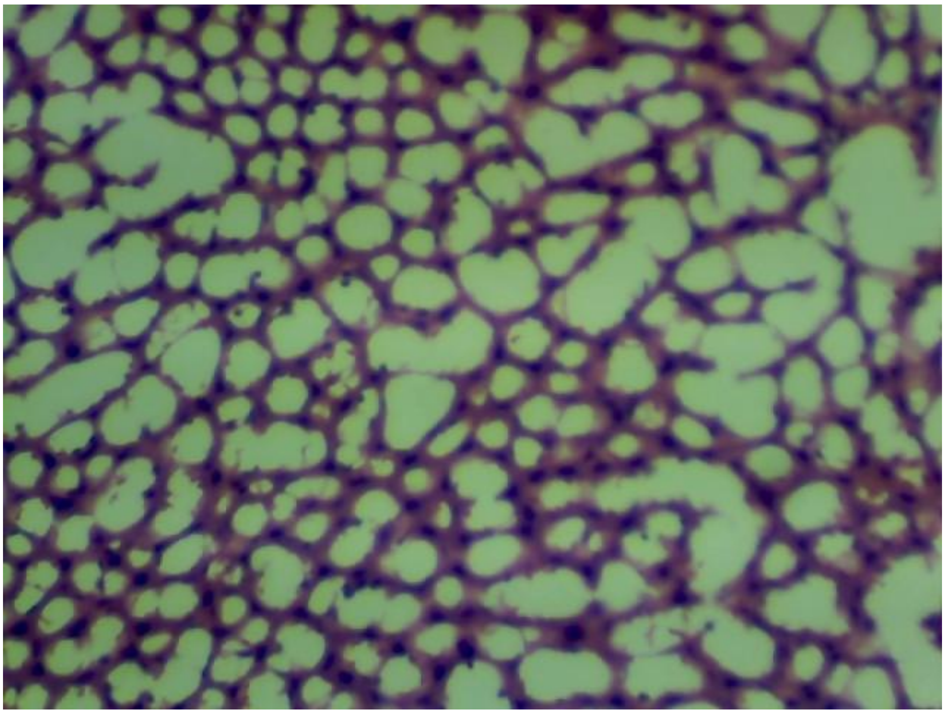

Plate V: Kidney tissue of rats treated with watermelon seed oil

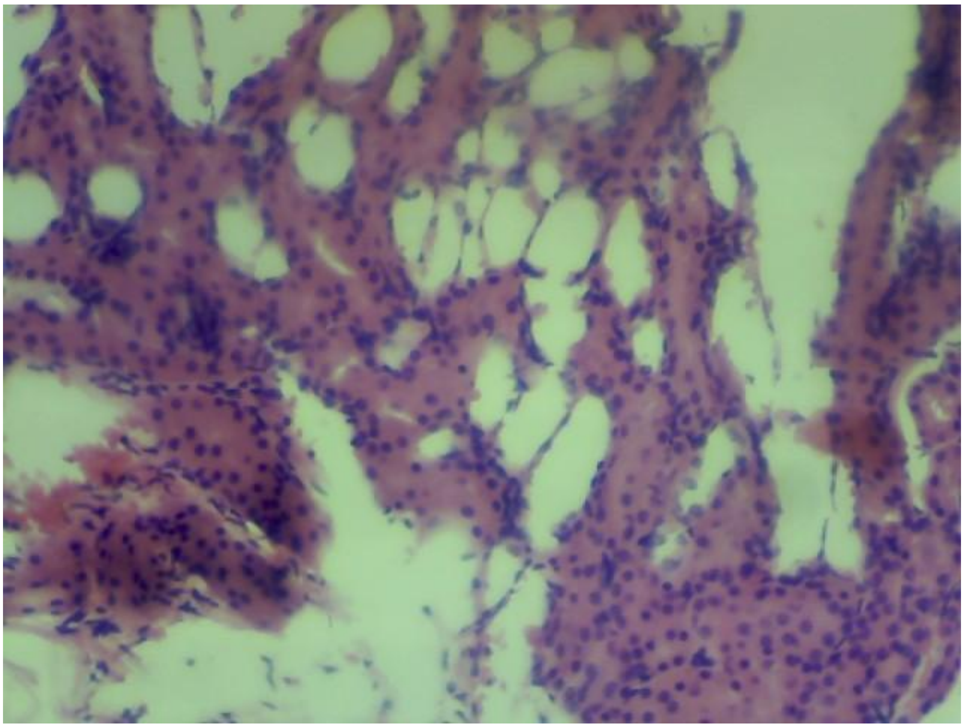

Plate VI: Kidney tissue of the untreated diabetic rats (negative control)

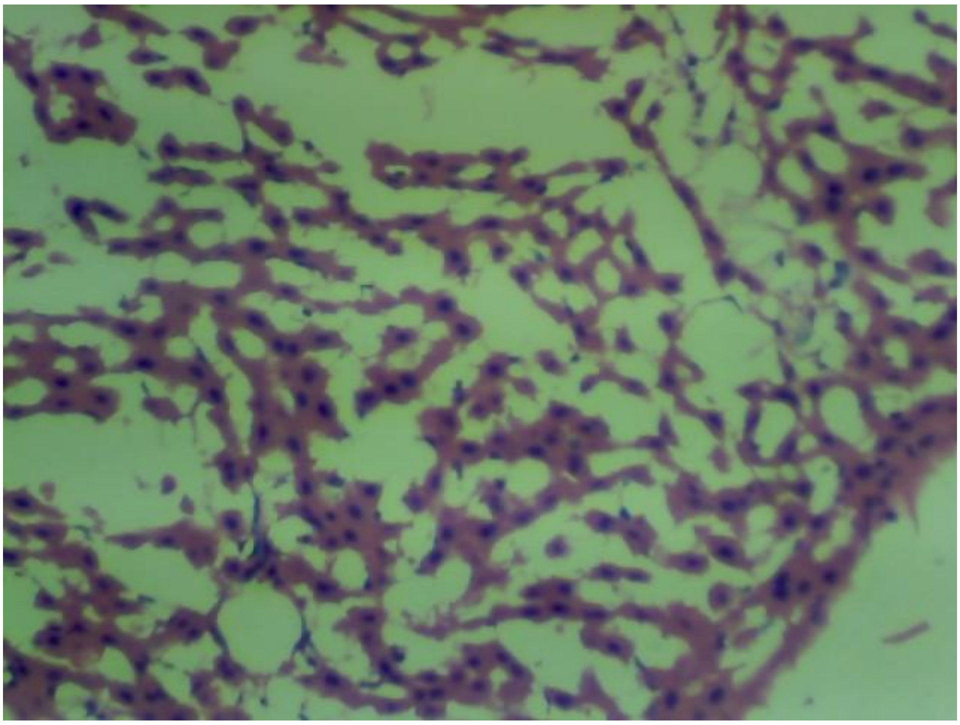

Plate VII: Liver tissue of the untreated diabetic rats (negative control)

CHAPTER FIVE

5. 0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It can be concluded from this study that;

(a) Although the induction of diabetes mellitus with alloxan presented an increase in blood glucose, serum alanine transferase, serum aspartate transferase, serum alkaline phosphatase, low density lipoprotein, creatinine levels, and a decrease in body weight, high density lipoprotein, packed cell volume and hemoglobin levels, these were reversed by the administration of the treatments (watermelon seed oil, pawpaw seed oil, watermelon seed powder and pawpaw seed powder).

(b) Watermelon oil treatment gave a more significant antidiabetic effect than watermelon seed powders, pawpaw seed oils and powders, closely related with the results observed when metformin was used for treatment.

(c) An inclusion of these treatments in diets can help improve the treatment option of diabetic subjects.

5.2 Recommendations

It is recommended that further studies should be carried out on:

i. exploring the seed oils for the formulation of suitable therapeutic agents.

ii. dose-dependent response and safe duration of consumption of the seed oils in diabetic subjects.

iii. The watermelon and pawpaw seed oils be used as substitutes or complements of other consumable oils on a large scale to reduce the cost incurred on other oil sources since the seeds are cheap and readily available.

5.3 Contribution of Research to Knowledge

This research work on the antidiabetic effect of watermelon and pawpaw seed powders and oils in alloxan- induced diabetic rats has identified that these widely available but underutilized seeds can be exploited as nutraceuticals in the treatment or prevention of diabetes mellitus. This, it achieved by:

(a) **Reducing the fasting blood glucose**: the increased blood glucose levels of the test animals reduced significantly as the treatment progressed. This was especially noticeable with the group that received the watermelon seed oil which gave a percentage reduction of 50.5 %, comparable to the group that received metformin (71.67 %).

(b) **Reducing the level of LDL-cholesterol and increasing the level of HDL-cholesterol**: these serum lipoproteins increase (LDL) or reduce (HDL) to indicate a dysfunction in the liver. However, there levels in the serum of the test animals were reversed upon treatment with the watermelon and pawpaw seed powders and oils, especially with the group given watermelon seed oil.

(c) **Reducing the creatinine level**: serum creatinine level was reduced as treatment progressed, thus highlighting that the treatments increased glomerular filtration rate in the kidney of the diabetic animals.

(d) **Increasing the level of packed cell volume (PCV) and hemoglobin (Hb)**: these hematological parameters were increased significantly in the diabetic animals

(e) **Reducing the level of serum aspartate transferase (AST), alanine transferase (ALT) and alkaline phosphatase (ALP)**: the treatments used in this study, particular watermelon seed oil, reduced the elevated levels of these enzymes.

(f) **Increasing the body weight of the alloxan – induced diabetic rats**: as the treatment progressed, there was a noticeable increase in the body weight of the diabetic rats, which could be attributed to the ability of these treatments to induce effective utilization of body glucose.

(g) The histological examination of the kidney and liver tissues of the animals treated with watermelon seed oil (which gave a most profound treatment among the treatment options) revealed that there was a reversal in the damaging effect of diabetes to these organs, comparable to metformin.

REFERENCES

A. O. A. C. (1990). Offcial Methods of Analysis, Association of Official Analytical Chemists, 15th Edition, Volume 2. Washington D. C., USA.

Abdelhamid, A. S., Martin, N., Bridges, C., Brainard, J. S., Wang, x., Brown, T. J., Hanson, S., Jimoh, O. F., Ajabnor, S. M., Deane, K. H., Song, F. & Hooper, L. (2018). Polyunsatuirated fatty acids for the primary and secondary prevention of cardiovascular disease. *Cochrane Database of Systematic Reviews*, 7(7), 012345.

Abdel- Moneim, A., Yousef, A. I., El-Twab, S. M. A., Reheim, E. S. A. & Ashour, M. B. (2017). Gallic acid and 0-coumaric acid attenuate Type 2 Diabetes- induced neurodegeneration in Rats. *Metabolic Brain Disease*, 32(4), 1279- 1286.

Abou- seif, M. A., & Youssef, A. A. (2004). Evaluation of some biochemical changes in diabetic patients. *International Journal of Clinical Chemistry*, 346, 161- 170.

Adam, S. H., Giribabu, N., Rao, P. V., Sayem, A. S., Arya, A., Panichayupakaranant, P., Korla, P. K. & Salleh, N. (2016). Rhinacanthin C ameliorates hyperglycaemia, hyperlipidemia and pancreatic destruction in streptozotocin-nicotinamide induced adult male diabetic rats. *European Journal of Pharmacology*, 771, 173- 190.

Adam, S., Mcintyre, H. D., Tsoi, K. Y., Kapur, A., Ma, R. C., Dias, S., Okong, P., Hod, M., Poon, L. C., Smith, G. N., Bergman, L., Algurjia, E., O'Brien, P., Medina, V. P., Maxwell, C. V., Regan, L., Rosser, M. L., Jacobsson, B., Hanson, M. A., O'Reilly, S. L., & McAuliffe, F. M. (2023). Pregnancy as an opportunity to prevent type 2 diabetes mellitus, FIGO Bests Practice Advice. *International Journal of Gynecology and Obstetrics*, 160(1), 56- 57.

Adefolalu, F. S., Salawa, J. S., Gara, T. Y. & Abubakar, A. N. (2019). Hypoglycemic and hypolipidemic effect of methanol extract of *Hibiscus sabdariffa* seed in alloxan induced diabetic albino Rats. *Nigerian Journal of Basic and Applied Sciences*, 27(2), 151- 156.

Adesuyi, A. O. &Ipinmoroti, K. O. (2011). The nutritional and functional properties of the seed flour of three varieties of *Carica papaya*. *Current Research in Chemistry*, 3(1), 70-75.

Afolabi, I. S., Marcus, G. D., Olanrewaju, T. O. & Chizea, V. (2011). Biochemical effect of some food processing methods on the health promoting properties of under- utilized *Carica papaya* seed. *Journal of Natural Products*, 4, 17-24.

Afolabi, I. S. & Ofobrukweta, K. (2011). Physicochemical and nutritional qualities of *Carica papaya* seed products. *Journal of Medicinal Plants Research*, 5(14), 3113-3117.

Ahlquist, E., Storm, P., Karajamaki, A., Martinell, M., Dorkhan, M., Carlsson, A., Vikman, P., Prashard, R. B., Aly, D. M., Almgren, P., Wessman, Y., Shaat, N., Spegel, P., Mudler, H., Lindholm, E., Melander, O., Hansson, O., Malmqvist, U., Lernmark, A., Lahti, K., Forsen, T., Tuomi, T., Rosengren, A. H. & Groop, L. (2018). Novel subgroups of adult- onset diabetes and their association with outcomes, a data- driven cluster analysis of six variables. *Lancet Diabetes Endocrinology*, 6, 361- 368.

Aladekoyi, G., Karimu, A. O. & Jide, A. O. (2016). Physico- chemical and antibacterial evaluation of oil extracted from ripe and unripe pawpaw seed (*Carica papaya*). *Research Journal of Food Science and Nutrition*, 1, 10 – 14.

AlAli, M., Alqubaisy, M., Aljaafari, M. N., AlAli, A. O., Baqais, L., Molouki, A., Abushelaibi, A., Lai, K. S. & Lim, S. H. E. (2021). Nutraceuticals, transformation of conventional foods into health promoters/ disease preventers and safety considerations. *Molecules*, 26, 2540.

Alemika, T. E., Ojerinde, O. S., Samali, A., Mustapha, B. K. & Gamaniel, K. S. (2017). Nutraceutical potentials of nigerian grown *Citrullus lanatus* (Watermelon) seed. *Journal of Pharmacy and Bioresources, 14*, 253–259.

Alkhatib, A., Tsang, C., Tiss, A., Bahorun, T., Arefanian, H., Barake, R. & Tuomilehto, J. (2017). Functional Foods and Lifestyle Approaches for Diabetes Prevention and Management. *Nutrients*, 9(12), 1310.

Almanza- Aguilera, E., Hernaez, A., Corella, D., Sanllorente, A., Rose, E. & Portoles, O. (2020). Cancer signalling transcriptome is upregulated in type 2 diabetes mellitus. *Journal of Clinical Medicine*, 10, 85.

Alqathama, A., Alluhiabi, G., Baghdadi, H., Aljahani, L., Khan, O., Jabal, S., Makkawi, S. & Alhomoud, F. (2019). Herbal medicine from the perspective of type ii diabetic patients and physicians. What is the relationship? BMC Complement. *Journal of Medical Internet*, 20, 65.

Altas, S., Kizil, A., Kizil, M., Ketani, A. & Haris, P. C. (2011). Protective effect of *Diyarbakir* watermelon juice on carbon tetrachloride induced toxicity in Rats. *Food and Chemical Toxicology*, 49, 2433- 2438.

American Diabetes Association. (2018). Economic costs of diabetes in the US in 2017. *Diabetes Care*, 41, 917- 928.

Angelova- Romova, M., Simeonova, Z. B., Petkova, Z. Y., Antova, G. & Teneva, O. (2019). Lipid composition of watermelon seed oil. *Bulgarian Chemical Communications*, 51, 268–272.

Anthony, P. & Vijayan, R. (2021). Bioactive peptides as potential nutraceuticals for diabetes therapy, a comprehensive review. *International Journal of Molecular Science*, 22, 9059.

Aravind, G., Bhowmik, D.S.D. & Harish, G. (2013). Traditional and medicinal uses of *Carica papaya*. *Journal of Medicinal Plants Studies*, 1, 7–15.

Ariyike, O. A., Hezekiah, A. G., Obajimi, A. O. & Olusola, O.O. (2019). Extraction and GC-MS analysis of fatty acids in commonly consumed melon seed varieties in Nigeria. *GSC Biological and Pharmaceutical Sciences*, 7, 77- 92.

Atolani, O., Omere, J., Otuechere, C. A. & Adewuyi, A. (2012). Antioxidant and cytotoxicity effects of seed oils from edible fruits. *Journal of Acute Disease*, 5, 130- 134.

Autherson, P. B., Nalla, B. T., Srinivasan, K., Mehar, K. & Devarajan, Y. (2021). Biofuel production from novel prunus domestica kernel oil, process optimization technique. *Biomass Conversion and Biorefinery,* 10, 1551- 1555.

Azizi, S., Mahdavi, R., Vaghef-Mehrabany, E., Maleki, V., Karamzad, N. & Ebrahimi-Mameghani, M. (2020). Potential roles of citrulline and watermelon extract on metabolic and inflammatory variables in diabetes mellitus, current evidence and future directions, a systematic review. *Clinical and Experimental Pharmacology and Physiology*, *47*, 187–198.

Baker, T. P., Corwin, B. & Jett, L. W. (2012). Watermelon bacterial fruit blotch. University of Missouri Extension Library.

Bang, H., Kim, S., Leskovar, D. & King, S. (2007). Development of a co-dominant CAPS marker for allelic selection between canary yellow and red watermelon based on SNP in lycopene β-cyclase (LCYB) gene. *Molecular Breeding*, 20, 63–72.

Barosso, P. T. W., De Carvalho, P. P., Rocha, T. B., Pessoa, F. I. P, Azevedo, D. A. & Mendes, M. F. (2016). Evaluation of the composition of *Carica papaya* L. seed oil extracted with supercritical CO_2. *Biotechnology Reports*, 11, 110–116.

Becraft, A. R., Sturm, M. L., Mendez, R. L., Park, S. H., Lee, S. I. & Shay, N. F. (2020). Intake of watermelon or its by- products alters glucose metabolism, the microbiome, and hepatic proinflammatory metabolites in high-fat–fed male C57bl/6 J Mice. *Journal of Nutrition*, 150, 434–442.

BhanuTeja, N., Mohammed, A. H. M., Surrendran, G., Rajeshwaran, M., & Alagumurthi, N., (2020). Investigations of performance and emission characteristics in diesel engine fueled with hemp oil methyl ester. *International Journal of Ambient Energy*, 11, 1-7.

Bowen, K. J., Krist- Etherton, P. M., Shearer, G. C., West, S. G., Reddivari, L. & Jones, P. J. H. (2017). Oleic acid derived oleoylethanolamide, a nutritional science perspective. *Progress in Lipid Research*, 67, 1- 15.

Briones- Labarca, V., Plaza- Morales, M., Giovagnoli- Vicuna, C. & Jamett, F. (2015). High hydrostatic pressure and ultrasound extractions of antioxidant compounds, sulforane and fatty acids from chilean papaya (*Vasconcellea pubescens*) seeds. Effects of extraction conditions and methods. *LWT Food Science and Technology*, 60(1), 525- 534.

Calderon, G., Juarez, O., Hernandez, G., Punzo, S. & De la Cruz, Z. (2017). Oxidative stress and diabetic retinopathy, development and treatment. *Eye*, 31, 1122.

Campos, J. R., Severino, P., Ferreira, C. S., Zielinska, A., Santini, A., Souto, S. B. & Souto, E. B. (2019). Linseed essential oil–source of lipids as active ingredients for pharmaceuticals and nutraceuticals. *Current Medicinal Chemistr*y, 12, 1-2.

Carrasquilla, G.D., Jakupovic, H. & Kilpelainen, T. O. (2019). Dietary fat and the genetic risk of type 2 diabetes. *Current Diabetes Reports*, 19, 109.

Carrillo, C., Cavia, M. M. & Alonso-torre, S. (2012). Role of oleic acid in immune system; mechanism of action; a review. *Nutricion Hospitalaria*, 27(4), 978-990.

Cena, H. & Calder, P. C. (2020). Defining a healthy diet, evidence for the role of contemporary dietary patterns in health and disease. *Nutrients*, 12(2), 334.

Chakrabarty, N., Mourin, M. M., Islam, N., Haque, A. R., Akter, S., Siddique, A. A. & Sarker, M. (2020). Assessment of the potential of watermelon rind powder for the value addition of noodles. *Journal of Biosystems Engineering*, 45(4), 223–231.

Chatterjee, S., Khunti, K., & Davies, M. J. (2017). Type 2 diabetes. *The Lancet*, 389, 2239–2251.

Chen, C., Yang, Y., Yu, X., Hu, S. & Shao. S. (2017). Association between Omega- 3 fatty acids consumption and the risk of type 2 diabetes, a meta- analysis of cohort studies. *Journal of Diabetes Investigations*, 8(4), 480- 488.

Cho, N. H., Shaw, J. E., Karuranga, S., Huang, Y., da Rocha- Fernandes, J. D., Ohlrogge, A. W. & Malanda, B. (2018). IDF Diabetes Atlas, Global estimates of diabetes prevalence for 2017 and projections for 2045. *Diabetes Research and Clinical Practice*, 138, 271- 281.

Chauhan, B., Kumar, G., Kalam, N. & Ansari, S. H. (2013). Current concepts and prospects of herbal nutraceutical, a review. *Journal of Advanced Pharmaceutical Technology Resource*, 4, 4.

Chrysohoou, C., Panagiotakos, D. B., Pitasovos, C., Kosma, K., Barbetas, J., Karagiora, M., Ladis, I. & Stefanadis, C. (2004). Distribution of serum lipids and lipoproteins in patients with beta thalassaemia major, an epidermiological study in young adults from Greece. *Lipids in Health and Disease*, 3, 3.

Clarke, S. D. (2004). The multidimensional regulation of gene expression by fatty acids, polyunsaturated fat as nutrient sensors. *Current Opinion in Lipidology*, 15, 13-18.

Cole. J. B. & Florez, J. C. (2020). Genetics of diabetes mellitus and diabetes complications. *Nature Reviews Nephrology*, 16(7), 337- 390.

Dabelea, D., Mayer- Davis, E. J., Saydah, S., Imperatore, G., Linder, B., Divers, J., Bell, R., Badaru, A., Talton, J. W., Crume, T., Liese, A. D., Merchant, A. T., Lawrence, J. M., Reynolds, K., Dolan, L., Liu, L. L. & Hamman, R. F. (2009). Prevalence of type 1 and type 2 diabetes among children and adolescents from 2001 to 2009. *JAMA*, 311(17), 1778- 1786.

Daliu, P., Santini, A. & Novellino, E. (2018). A decade of nutraceutical patents, Where are we now in 2018? *Expert Opinion on Therapeutic Patents*. 28, 875- 882.

Dall, T. M., Yang, W., Halder, P., Pang, B., Massoudi, M., Wintfeld, N., Semilla, A. P., Franz, J. & Hogan, P. F. (2012). The economic burden of elevated blood glucose levels in 2012, diagnosed and undiagnosed diabetes, gestational diabetes and prediabetes. *Diabetes Care*, 37, 3172- 3179.

Dammak, M. I., Salem, Y. B., Belaid, A., Mansour, H. B., Hammami, S., Le Cerf, D. & Majdoub, H. (2019). Partial characterization and antitumor activity of a polysaccharide isolated from watermelon rinds. *International Journal of Biological Macromolecules*, 136, 632– 641.

Dangarembizi, R., Chivandi, E., Dawood, S., Erlwanger, K., Gundidza, M., Magwa, M., Muredz, P. & Samie, A. (2015). The fatty acid composition and physicochemical properties of the underutilized *Cassia abbrevieta* seed oil. *Pakistan Journal of Pharmaceutical Sciences*, 28(3), 1005- 1008.

Darmanto, Y. S. Kurnaishi, R. A., Romadhon, R., Riyadi, P. H. & Anggraeni, N. (2022). Characteristic of analog rice made from Arrowroot (*Maranta arundinacease*) and Seaweed (*Gracillaria verrucossa*) flour fortified with fish collagen. *Food Research*, 6(5), 370- 379.

De Conto, L. C., Gragnani, M. A. L., Maus, D., Ambiel, H. C., Chiu, M. C., Grimaldi, R. and Goncalves, L. A. G. (2011). Characterization of crude watermelon seed oil by two different extraction methods. *Journal of the American Oil Chemists' Society*, 88, 1709- 1714.

Durazzo, A., Lucarini, M., Novellino, E., Souto, E. B., Daliu, P. & Santini, A. (2019). *Abelmoschus esculentus* (*L*.), bioactive components beneficial properties-focused on antidiabetic role—for sustainable health applications. *Molecules*, 24(1), 38.

Eddouks, M., Jouad, H., Maghrani, M., Lemhadri, A. & Burcelin, R. (2003). Inhibition of endogeneous glucose production accounts for hypoglycemic effect of *Spergularia purpurea* in Streptozotocin Mice. *Phytomedicine*, 10, 594- 599.

Ediangbe, G. O., Ojieh, G. C., Idonije, B. O. & Oluba, O. M. (2010). Palm and egusi melon oils lower serum and liver lipid profile and improve antioxidant activity in Rats fed a high fat diet. *International Journal of Medicine and Medical Sciences*, 3(2011), 47-51.

Egbuonu, A. C. C., Aguguesi, R.S., Ojunkwu, O., Onyenmeri, F. & Uzuegbu, U. (2015). Some physicochemical properties of the petroleum ether extracted watermelon (*Citrullus lanatus*) seed oil. *Asian Journal of Scientific Research,* 8, 519-525.

Ejikeme, P. M., Obasi, N. L. & Egbuonu, A. C. C. (2010). Physicochemical and toxicological studies of Afzelia africana seed and oil. *African Journal of Biotechnology*, 9, 1959- 1963.

Eke, R., Ejiofor, E., Oyedemi, S., Onoja, S. & Omeh, N. (2021). Evaluation of nutritional composition of *Citrullus lanatus* Linn (Watermelon) seed and biochemical assessment of the seed oil in Rats. *Journal of Food Biochemistry,* 10, 13.

Elvianto, D. D. & Erni, J. S. (2017). Rapid *in situ* transesterification of Papaya seeds to biodiesel with the aid of CO solvent. *International Journal of Renewable Energy Research*, 7, 1.

Enemor, V., Oguazu, C., Odiakosa, A. & Okafor, S. (2019). Evaluation of the medicinal properties and possible nutrient composition of *Citrullus lanatus* (Watermelon) seeds. *Research Journal of Medicinal Plant*, 13, 129–135.

Esparza, I., Jim´Enez-Moreno, N., Bimbela, F., Ancín-Azpilicueta, C., & Gandía, L. M. (2020). Fruit and vegetable waste management, conventional and emerging approaches. *Journal of Environmental Management*, 265, 110- 510.

Essien, E. A. & Eddouk, U. M. (2013). Chemical analysis of *Citrullus lanatus* seed oil obtained from Southern Nigeria. *Organic Chemistry*, 54, 12700- 12703.

Feng, X., Ameer, K., Ramachandraiah, K., Wu, Z., Huo, N., Bai, x., Nie W. & Jiang, G. (2022). Effect of Papaya (*Carica papaya*) seed supplementation on quality attributes, adsorption capacities, and in vitro starch digestibility of wheat bread. *Journal of Food Measurement and Characterization*, 16(4), 3226- 3239.

Forrester, S. J., Kikuchi, D. S., Hernandes, M. S., u, Q., & Griendling, K. K. (2018). Reactive oxygen species in metabolic and inflammatory signaling. *Circulation Research*, 122, 877- 902.

Francis, D., Ani, C., Nworgu, C., Pamela, O., Uzoma, I., Uzoigwe, J., Ugwu, P., Pamela, A. & Daniel, N. (2019). The effect of ethanolic seed extract of *Citrullus lanatus* (Watermelon) on blood glucose level and lipid profile of diabetic Wistar Rats. *European Journal of Medicinal Plants*, 26(4), 1–6.

Gabriel, A. F., Igwemmar, N. C., Sadam, A. A. & Babalola, S. A. (2018). Characterization of seed oil from *Citrullus lanatus* (Watermelon). *Direct Research Journal of Public Health and Environmental Technology*, 3(2), 34- 40.

Gabriel, A. F., Igwemmar. N. C., Ilodinke, E., Omoniyi, A. O. & Adeyemo, B. (2017). Effect of preservatives on the physico- chemical properties of Watermelon and Soursop fruit blend. *Direct Research Journal of Agriculture and Food Science*, 5 (10), 333-337.

Galit, I., Grosu, A. C., Popa, O. & Babeanu, N. (2020). Extraction and characterization of Watermelon seed oil. *Scientific Bulletin Series F. Biotechnologies*, 24(2), 179- 183.

Golpour, P., Nourbakhsh, M., Mazaherioun, M., Janani, L., Nourbakhsh, M. & Yaghmaei, P. (2020). Improvement of NRF 2 gene expression and antioxidant status in patients with type 2 diabetes mellitus after supplementation with Omega- 3 polyunsaturated fatty acids, a double- blind randomized placebo-controlled clinical trial. *Diabetic Research and Clinical Practice*, 162, 108- 120.

Gornas, P. & Rudzinska, M. (2016). Seeds recovered from industry by- products of nine fruit species with a high potential utility as a source of unconventional oil for biodiesel and cosmetic and pharmaceutical sectors. *Industrial Crops and Products*, 83, 329- 338.

Goya, K., Sumitani, S. U., Kitamura, T., Yamamoto, H., Kurebayashi, S., Saito, H., Houhara, H., Kasayama, S. & Kawase, I. (2004). Peroxisome proliferator activated receptor alpha agonists increase nitric oxide synthase expression in vascular endothelial cells. *Atherosclerosis Thrombosis and Vascular Biology*, 24(4), 659- 663.

Haeusler, R. A., Camastra, S., Astiarraga, B., Nannipieri, M., Anselmino, M. & Ferrannini, E. (2015). Decreased expression of hepatic glucokinase in type 2 diabetes. *Molecular Metabolism*, 4(3), 222-226.

Harita, N., Hayashi, T. & Sato, K. K. (2009). "Lower serum creatinine is a new risk factor of type 2 diabetes, the Kanasi healthcare study". *Diabetes Care*, 32(3), 424- 426.

Hoffbrand, A. V. & Moss, P. A. H. (2011). Introduction to Hematology in, Essential Hematology. 6th Edition, Blackwell Publishing LTD., Oxford, UK.

Hu, M. H. & Ao, Y. (2003). Characteristics of some nutritional composition of melon (*Cucumis melon* hybrid "ChunLi") seeds. *International Journal of Food Science and Technology*, 42(12), 1397- 1401.

International Diabetes Federation. (2019). IDF Diabetes Atlas, 9th Edition, Brussels, Belgium.

Imamura, F., Micha, R., Wu, J. H. Y., de Oliveira Otto, M. C., Otite, F. C., Abioye, A. I. & Mozaffarian, D. (2016). Effects of saturated fat, polyunsaturated fat, monounsaturated fat and carbohydrate on glucose-0 insulin homeosatsis, a systematic review and meta- analysis of randomized controlled feeding trials. *PLoS Medicine*, 13(7), 002087.

Jacob A. G., Etong, D. I. & Tijjani A. (2015). Proximate, mineral and anti- nutritional compositions of Watermelon (*Citrullus lanatus*) seeds. *British Journal of Research*, 2(5), 142-151.

Jacobson, A. M. (2009). Impact of improved glycemic control on quality of life in patients with diabetes. *Endocrine Practice*, 10(6), 502-508.

Jiao, M., Chao, L., Prieto, M., Lu, X., Wu, W., Tang, X., Xiao, J., Simal- Gandara, J., Hu, D. & Li. N. (2022). Biological functions and utilization of different parts of the Papaya, a review. *Food Reviews International*, 58(8), 1- 24.

Johnson, J. T., Iwang, E. U., Hemen, J. T., Odey, M. O., Effiong, E. E. & Eteng, O. E. (2012). Evalution of anti- nutrients contents of Watermelon (*Citrullus lanatus*). *Annals of Biological Research*, 3, 5145- 5150.

Kadiri, O., Olawoye, B., Fawale, O. S. & Adalumo, O. A. (2016). Nutraceutical and antioxidant properties of the seeds, leaves and fruits of *Carica papaya*, potential relevance to human diet, the food industry and the pharmaceutical industry - a review. *Turkish Journal of Agriculture - Food Science and Technology*, 4(12), 1039-1052.

Karrar, E., Sheth, S., Wei, W. & Wang, X. (2019). Gurum (*Citrullus Lanatus* Var. *Colocynthoide*) seed, lipid, amino acid, mineral, proximate, volatile compound, sugar, vitamin composition and functional properties. *Journal of Food Measurement and Characterization, 13*, 2357–2366.

Kjeldahl (1883). New method for determination of nitrogen in organic substances. *Zeitchhrift fur Analitische Chemie*, 22(1), 366- 383.

Kolawole, T., Dapper, D., & Olatunde, O. (2016). Effects of methanolic extract of the rind of *Citrullus lanatus* (Watermelon) in aspirin induced gastric ulceration in male Wistar Rats. *Journal of Medicine and Medical Sciences,* 4.

Kowluru, R. A. & Chan, P. S. (2007). Oxidative stress and diabetic retinopathy, *Experimental Diabetes Research.*

Kumar, N. S. & Devi, S. (2017). The surprising health benefits of Papaya seeds, a review. *Journal of Pharmacognosy and Phytochemistry*, 6(1), 424-429.

Lakhe, P., Chopde, M. & Borikar, M. (2022). Watermelon seed oil- a potential skin hydrating agent. *International Journal of Researches in Biosciences, Agriculture and Technology*, 2(10), 229- 233.

Lebovitz, H. E. (2019). Thiazolidinediones, the forgotten diabetes medications. *Current Diabetes Reports*, 19- 151.

Li, F., Chen, Y., Li, Y., Huang, M. & Zhao, W. (2020). Genopiside alleviates diabetic nephropathy of Mice through AMPK/ SIRT1/ NF- kB pathway. *The European Journal of Pharmacology*, 886, 173- 449.

Lin, X., Xu, Y., Pan, X., Xu, J., Ding, Y., Sun, X., Ren, Y. & Shan. P. F. (2020). Global, regional and national burden and trend of diabetes in 195 countries and territories, an analysis from 1990 to 2025. Scientific Reports, 10, 14790.

Lorke, D. (1983). A new approach to practical acute toxicity testing. *Archives of Toxicology*, 54, 275- 287.

Madhavi, P., Maruthi, R., Kamala, V., Habibur, R. & Chinna, E.M. (2012). Evaluation of anti- inflammatory activity of *Citrullus lanatus* seed oil by In vivo and in vitro models. *International Research Journal of Pharmaceutical and Applied Sciences*, 2, 104- 108.

Makanjuola, O. M. & Makanjuola, J. O. (2018). Proximate and selected mineral composition of ripe Pawpaw (Carica papaya) seeds and skin. *Journal of Scientific and Innovative Research*, 7(3), 75- 77.

Mandel, H., Levy, N., Izkovitch, S. & Korman, S.H. (2005). "Elevated plasma citrulline and arginine due to consumption of *Citrullus vulgaris* (Watermelon)". *Berichte Der Deutschen Chemischen Gesellschaft*, 28 (4), 467–472.

Mariod, A.A., Ahmed, Y. M. & Matthaus, B. (2009). A comparative study of the properties of six Sudanese Cucurbit seeds and seed oils. *Journal of the American Oil Chemists' Society,* 86, 1181- 1188.

Marklund, M., Wu, J. H. Y., Imamura, F., Del Gobbo, L. C., Fretts, A., de Goede, J., Shi, P., Tintle, N. & Wennberg, M. (2019). Cohorts for Heart and Aging Research in Genomic Epidermiology (CHARGE) Fatty Acids and Outcomes Research Consortium (FORCE). Biomarkers of dietary omega- 6 fatty acids and incident cardiovascular disease and mortality. *Circulation*, 139, 2422- 2436.

Maria, G. R. & Giovanni, C. (2019). Nutraceuticals for the treatment of diabetic retinopathy. *Nutrients*, 11, 771.

Martinez, J. A. & Milagro, F. I. (2000). Effects of the oral administration of a β-adrenergic agonist on lipid metabolism in Alloxan- diabetic Rats. *The Journal of Pharmacy and Pharmacology,* 52, 851- 856.

Mathew, T. J., Ndamitso, M. M., Otori, A. A., Shaba, E. Y., Inobeme, A. & Adamu, A. (2014). Proximate and mineral compositions of seeds of some conventional and non-conventional fruits in Niger State, Nigeria. *Academic Research International*, 5(2), 113-118.

Mello, V. D., Zelmanovitz, T., Azevedo, M. J., de Paula, T. P. & Gross, J. L. (2008). Long term effect of a chicken- based diet versus *Enalapril* on Albuminuria in type 2 diabetic patients with Microalbuminuria. *Journal of Renal Nutrition*, 18(5), 440- 447.

Mehra, M., Pasricha, V. & Gupta, R. K. (2015). Estimation of nutritional, phytochemical and antioxidant activity of seeds of Musk Melon (*Cucumis melo*) and Watermelon (*Citrullus lanatus*) and nutritional analysis of their respective oils. *Journal of Pharmacology and Pharmacognosy*, 3(6), 98- 102.

Mensink, R. P., Zock, P. L., Kester, A. D. & Katan, M. B. (2003). Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins, a meta- analysis of 60 controlled trials. *The American Journal of Clinical Nutrition*, 77, 1146- 1155.

Mogotlane, E., Mokwala, P. W. & Mangena, P. (2018). Comparative analysis of the chemical compositions of indigenous Watermelon (*Citrullus lanatus*) seeds from two districts in Limpopo Province, South Africa. *African Journal of Biotechnology*, 17, 1001- 1006.

Mohammad, A., Mohammad, G. R., Nanjappa, A. & Nurun, N. (2019). The potential of utilizing Papaya seed oil and stone fruit Kernel oil as non- edible feedstock for biodiesel production in Australia. *Energy Reports*, 5, 280- 282.

Morais, D. R., Rotta, E. M., & Sargi, S. C. (2017). Proximate composition, mineral contents and fatty acid composition of the different parts and dried peels of tropical fruits cultivated in Brazil. *Journal of the Brazillian Chemical Society*, 28(2), 308- 318.

Nehdi, I. A. Sbihi, H. & Tan, C. P. (2013). Evaluation and characterization of *Citrullus colocynthis* (L.) schrad seed oil, comparison with *Helianthus annus* (Sunflower) seed oil. *Food Chemistry*, 136, 348- 353.

Neuenschwander, M., Barbaresko, J., Pischke, C. R., Iser, N., Beckhaus, J. & Schwingshackl, L. (2020). Intake of dietary fats and fatty acids and the incidence of type 2 diabetes, a systematic review and dose- response meta-analysis of prospective observational medicine. *PLoS Medicine*, 17, 1003347.

Nkoana, D. K., Mashilo, J., Shimeli, H. & Ngwepe, R. M. (2022). Nutritional, phytochemical compositions and natural therapeutic values of Citron Watermelon (*Citirullus lanatus* var. citroides), a review. *South African Journal of Botany*, 145, 65- 77.

Ngwepe, R. M., Mashilo, J. & Shimeli, H. (2019). Progress in genetic improvement of Citron Watermelon (*Citirullus lanatus* var. citroides), a review. *Genetic Resources and Crop Evolution*, 66, 735- 758.

Noorzianna, A. M. Y., Jalaldeen, M. N. M., Bangun, P. N. Kamariah, L. & Hasanah, M. G. (2014). Physic- chemical Characteristics of Papaya (*Carica papaya* L.) Seed Oil of the Hong Kong/ Sekaki Variety. *Journal of Oleo Science*, 63(9), 885- 892.

Nwosu, J. N., Owuamanam, C. I., Omeire, G. C. & Eke, C. C. (2014). Quality parameters of bread produced from substitution of wheat flour with cassava flour using Soybean as an improver. *American Journal of Research Communication*, 2(3), 99- 118.

Nyam, K. L., Tan, C. P., Lai, O. M. & Cheman, Y. B. (2009). Physicochemical properties and bioactive compounds of selected seed oils. *Food Science and Technology*, 42, 1396- 1403.

Okediran, B. S., Olurotimi, A. E., Rahman, S. A., Michael, O. G. & Olukunle, J. O. (2015). Alterations in the lipid profile and liver enzymes of rats treated with monosodium glutamate. *Sokoto Journal of Veterinary Science*, 12, 42- 46.

Okunrobo, O. L., Uwaya, O. J., Imafidon, E. K., Osarumwense, O. P. & Omorodion, E. J. (2012). Quantitative determination, metal analysis and anti- ulcer evaluation of methanol seeds extract of *Citrullus lanatus* Thunb (*Cucurbitaceae*) in Rats. *Asian Pacific Journal of Tropical Disease*, 2(3), 1261- 1265.

Osawa, T. & Kato, Y. (2005). Protective role of antioxidative food factors in oxidative stress caused by hyperglycemia. *Annals of the New York Academy of Sciences*, 1043(1), 440- 451.

Oseni, K., Babatunde, O., Olumide, S. F. & Olusoji, A. A. (2018). Nutraceutical and antioxidant properties of seed leaves and fruits of *Carica papaya*, relevance to human diet, the food industry and pharmaceutical industry. *Turkish Journal of Agriculture- Food Science and Technology*, 4(12), 1039- 1052.

Owoyele, B.V., Adebukola, O.M., Funmilayo, A.A. & Soladoye, A.O. (2008). Anti-inflammatory activities of ethanolic extract of *Carica papaya* leaves. *Inflammopharmacology*, 16,168–173.

Oyagbemi, A. A., Salihu, M., Oguntibeju, O. O., Esterhuyse, A. J. & Farombi, E. O. (2014). Some selected medicinal plants with antidiabetic potentials. *Antioxidant, antidiabetic and human health*, pp 95- 113.

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

Panneerselvam, N., Murugesan, A., Vijayakumar, C. & Subramanaim, D. (2016). Optimization of biodiesel produced from Watermelon (*Citrullus vulgaris*) using batch- type production unit. *Energy Sources, Part A, Recovery, Utilization and Environmental Effects*, 38(16), 2343- 2348.

Pari, L. & Amarnath, S. M. (2004). Antidiabetic activity of *Boorhaavia diffusa* L., effect on hepatic key enzymes in experimental diabetes. *Journal of Ethnopharmacology*, 91, 109- 113.

Pari, L. & Saravanan, G. (2002). Antidiabetic effect of cogent dB, a herbal drug in Alloxan induced diabetes. *Comparative Biochemistry and Physiology*, 131, 19-25.

Parni, B. & Verma, Y. (2014). Biochemical properties in peel, pulp and seeds of *Carica papaya*. *Plant Archives*, 14(1), 565-568.

Patra, A., Abdullah, S. & Pradhan, R. C. (2022). Review on the extraction of bioactive compounds and characterization of fruit industry by- products. *Bioresources and Bioprocessing*, 9(1), 1- 25.

Pearson- Stuttard, J., Buckley, J., Cicek, M. & Gregg, E. W. (2021). The changing nature of mortality and morbidity of patients with diabetes. *Endocrinology and Metabolism Clinics of North America*, 50, 357- 368.

Perdomo, L., Beneit, N., Otero, Y. F., Escribano, O., Diaz- castroverde, S., Gomez- Hernendez, A. & Benito, M. (2015). Protective role of oleic acid against cardiovascular insulin resistance and in the early and late cellular atherosclerotic process. *Cardiovascular Diabetology*, 14, 75.

Peter, A., Stefan, N., Cegan, A., Walenta, M., Wagner, S., Königsrainer, A. & Schleicher, E. (2011). Hepatic glucokinase expression is associated with lipogenesis and fatty liver in humans. *The Journal of Clinical Endocrinology and Metabolism*, 96(7), 1126-1130.

Poitout, V. & Robertson, R. P. (2008). Glucolipotoxicity, fuel excess and beta- cell dysfunction. *Endocrine Reviews*, 28, 351- 366.

Rabrenovic, B. B., Dimic, E. B. & Novakovic, M. M. (2014). The most bioactive components of cold pressed oil from different pumpkin (*Curcurbita pepo* L.) seeds. *Food Science and Technology*, 55(2), 521- 527.

Ravnskjaer, K., Boergesen, M., Rubi, B., Larsen J. K., Nielsen, T., Fridriksson, J., Maechler, P. & Mandrup, S. (2005). Peroxisome Proliferator Activated Receptor Alpha (PPAR alpha) potentiates, whereas PPAR Gamma attenuates, glucose stimulated insulin secretion in pancreatic beta- cells. *Endocrinology*, 146(8), 3266- 3276.

Raziq, B. S., Anwar, F., Mahmood, Z., Shahid, S. A. & Nadeem, R. (2012). Characterization of seed oils from different varieties of Watermelon (*Citrullus lanatus* (Thunb.)) from Pakistan. *Grasas y Aceites*, 63(4), 365- 372.

Renner, S. S., Sousa, A., & Chomicki, G. (2017). Chromosome numbers, sudanese wild forms, and classification of the Watermelon genus *Citrullus*, with 50 names allocated to seven biological species. *Taxon,* 66, 1393–1405.

Rezig, L., Chouaibi, M., Meddeb, W. & Salem, H. (2019). Chemical composition and bioactive compounds of *Cucurbitaceae* seeds, potential sources for new trends of plant oils. *Process Safety and Environment Protection*, 127, 73- 81.

Rezq, A. A. (2017). Antidiabetic activity and antioxidant role of Watermelon (*Citrullus lanatus*) peels in Streptozotocine- induced diabetic Rats. *Egyptian Journal of Nutrition, 32,* 2.

Russo, G. L. (2009). Dietary n- 6 and n- 3 polyunsaturated fatty acids, from Biochemistry to clinical implications in cardiovascular prevention. *Biochemical Pharmacology*, 77, 937- 946.

Saba, S. & Pattan, N. (2022). The potential health benefits of Papaya seeds. *International Journal of Research in Applied Science and Engineering Technology*, 10(1), 45- 98.

Saeedi, P., Petersohn, I., Salpea, P., Malanda, B., Kuranga, S., Unwin, N., Colaguri, S., Guariguata, L., Motala, A. A., & Ogurtsova, K. (2019). Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045, results from the International Diabetes Federation, Diabetes Atlas, 9th Edition. *Diabetes Research and Clinical Practice*, 157, 107843.

Saurabh, N. & Vrish, D. A. (2018). Nutraceuticals in the management of diabetes mellitus. *Pharmacy and Pharmacology International Journal*, 6(2), 114- 120.

Shaw, J. E., Sicree, R. A. & Zimmet, P. Z. (2010). Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Research and Clinical Practice,* 87(1), 4-14.

Syed, H. M., Kunte, S. P., Jadhav, B. A. & Salve, R. V. (2012). Extraction and characterization of *Papaya* seed oil. *International Journal of Applied Physics and Biochemical Resources*, 2(1), 33-43.

Syed, F. Z. (2022). Type 1 diabetes mellitus. *Annals of Internal Medicine*, 175(3), 33-48.

Tabiri, B., Agbenorhevi, J. K., Dreko- Manu, F. & Ompouma, E. (2016). Watermelon seeds as food, nutrient composition, phytochemicals and antioxidant activity. *International Journal of Nutrition and Food Sciences*, 5, 139- 144.

Taiwo, A. A., Agbotaba, M. O., Oyedepo, J. A. & Shobo, M. (2008). Effects of drying methods on properties of Watermelon (*Citrullus lanatus*) seed oil. *African Journal of Food, Agriculture, Nutrition and Development,* 8(4), 130- 139.

Tarun, V. & Yash, P. (2015). A review on medicinal properties of *Carica papaya Linn*. *Asian Pacific Journal of Tropical Diseases*, 5(1), 1-6.

Tasyurek, H. M., Altunbas, H. A., Balci, M. K. & Sanlioglu, S. (2014). Incretins, their physiology and application in the treatment of diabetes mellitus. *Diabetes Metabolism Research and Review*, 30(5), 354- 371.

Telle- Hansen, V. H., Gaundal, L. & Myhrstad, M. C. W. (2019). Polyunsaturated fatty acids and glycemic control in type 2 diabetes. *Nutrients*, 11, 1067.

Temitope, A., Bamidele, O. & Extracts of *Citrullus lanatus* Seeds. *British Journal of Pharmaceutical Research*, 15, 1- 10.

.Thapa, B. R. & Anuj, W. (2007). Liver function tests and interpretation. *Indian Journal of Paediatrics*, 74, 663- 671.

Tomic, D., Shaw, J. E. & Magliano, D. J. (2022). The burden and risks of emerging complications of diabetes mellitus. *Endocrinology*, 18, 525- 539.

Tortosa- Caparros, E., Navas- Carrillo, D., Marin, F. & Orenes- Pinero, E. (2017). Anti-inflammatory effects of omega 3 and omega 6 polyunsaturated fatty acids in cardiovascular disease and metabolic syndrome. *Critical Reviews in Food Science and Nutrition*, 57, 3421- 3429.

Traynor, J., Macher, R., Geddes, C. C. & Fox, J. G. (2006). How to increase renal function in clinical practice. *British Medicine Journal*, 333(7571), 733- 737.

Udler, M.S., Kim, J., Grotthus, M. V., Bornas- Guarch, S., Cole, J. B., Chiou, J. & Anderson, C. D. (2018). Type 2 diabetes genetic loci informed by multitraits associations point to disease mechanisms and subtypes, a soft clustering analysis. *PLOS Medicine*, 15, 1002654.

Verma, S., Varma, R. K. & Singh, S. (2017). Medicinal and pharmacological parts of *Carica papaya*, A Review. *Indian Journal of Drugs*, 5, 88- 93.

Vieira, R., Souto, S. B., Sánchez-López, E., Machado, A. L., Severino, P., Jose, S., Santini, A., Fortuna, A., García, M.L., Silva, A.M. & Souto, E. B. (2019). Sugar- lowering drugs for type 2 diabetes mellitus and metabolic syndrome- review of classical and new compounds, part-I. *Pharmaceuticals*, 12(4), 152.

Vilsboll, T. & Holst, J. J (2004). Incretins, insulin secretion and type 2 diabetes mellitus. *Diabetologia*, 47(3), 357- 366.

Wang, W. & Lo, A. (2018). Diabetic retinopathy, pathophysiology and treatments. *International Journal of Molecular Science*, 19, 1816.

Whiting, D. R., Guariguata, L., Weil, C. & Shaw, J. (2011). IDF Diabetes Atlas, Global estimates of the prevalence of diabetes for 2011 and 2030. *Diabetes Research and Clinical Practice*, 94, 311- 321.

Whitman, M. (2001). Understanding the perceived need for complementary and alternative nutraceuticals, lifestyle issues. *Clinical Journal of Oncology Nursing*, 5(5), 190- 194.

Win, D. T. (2005). Oleic Acid – The anti- breast cancer component in Olive Oil. *AU Journal of Technology*, 9(2), 75-78.

Yanty, N. A. M., Marikkar, J. M. N., Nusantoro, B. P., Long, K. & Ghazali, H. M. (2014). Physico- chemical characteristics of Papaya (*Carica Papaya*) seed oil of the Hong Kong/ Sekaki variety. *Journal of Oleo Science*, 63(9), 885-892.

Ye. J. M., Doyle, P. J., Iglesias, M. A., Watson, D. G., Gooney, G. J. & Kraegen, E. W. (2001). Peroxisome Proliferator Activated Receptor (PPAR) Alpha activation lowers muscle lipids and improves insulin sensitivity in high fat- fed rats, comparison with PPAR gamma activation. *Diabetes*, 50(2), 411- 417.

Yoo, K. S., Bang, H., Lee, E. J., Crosby, K. & Patil, B. S. (2012). Variation of carotenoid, sugar, and ascorbic acid concentrations in watermelon genotypes and genetic analysis. *Horticulture, Environment, and Biotechnology*, 53, 552–560.

Youn, J. Y., Park, H. Y. & Cho, K. H. (2004). Antihyperglycemic activity of *Commelina communis* L., inhibition of alpha- glucosidase. *Diabetes Research and Clincial Practice*, 66, 149- 155.

Youn, S., Munekata, P. E., Gull´on, B., Rocchetti, G., Montesano, D., & Lorenzo, J. M. (2021). *Citrullus lanatus* as source of bioactive components, an up-to-date review. *Trends in Food Science and Technology,* 111, 208–222.

Zhan, Y. Y., Wang, J. H., Tian, X., Feng, S. X., Xue, L. & Tian, L. P. (2016). Protective effects of seed melon extract on CCl_4 induced hepatic fibrosis in Mice. *Journal of Ethnopharmacology*, 193, 531- 537.

Ziyada, A., & Elhussien, S. (2008). Physical and chemical characteristics of *Citrullus lanatus* variant *Colocynthoide* seed oil. *Journal of Physical Science*, 19, 69–75.

APPENDIX A

Percentage Yield for Oil Obtained from Watermelon and Pawpaw Seed

$$\text{Percentage oil yield} = \frac{\text{Weight of extracted oil}}{\text{Weight of seed}} \times 100$$

Watermelon seed

Weight of seed= 320 g

Weight of extracted oil= 124.54 g

Therefore:

$$\frac{125.54}{320} \times 100 = 38.92\ \%$$

Pawpaw seed

Weight of seed= 235 g

Weight of extracted oil= 46.23 g

Therefore:

$$\frac{46.23}{235} \times 100 = 19.72\ \%$$

Plate VIII: Locally fabricated oil extractor