Chapter One

Introduction

1.1. Background to the study

Blood sugar, also known as glucose, is the chief sugar circulating in the bloodstream and serves as the body's main energy source. This vital sugar is derived from the food consumed daily [1]. Most of the food we eat is converted by the body into glucose, which then enters the bloodstream. This rise in blood glucose prompts the pancreas to release insulin. As a key hormone, insulin facilitates the entry of glucose into the body's cells, where it is utilized for energy [2].

Glucose serves as the body's principal energy source and is essential for the proper functioning of all organs and tissues. For optimal health, however, blood glucose concentration must be maintained within a narrow physiological range [3]. Maintaining balanced blood sugar is crucial because levels that fluctuate excessively either too high or too low can result in serious health complications such as diabetes mellitus, cardiovascular disease, and neurological disorders. Consequently, the body employs an intricate regulatory system to ensure glucose homeostasis remains stable [4].

When this regulatory mechanism fails, chronic elevation of blood glucose levels occurs, leading to diabetes mellitus a metabolic disorder that has become a major global health concern. Currently, an estimated 537 million adults aged 20–79 years, representing 10.5% of the world's population within this age group, are living with diabetes. This number is projected to rise sharply to 643 million (11.3%) by 2030 and further to 783 million (12.2%) by 2045, indicating a continuing upward trend. Alarmingly, around 240 million people are believed to have undiagnosed diabetes,

meaning one in two adults with the condition are unaware of their status. Nearly 90% of these undiagnosed cases occur in low and middle-income countries, where access to screening and healthcare remains limited. In regions such as Africa, South East Asia, and the Western Pacific, more than half of people with diabetes do not know they have the disease. Additionally, diabetes also affects younger populations, with over 1.2 million children and adolescents living with type 1 diabetes, more than half (54%) of whom are under 15 years old. These statistics underscore the escalating global burden of diabetes and the urgent need for improved awareness, early detection, and effective management strategies [5].

Within this global context, Nigeria, one of the 48 countries in the International Diabetes Federation (IDF) African region, is facing a similar upward trend. In 2024, the country's total adult population was estimated at 106,054,100, with a 3.0% prevalence rate of diabetes among adults, translating to approximately 2,988,500 adults currently living with the condition. Although this percentage may appear modest, the absolute number represents a significant public health challenge due to Nigeria's large and rapidly growing population. In African region, the number of people with diabetes, currently around 25 million, is expected to rise to about 60 million by 2045. This anticipated increase suggests that Nigeria's diabetes burden will also grow substantially if current trends continue. The relatively high prevalence is attributed to factors such as urbanization, sedentary lifestyles, unhealthy diets, obesity, and limited access to healthcare for early diagnosis and management. Consequently, diabetes represents a major emerging non communicable disease in Nigeria, calling for urgent public health interventions centered on prevention, lifestyle modification, and improved healthcare delivery [6].

Glucose serves as a primary fuel source for the body. This monosaccharide sugar is packed with energy and is broken down within our cells to generate adenosine triphosphate (ATP). ATP

provides small bursts of chemical energy that drive the countless biochemical reactions occurring throughout the body every second [7]. Glucose is derived from the food consumed, primarily starch-rich foods like potatoes, rice, bread, and pasta. Starch, a polysaccharide composed of a chain of glucose molecules, is broken down by digestive enzymes into individual glucose molecules. In the small intestine, glucose is absorbed into the blood and travels to the liver via the hepatic portal vein [8]. Liver cells, known as hepatocytes, take up a large amount of glucose and transform it into glycogen, which is an insoluble glucose polymer. The liver stores this glycogen, and when blood sugar concentrations drop, it can be converted back into glucose. Additionally, other simple dietary sugars like fructose, sucrose, and lactose serve as energy sources that contribute to the generation of ATP [9]. All of the body's cells need to make energy and most can use other fuels such as lipids. However, neurons (nerve cells) rely mostly exclusively on glucose for their energy. This is why the maintenance of blood glucose levels is essential for the proper functioning of the nervous system [10, 11].

The two primary hormones involved in glucose regulation are insulin and glucagon. Insulin is produced by the beta cells of the pancreas, while glucagon is produced by the alpha cells of the pancreas [12]. These hormones work in opposition to each other to regulate blood sugar levels. When blood sugar levels are high, such as after a meal, insulin is released into the bloodstream [13]. Insulin signals to the cells to take up glucose from the bloodstream, where it can be used for energy or stored as glycogen in the liver and muscle tissue. Insulin also signals the liver to stop producing glucose and start storing it as glycogen. Conversely, when blood sugar levels are low, such as during fasting or exercise, glucagon is released into the bloodstream. Glucagon signals to the liver to break down glycogen into glucose and release it into the bloodstream.

This process is known as glycogenolysis. Glucagon also signals the liver to produce glucose from non-carbohydrate sources, such as amino acids and fatty acids. This process is known as gluconeogenesis [14].

Elevated blood glucose is a key component of conditions like metabolic syndrome, impaired glucose tolerance, obesity, and diabetes, which are often linked to the consumption of high glycemic index (GI) foods. Furthermore, evidence from clinical trials demonstrates that adopting a low GI dietary pattern is effective in improving glycemic management in diabetic patients, increasing sensitivity to insulin, and lowering both caloric consumption and body mass [15]. Low glycemic index eating plans have been linked in observational studies to a reduced risk of several major health issues, such as cardiac problems, diabetes, metabolic dysfunction, long-term inflammation, and a possible lower incidence of some cancers [16,17]. The glycemic response a person has after eating (postprandial) can be influenced significantly by how the food is prepared. Various processing methods may change the content and nutritional quality of the food's carbohydrates. When carbohydrates are subjected to methods like boiling, cooking, or heating, their physical structure is modified through processes such as gelatinization and retrogradation. Ultimately, changing the physical structure of a complex carbohydrate modifies the resulting glucose and insulin levels in the blood following consumption [18]. Starch digestibility in both living subjects and laboratory tests is impacted by the type and duration of cooking applied to carbohydrate foods. Specifically, moist heat (boiling, pressure cooking) has been found to yield a faster digestion rate compared to dry heat (roasting) [19]. Treatments that increase starch digestibility are those that encourage significant hydration of the granules while preserving their chemical makeup and organized structural integrity [20].

The consensus indicates a correlation between the extent of a food's physical transformation and the magnitude of the resulting glycemic response. Concurrently, numerous investigations have focused on the utility of natural materials, such as plant-based foods and botanicals, which have been historically utilized in folk medicine for the management of diabetes mellitus (DM) [21,22]. Natural products offer a pharmacologically effective and cost-efficient alternative to synthetic hypoglycemic agents, typically causing fewer or less severe adverse reactions. Additionally, consuming fruits and vegetables has historically played a therapeutic role in managing various metabolic syndromes, including diabetes and obesity [23].

It is crucial to understand how food's composition and preparation influence glycemic response, particularly for staple crops such as plantain that serve as major energy sources in many communities. Their diverse carbohydrate profiles, ranging from resistant starches to rapidly digestible sugars, determine how quickly glucose enters the bloodstream. Historically, before the introduction of modern pharmacological therapies for diabetes mellitus, dietary management was the primary means of controlling blood glucose levels, with plantain commonly emphasized for its moderate glycemic properties [24].

Previous studies have provided substantial insight into the glycemic behavior of plantain. Research consistently shows that ripeness significantly affects glycemic index (GI): unripe plantain contains higher levels of resistant starch and produces a lower GI, whereas ripening increases free sugars and elevates glycemic response [25]. Similarly, studies examining food processing indicate that the cooking method plays a critical role. Boiled unripe plantain is frequently reported to yield the lowest postprandial glucose elevation, whereas frying, due to increased fat absorption and reduced fiber integrity, raises both caloric density and glycemic load [26].

Roasting and steaming produce moderate glycemic effects and fall between boiling and frying in terms of glucose impact [27]. Comparative evaluations of plantain with other staples such as yam, cassava, and cocoyam further underscore its nutritional advantages. Cassava-based meals often produce higher glycemic responses, while plantain, particularly in unripe or minimally processed forms, elicits a more controlled rise in blood glucose [28]. Studies on traditional West African dietary patterns also highlight the value of plantain-based dishes in dietary management strategies for individuals with diabetes or metabolic disorders [29].

Overall, evidence from previous studies emphasizes the importance of considering food maturity, composition, and processing methods when assessing the glycemic impact of staple crops such as plantain. These findings reinforce the need for ongoing research into how local dietary practices can be optimized to improve metabolic health outcomes.

The carbohydrate reserves within plantain are maintained in the form of starch. Furthermore, carbohydrate containing foods exhibit different rates of metabolism and absorption [30]. Certain carbohydrate foods are digested rapidly releasing glucose into the blood stream where as some carbohydrate foods are digested slowly releasing glucose slowly into the blood stream [31]. The glycemic index (GI) scale classifies carbohydrate rich foods based on how quickly they affect blood glucose levels. Foods that prompt a slow and steady release of glucose into the bloodstream are categorized as low GI, with values of 55 or less. Foods that cause a swift spike in blood sugar after eating are considered high GI, having a rating of 70 or more [32].

Eggplant, often referred to as garden egg or scarlet eggplant in West Africa, is deeply rooted in traditional remedies due to its potential health benefits. It is used to manage elevated blood sugar levels and assist in regulating weight in Nigeria [33,34]. This plant-based food is considered beneficial for addressing degenerative conditions, as supported by studies. Additionally, laboratory research on eggplant (Solanum melongena) indicates its significant influence on enzymes linked to diabetic conditions, highlighting its potential role in managing such health issues [35].

1.2. Statement of the Problem

Diabetes mellitus and similar disorders related to blood glucose are becoming more common worldwide, necessitating the exploration of dietary interventions to manage postprandial blood sugar levels effectively. Traditional dietary approaches often focus on individual food items, but limited research has been conducted on the potential synergistic effects of combining specific functional foods. Unripe plantain and garden egg are both known for their low glycemic indices and bioactive compounds that may contribute to blood sugar regulation [1,3,7,9]. However, there is a lack of comprehensive studies investigating their combined effect on postprandial blood sugar levels. This research aimed to address this gap by exploring the synergistic impact of unripe plantain and garden egg extract, providing insights into their potential as a natural dietary strategy for blood glucose management.

1.3. Justification of the Study

The foremost justification for this research is the increasing occurrence of drug induced hypoglycemia resulting from the prolonged use of synthetic antidiabetic medications such as

insulin, sulfonylureas, and biguanides. Although these agents are effective in lowering blood glucose levels, they often lead to undesirable side effects, with hypoglycemia being one of the most critical complications. Severe hypoglycemia can cause dizziness, confusion, of loss consciousness, seizures, or even death if not properly managed. This health risk highlights the urgent need for safer and more natural alternatives capable of maintaining optimal blood glucose control without inducing such life threatening effects.

In view of these limitations, unripe plantain (*Musa paradisiaca*) and garden egg (*Solanum melongena*) have emerged as promising candidates for natural blood glucose regulation. Both are nutrient rich, locally available, and affordable food materials known for their low glycemic indices and abundance of bioactive compounds. These components have been shown to promote glucose homeostasis through mechanisms such as delayed glucose absorption, enhanced insulin sensitivity, and antioxidant activity. Unlike synthetic drugs, these natural foods are less likely to trigger hypoglycemic episodes, making them safer for long-term dietary management of diabetes mellitus.

This study is further justified by the limited scientific research on the combined effects of unripe plantain and garden egg. While their individual antidiabetic properties have been documented, little is known about their synergistic influence when used together. Exploring their joint effect could reveal a stronger and more sustainable blood glucose-lowering action compared to their isolated use. The study's findings could thus provide critical data supporting the incorporation of these foods as functional dietary components in diabetes management plans, particularly for individuals seeking non-pharmacological approaches. By employing a drug induced diabetic wistar rat model, the research aims to simulate the physiological conditions of diabetes and assess postprandial blood glucose responses to the combined flours. This

experimental approach will help establish a scientific basis for understanding the effectiveness and safety of unripe plantain and garden egg in controlling hyperglycemia. Ultimately, the study's outcomes are expected to contribute valuable evidence towards developing natural, accessible, and culturally acceptable alternatives to synthetic hypoglycemic agents, thereby reducing the burden of drug induced hypoglycemia and improving diabetic care outcomes.

1.4. Aim and Objectives of the Study

The aim of this research was to investigate the synergistic effect of unripe plantain and garden egg flour on postprandial blood glucose level in diabetes mellitus wistar rats.

The objectives are to**:**

i. assess the combined effects of unripe plantain and garden egg on reducing hyperglycemia and improving insulin sensitivity in diabetic subjects.
ii. analyze the postprandial glycemic response of the unripe plantain and garden egg in comparison with conventional antidiabetic drugs.
iii. evaluate the effects of the unripe plantain and garden egg formulation on lipid profile parameters, including total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL).
iv. determine the impact of the unripe plantain and garden egg formulation on liver function biomarkers, such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP), to assess hepatic integrity in diabetic conditions.
v. assess the influence of the unripe plantain and garden egg formulation on kidney function parameters, including urea, creatinine, and electrolytes, to determine its nephroprotective potential.

1.5. Research Questions:

i. Does the combined administration of unripe plantain and garden egg effectively reduce hyperglycemia and improve insulin sensitivity in diabetic subjects?

ii. How does the postprandial glycemic response of unripe plantain and garden egg compare with that of conventional antidiabetic drugs?

iii. What effect does the unripe plantain and garden egg formulation have on lipid profile parameters, including total cholesterol, triglycerides, high-density lipoprotein (HDL), and low-density lipoprotein (LDL)?

iv. How does the unripe plantain and garden egg formulation influence liver function biomarkers such as aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP) in diabetic conditions?

v. What is the effect of the unripe plantain and garden egg formulation on kidney function parameters, including urea, creatinine, and electrolytes, in diabetic subjects?

1.6. Significance of the Study

The significance of this research, which examines the concurrent action effect of unripe plantain and garden egg flour on postprandial blood sugar is multifaceted. Firstly, this research addresses the growing prevalence of diabetes and other blood sugar related disorders, offering a potential dietary intervention that combines two functional foods known for their low glycemic indices. This study seeks to offer novel information regarding natural dietary approaches for controlling after meal blood glucose. It achieves this by examining the synergistic effects of combining unripe plantain and garden egg flours, which could prove advantageous for individuals with or at risk of diabetes. Secondly, the study contributes to the scientific understanding of how specific food

combinations can influence blood glucose regulation, potentially leading to more effective dietary recommendations. The exploration of synergistic effects between these foods may reveal whether their combination provides enhanced benefits compared to their individual consumption, thus offering a novel approach to dietary management of blood glucose levels.

Also, the research supports the use of natural products with minimal side effects as opposed to synthetic hypoglycemic agents, aligning with a growing interest in using food based solutions for health management. The findings could also pave the way for further studies and applications in nutritional science, particularly in developing functional foods that target metabolic disorders. This study holds significance in advancing knowledge in nutrition and health sciences, potentially influencing dietary guidelines and contributing to public health strategies aimed at combating diabetes and related conditions.

1.7. Scope of the Study

This research aims to explore the synergistic effects of unripe plantain and garden egg flour on postprandial blood sugar levels, focusing on their potential role in managing diabetes and other blood sugar related disorders. The study is designed to investigate both individual and combined effects of these functional foods, providing a comprehensive understanding of their impact on blood glucose regulation. Specific areas of focus within this scope may include**:**

i. **Experimental Design:** The study involved inducing diabetes in albino rats to establish a suitable model for evaluating postprandial blood glucose response. This model will allow for controlled experimentation and accurate measurement of glucose levels following the consumption of unripe plantain and garden egg flour.

ii. **Assessment of Glycemic Impact**: The research assessed the glycemic impact of unripe plantain and garden egg flour individually and in combination. This included measuring postprandial blood glucose levels and determining whether the combination exhibits synergistic, additive, or antagonistic effects compared to their individual impacts.

iii. **Data Collection and Analysis:** Scientific data was collected to support the use of these food materials as part of dietary strategies for managing diabetes or preventing blood sugar spikes. The data was analyzed to provide insights into the potential benefits and efficacy of these functional foods in blood sugar management.

iv. **Evaluation of Dietary Strategies:** The study explored the potential use of unripe plantain and garden egg as part of dietary strategies for managing diabetes or preventing blood sugar spikes. This includes examining their bioactive compounds and low glycemic indices, which may contribute to effective blood sugar regulation.

v. **Contribution to Nutritional Science:** The findings from this research are expected to contribute to the field of nutritional science by providing evidence based insights into the role of specific functional foods in blood sugar management. The study aims to fill the existing gap in research regarding the combined effects of unripe plantain and garden egg flour on postprandial blood sugar levels.

1.8. Limitation of the Study

This research explored the synergistic effects of unripe plantain and garden egg flour on postprandial blood glucose levels, during the course of the study, a few limitations were encountered

i. At certain times, the Wistar rats escaped from their cages during handling, causing delays in the procedure and requiring me to repeat some steps to ensure accuracy.

ii. The rats did not all respond uniformly to feeding or handling. Some refused to eat on schedule or displayed aggressive behavior, which extended the feeding process.

iii. The drying process for the unripe plantain and garden egg was hindered by an inconsistent power supply.

iv. Due to the manual nature of many processes, such as rat handling and extract preparation, there was a possibility of minor errors in measurement or timing that could have influenced the results.

v. The rainy weather caused fluctuations in the overall temperature within the animal house, making it more challenging to maintain stable conditions for the rats.

1.9. Definition of Terms

Blood Glucose: It is the primary sugar circulating in the blood and acts as the body's main fuel source.

Insulin: The **pancreas** secretes this hormone, which is essential for allowing glucose to enter individual cells to be converted into energy.

Glucose Regulation: This term refers to the biological mechanism used by the body to keep **blood sugar levels** within a safe, tight range for overall well-being.

Adenosine Triphosphate (ATP): It is the molecule responsible for capturing, storing, and delivering chemical energy throughout the body's cells.

Starch: A polysaccharide composed of glucose molecules, found in carbohydrate rich foods like potatoes and rice.

Hepatic Portal Vein: A vein that transports absorbed nutrients, including glucose, from the gut to the liver.

Glycogen: This is an insoluble form of glucose that the body stores primarily in the liver. It can be transformed back into glucose whenever blood sugar levels drop too low.

Glycemic Index: This metric assesses the rate at which a specific food elevates the concentration of glucose in the blood following a meal.

Postprandial Glycemic Response: Changes in blood sugar levels following a meal.

Gelatinization: The process by which starch molecules absorb water during cooking, altering their physical properties.

Retrogradation: The process by which gelatinized starch crystallizes over time, affecting its digestibility.

Digestive Enzymes: Proteins that break down food into smaller molecules for absorption, such as glucose from starch.

Folklore Medicine: Traditional practices using natural products like plants for treating diseases such as diabetes.

Hypoglycemic Agents: Substances or medications used to lower blood sugar levels.

Bioactive Compounds: Chemical substances in foods that have biological effects on the body, such as improving blood sugar regulation.

Functional Foods: Foods with health benefits beyond basic nutrition, often used to manage chronic conditions.

Albino Rat Model: Laboratory rats used as experimental models to study diseases like diabetes and test dietary interventions.

High Glycemic Index Foods: Foods that raise blood glucose levels quickly after consumption, with a glycemic index value of 70 or above.

Diabetes Mellitus (DM): A chronic condition characterized by high blood sugar levels due to insulin dysfunction.

Obesity: A condition involving excessive body fat that contributes to metabolic disorders like diabetes.

Induced Diabetes: Diabetes artificially created in laboratory animals for research purposes.

Dietary Strategies: Planned approaches using specific foods or diets to manage health conditions like diabetes.

Synergistic Effect: An interaction between substances (e.g., foods) that results in a combined effect greater than their individual effects.

Additive Effect: An interaction where the combined effect of substances equals the sum of their individual effects.

Antagonistic Effect: An interaction where substances counteract each other's effects, reducing their impact.

Solanum Melongena: The scientific name for eggplant, studied for its potential role in managing diabetes related enzymes.

Garden Egg: A type of eggplant commonly used in West African remedies for blood sugar control and weight management.

Plantain: A starchy fruit rich in carbohydrates, often used in dietary management of diabetes before modern treatments were available.

Pressure Cooking: A cooking method that alters starch digestibility, impacting glycemic response.

Boiling: A cooking method that hydrates starch granules, affecting their digestibility and glycemic impact.

Food Processing Methods: Techniques like cooking and roasting that change the physical and nutritional properties of food carbohydrates.

Degenerative Conditions: Chronic illnesses like diabetes and obesity that worsen over time without proper management.

Synergistic Mechanisms: Biological pathways through which combined substances exert enhanced effects on health outcomes.

Controlled Laboratory Setting: An environment where experiments are conducted under regulated conditions to minimize external influences.

Bioavailability: The extent to which nutrients or bioactive compounds are absorbed and utilized by the body.

Postprandial Blood Glucose Levels: Blood sugar levels measured after consuming food, used to evaluate dietary impacts on glucose regulation.

Endnotes

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Chapter Two

Literature

Review

2.1 Conceptual Review

Glucose, commonly known as blood sugar, serves as one of the body's primary energy sources. This energy-rich monosaccharide is metabolized within our cells to generate adenosine triphosphate (ATP), which acts as a tiny, essential packet of chemical energy. ATP powers the millions of biochemical processes that occur in the body every second. We mainly acquire glucose from the foods we consume, particularly those high in starch, such as bread, rice, pasta, and potatoes. Starch, which is a polysaccharide (a long chain of glucose units), must first be broken down into individual glucose molecules by digestive enzymes [1]. Following digestion, glucose is absorbed from the small intestine and carried to the liver through the hepatic portal vein. Liver cells, or hepatocytes, readily take in this glucose and convert it into the stored form, known as glycogen (an insoluble polymer). This stored glycogen can be converted back to glucose to raise blood sugar when needed. Similarly, other basic dietary sugars, such as lactose, fructose, and sucrose, also serve as metabolic fuels essential for producing ATP [2]. The proper function of the nervous system hinges on consistent blood glucose levels because its cells, the neurons, depend almost exclusively on glucose for energy, whereas most other cells can also use fuels like lipids [3]. Extremely high (hyperglycemia) or extremely low (hypoglycemia) blood glucose levels can impair normal neurological processes within the brain [4]. Experiencing low blood glucose is common, often presenting as dizziness, physical weakness, tremors, and difficulty concentrating. However, the long-term presence of high blood glucose or chronic hyperglycemia is a hallmark of diabetes.

This state is known to cause neurological dysfunction and is a significant factor in the development of both kidney failure and arterial disease [5].

2.1.1. Glucose Regulation

As food intake shifts over the course of a day, blood glucose levels also fluctuate. Following a meal, the body is in an absorptive state, taking in nutrients from the gut. Even though blood sugar increases at this point, the liver buffers the rise by storing glucose [6]. Once digestion ends and nutrient absorption slows, the body enters its post absorptive state. Since cells are constantly drawing on glucose for energy production, blood glucose levels fall. Despite these natural fluctuations, the body employs homeostatic mechanisms which we will discuss shortly to keep blood sugar tightly regulated within necessary limits [7].

2.1.2. What are Typical Blood Glucose Levels?

Blood glucose concentration during the period immediately following a meal (the absorptive state) is highly variable, influenced by both the quantity and type of food ingested. Consequently, a more reliable measure the fasting state or post absorptive glucose level is the standard used by medical practitioners for blood sugar testing, as it avoids the temporary spikes caused by recent heavy eating [8]. A fasting blood glucose measurement should ideally be between 3.3 and 6.1 mmol/L. If test results exceed or fall below this reference range, it suggests a potential malfunction in the body's ability to regulate glucose, a condition commonly seen in patients with diabetes mellitus.

2.2. Understanding the Pancreas's Role in the Body

The pancreas is a major gland situated under the stomach that is essential for glucose regulation. It is unusual because it operates as both an endocrine and an exocrine gland. In its exocrine capacity, which makes up more than 90% of the gland, it produces digestive enzymes that travel through the pancreatic duct and into the duodenum [10]. The pancreas is positioned adjacent to other organs and functions as an endocrine gland, producing hormones like insulin, glucagon, and

somatostatin that control blood glucose. These hormones are manufactured in microscopic cell clusters, or "islands," which were originally discovered by a German anatomist [11].

2.3.Physiological Mechanism for Reducing High Blood Glucose

When blood glucose levels rise during the absorptive state, this increase is sensed by the beta cells within the pancreatic islets. This detection triggers the release of insulin into the bloodstream. Insulin then works to promote the uptake of glucose from the blood, primarily by muscle and adipose (fat) cells [12].

2.4. The Role of Insulin in Facilitating Glucose Uptake by Cells

Glucose must pass through the cell membrane to enter a cell, a process that requires specialized trans membrane proteins collectively known as GLUT (Glucose Transporter). The most common of these is GLUT4, which is predominantly located on fat and muscle cells.[13]. When insulin attaches to its specific receptors on a cell's surface, it triggers the cell to manufacture and move more glucose transporters to the cell membrane. This action increases the uptake of glucose by the cell, which subsequently lowers the blood glucose level. However, the exact process by which insulin binding leads to this movement (translocation) of transporters is not yet fully understood (Sanger Institute). It is important to note that certain tissues, such as brain and liver cells, do not rely on insulin for glucose uptake; instead, they utilize independent GLUT transporters. [14].

2.4.1. Other Physiological Effects of Insulin

The hormone insulin has numerous secondary effects on cells that contribute to lowering blood sugar by increasing how glucose is used and stored. Specifically, insulin does the following:

- It accelerates the process of glycolysis, which extracts cellular energy from glucose.
- It stimulates glycogenesis, turning glucose into glycogen for future storage.
- It prevents the breakdown of fats for energy by inhibiting lipolysis.

These combined actions cause the metabolic balance to favor glucose over fat, effectively making the body rely on carbohydrates for energy and hold onto its reserves of fat.

2.5.Physiological Mechanism for Elevating Low Blood Glucose

In the post-absorptive state, which occurs several hours after a meal both blood glucose and insulin levels decline. This drop triggers the alpha cells of the pancreas to release the hormone glucagon to counteract the decrease [15].

2.5.1. The Role and Importance of Glucagon

Glucagon has the opposite effect to insulin in that it increases blood-glucose levels and promotes processes that spare glucose utilization [16]. Glucagon primarily targets hepatocytes (liver cells) to raise blood glucose levels by two distinct actions: it converts stored glycogen into glucose for release into the bloodstream, and it stimulates gluconeogenesis, which is the creation of new glucose from compounds like lactic acid and other metabolites.

Glucagon initiates its effects by attaching to its specific G-protein-coupled receptors. This binding triggers a chain of linked enzyme reactions within the cell, ultimately activating glycogen phosphorylase. This crucial enzyme is what breaks down stored glycogen into free glucose. The secretion of glucagon itself is suppressed by the presence of both insulin and somatostatin in the bloodstream [17].

2.5.2. The Regulation of Internal Stability

Blood glucose regulation provides a perfect illustration of homeostatic control achieved through negative feedback. This mechanism ensures that a corrective action, initiated by a deviation from the normal setpoint, is halted once those levels are restored. For instance, low blood sugar triggers the release of glucagon, which, in turn, raises glucose levels. As glucose concentration increases, the signal that stimulated glucagon production is automatically suppressed [18].

2.5.3. Non Pancreatic Hormones Regulating Plasma Glucose

The regulation of blood glucose, similar to many other physiological functions, is an intricate process. While insulin and glucagon are key, several other hormones, like somatostatin, also play a significant role in its control [19].

While hormones such as amylin and pancreatic polypeptide (PP) also participate in regulating blood glucose, their specific functions are not as fully understood as others [20].

2.5.4. Neural Mechanisms for Regulating Blood Sugar

Insulin and glucagon release are controlled, in part, by the autonomic nervous system. During physical activity, sympathetic stimulation enhances glucagon production. This hormonal boost ensures blood glucose remains adequate, offsetting the energy demands of the muscles that are quickly utilizing glucose [21]. During the periods when the body is at rest, parasympathetic activity stimulates digestion and also the release of insulin to deal with the expected rise in blood glucose.

2.6.Age Specific Blood Glucose Ranges

Healthcare professionals frequently use the 2025 Standards of Care published by the American Diabetes Association (ADA) to guide diabetes management and establish desired glucose ranges for their patients. Rather than relying on a single glucose value, the ADA and other bodies depend primarily on the hemoglobin A1C test, which provides an average blood sugar level over three months. Although this test, introduced in the early 1990s, is considered the gold standard, it has drawbacks, such as not adequately reflecting short term blood sugar variability. Regardless, the ADA's guidelines suggest specific A1C targets for different age groups, while acknowledging that the most appropriate goal should be tailored to the individual's needs in consultation with their diabetes care team.

To assist individuals with diabetes and their doctors in establishing appropriate blood sugar targets, the American Diabetes Association (ADA) utilizes the estimated average glucose (eAG) tool. This eAG is essentially an "A1C to glucose converter." The accompanying chart provides specific glycemic goals tailored to different age groups [22].

Table 2.1: Age based groupings of individuals with diabetes

Age	Before meals (fasting)	After eating
Children and teens	90 to 130 mg/dL	
Adults	80 to 130 mg/dL	< 180 mg/dL (1 or 2 hours after)
Pregnant	70 to 95 mg/dL	110 to 140 mg/dL (1 hour after); 100 to 120 mg/dL (2 hours after)
65 and older	80 to 130 mg/Dl	
Without diabetes	99 mg/dL or below	140 mg/dL

Source:[22]

The ADA advises that these blood glucose goals must be integrated into each patient's personalized management plan, taking into account additional factors like their overall health and functional status. The American Diabetes Association's (ADA) 2023 guidelines emphasize that blood glucose targets must be flexible, providing specific examples:

- For very young children, immediate safety and simplicity may be prioritized over strict glycemic control. This less rigid approach can ease parental anxiety, build confidence, and ultimately prepare the family for stricter goals later.

- For healthy older adults, there's no inherent reason to relax control. However, less stringent targets may be advisable for individuals with a short life expectancy or when the risks of intensive treatment outweigh the potential benefits.

Crucially, you should always collaborate with your diabetes care team to determine and agree upon your personalized blood glucose targets [23].

2.6.1 Recommended Glycemic Control Objectives

For those with type 1 diabetes, the ADA recommends setting blood sugar targets in accordance with individual needs, goals, and factors like pregnancy. It is essential to consult with your provider and diabetes educator to determine the most suitable goals for you. The overall recommendations are:

Pre meal blood glucose objectives are:

- **Adults:** 90 to 130 mg/dL (5.0 to 7.2 mmol/L)

- **Adolescents** (13 to 19 years): 90 to 130 mg/dL (5.0 to 7.2 mmol/L)

- **Children** (6 to 12 years): 90 to 180 mg/dL (5.0 to 10.0 mmol/L)
- **Children under 6 years old:** 100 to 180 mg/dL (5.5 to 10.0 mmol/L)

Additionally, adults should aim for a blood sugar level of less than 180 mg/dL (10 mmol/L) one to two hours after eating a meal.

The ideal blood glucose reading at bedtime is:

- **Adults and Teens (13–19 years):** 90 to 150 mg/dL (5.0 to 8.3 mmol/L)
- **Children (6–12 years):** 100 to 180 mg/dL (5.5 to 10.0 mmol/L)
- **Children Under 6 years:** 110 to 200 mg/dL (6.1 to 11.1 mmol/L)

According to the American Diabetes Association's recommendations, blood glucose targets for those with type 2 diabetes shouldn't be uniform but should be customized for each patient. While you must discuss and decide on your optimal goals with your healthcare provider and diabetes educator, here are the general guidelines provided: Adults should aim for blood glucose levels in the following ranges: Fasting or pre meal glucose should fall within 80-130 mg/dL (4.4-7.2 mmol/L). Post meal glucose (measured 1 to 2 hours after consuming food) should remain below 180 mg/dL (10.0 mmol/L) [24].

2.6.2. Glycemic Analysis

A blood glucose test measures the concentration of sugar (glucose) in the blood, primarily as a tool for checking for diabetes [25].

2.6.3. The primary classifications of blood glucose tests are two fold:

- The capillary blood glucose test yields a result in just seconds. The procedure requires a healthcare provider to collect a small amount of blood, usually by pricking a finger (or an infant's heel). This sample is then analyzed using a test strip and a glucose meter.
- For a venous plasma glucose test, a blood sample is collected from a patient's vein by a phlebotomist. The healthcare provider then sends this specimen to a dedicated lab for testing. This type of glucose analysis is commonly incorporated into broader assessments, like a basic metabolic panel.

2.6.4. Further Blood Glucose Testing Methods:

- The fasting glucose sugar test is used for diabetes screening. Because what you eat affects your glucose concentration, fasting provides a more accurate view of your baseline blood sugar level.
- At-home glucose monitoring is necessary for those with diabetes. Individuals monitor their glucose using a glucose meter (which requires a finger prick) or a continuous glucose monitor (CGM). Consistent monitoring is essential for effective diabetes management

2.6.5. The Hemoglobin A1c Test (or HbA1c)

The A1C test (also known as the glycated hemoglobin test) measures the average amount of glucose attached to your red blood cells over the past quarter. This value is reported as a percentage, directly reflecting the mean concentration of sugar in your blood. Clinicians rely on this test to:

- Identify the presence of prediabetes.

- Confirm a diagnosis of Type 2 diabetes.
- Assess how well a current treatment plan is controlling blood sugar for individuals with either Type 1 or Type 2 diabetes. The A1C score is essential for informing any required adjustments to your treatment.

Healthcare providers administer the A1C test using one of two primary methods:

- Laboratory Analysis: The most common approach involves a phlebotomist drawing a blood sample from a vein, which is then sent to a lab for detailed analysis.
- Point of Care Testing: Alternatively, a provider may use a finger prick to quickly obtain a blood sample. This method yields results within minutes but is only suitable for monitoring existing diabetes management, not for an initial diagnosis [26].

2.7.Postprandial Blood Glucose

Blood glucose concentration measured after eating is known as postprandial blood sugar, which is also frequently called post meal blood sugar. It's a measure of how well the body is processing sugar and carbohydrates after eating, and it's often tested as part of diabetes screening or to monitor blood sugar control in individuals with diabetes [27]. It is measured 2 hours after a meal.

2.7.1. Importance Postprandial Blood Glucose

This measure is vital for assessing how effectively the body handles blood sugar after meals. This understanding is key to controlling glucose levels and averting complications for people who have diabetes or are at risk of developing it [28].

2.7.2. How Postprandial Blood Glucose is Tested

A blood test is typically taken to measure postprandial blood sugar. The test usually involves fasting overnight, taking a baseline blood sample, then eating a meal, and taking another blood sample 2 hours later [29].

2.7.3. Normal ranges:

- Ideally, a healthy individual without diabetes should have a blood glucose reading of under 140 mg/dL (7.8 mmol/L) two hours after a meal.
- For individuals with diabetes, the target postprandial blood sugar level is generally less than 180 mg/dL (10 mmol/L).

2.7.4. Factors affecting postprandial blood glucose:

Various factors can impact postprandial blood sugar levels, including the type and amount of carbohydrates consumed, physical activity, lifestyle habits, and underlying medical conditions[30,31].

2.7.5. Implications of high postprandial blood glucose:

Consistently high postprandial blood sugar can increase the risk of developing heart disease and other metabolic diseases, even in individuals without diabetes [32].

2.8.The Glycemic Rating System

The glycemic index (GI) is a metric for determining a food's potential to increase your blood glucose levels. This value is not fixed, as the GI can vary significantly depending on factors like

the cooking technique, the food's maturity (ripeness), and its blend of nutrients [33].

As a tool frequently utilized to support effective blood sugar regulation, the glycemic index of any given food can be influenced by several variables. These include the food's nutrient content, the method used to prepare it, how ripe it is, and the degree to which it has been processed [34]. The glycemic index is a system that ranks foods on a scale of 0 to 100, categorizing them as low, medium, or high. This tool can increase awareness of dietary choices and help achieve better health outcomes, such as weight reduction, reduced cholesterol, and lower blood sugar. Essentially, the lower a food's GI rating, the less pronounced its effect will be on elevating your blood glucose [35]. The GI scale divides foods into three categories based on the following values:

- A score of 55 or less is considered Low.
- A score between 56 and 69 is considered Medium.
- A score of 70 or greater is considered High.

Foods containing large amounts of refined carbohydrates and sugar are rapidly digested, often resulting in a high GI score. Conversely, foods rich in protein, fat, or fiber are generally digested more slowly and thus have a low GI. Foods that contain no carbohydrates whatsoever (such as meat, fish, poultry, nuts, seeds, herbs, spices, and oils) are not assigned a GI value [36].

Several other variables influence a food's Glycemic Index (GI), such as its degree of ripeness, how it was cooked, the specific type of sugar present, and the extent of processing it underwent. It's crucial to remember that the GI should not be confused with the Glycemic Load (GL) [37]. While

the Glycemic Index (GI) only measures how quickly a carbohydrate is digested without considering the serving size, the Glycemic Load (GL) provides a more complete picture. The GL accounts for the carbohydrate content in a typical serving of food, giving a better estimate of its actual impact on blood sugar. Therefore, when choosing foods to maintain healthy blood glucose levels, both the GI and the GL should be considered [38].

2.8.1. A Nutritional Strategy Emphasizing Foods with a Slow Glucose Release

The strategy behind a low glycemic diet is to exchange foods that elevate blood sugar quickly (high GI) for those that raise it more slowly (low GI) [36].

2.8.2. Health Gains from a Low Glycemic Strategy

The low glycemic index diet is associated with the following positive effects:

- **Enhanced Glycemic Regulation:** This dietary approach has been shown in various studies to both reduce blood sugar and facilitate better overall glucose management, particularly in patients with type 2 diabetes.
- **Assistance with Weight Management:** While some evidence points toward improved short term weight loss, further research is needed to determine the long-term effectiveness of the low GI diet for maintaining a healthy weight.
- **Benefit for Fatty Liver Disease:** For those with non alcoholic fatty liver disease, consuming low GI foods may help by decreasing the amount of fat in the liver and lowering liver enzyme concentrations [39].

2.8.3. Guidance on Adopting the Glycemic Index Diet

To follow a healthy low glycemic diet, you should base your meals on the following low GI food

categories:

- **Legumes:** Lentils, kidney beans, chickpeas, and black beans.
- **Fruits:** Apples, citrus fruits (oranges, lemons, limes, grapefruit), berries, garden egg, and unripe plantain.
- **Whole Grains:** Quinoa, oats, farro, barley, and buckwheat.
- **Non-Starchy Vegetables:** Tomatoes, spinach, broccoli, carrots, and cauliflower.

The following food groups naturally fit into a low glycemic eating plan, either because they have a negligible impact on blood sugar or are not ranked on the GI scale:

- **Meat and Poultry:** Pork, lamb, beef, bison, chicken, duck, turkey, and goose.
- **Fish and Shellfish:** Shrimp, salmon, tuna, mackerel, anchovies, and sardines.
- **Healthy Fats:** Avocado, olive, coconut, and vegetable oils.
- **Nuts:** Pistachios, walnuts, macadamia nuts, and almonds.
- **Seeds:** Sesame, chia, flax, and hemp seeds.
- **Herbs and Spices:** Basil, cinnamon, turmeric, cumin, dill, black pepper, and rosemary.
- **Select Pastas:** Whole grain and semolina pasta options.

No foods are entirely restricted on this plan, but you should practice moderation with items that have a high GI. Examples of high GI foods to consume sparingly are:

- **Grains:** White bread varieties (bagels, pita, naan), white rice (such as jasmine and arborio), and many breakfast cereals, including instant oats.
- **Potatoes:** Potatoes in general, including mashed potatoes and French fries.
- Desserts/Pastries: Muffins, cakes, cookies, croissants, and doughnuts.
- **Processed Snacks:** Chips, pretzels, chocolate, crackers, and microwave popcorn.
- **Sugary Drinks:** Fruit juice, soda, and sports drinks.

2.8.4. Food Classification by Glycemic Index (GI)

Glycemic Index (GI) is a number (0–100) that shows how quickly a food raises your blood sugar (glucose) after eating it.

Low GI foods (0–55) cause a slow, steady rise in blood sugar. Good for weight control, diabetes, and long lasting energy.

Medium GI foods (56–69) cause a moderate rise in blood sugar. Should be eaten in moderation.

High GI foods (70–100) cause a fast spike in blood sugar. Best to limit, especially for people managing blood sugar or weight.

For those following a low glycemic eating plan, knowing the GI of your regular food choices is a practical necessity.

Dairy products and dairy alternatives: Ice cream (62), Rice milk (79), Skim milk (37), Soymilk (41), Whole milk (41)

Fruits: Apples (44), Banana (62), Blueberries (53), Dates (55), Garden egg (30−38), Mango (60), Oranges (45), Pineapple (66), Strawberries (40), Unripe plantain (45−55), Watermelon (50)

Grains: Barley (28), Brown rice (79), Couscous (70), Popcorn (70), Quinoa (50), Rolled oats (57), White bread (81), White rice (70), Whole wheat bread (73)

Legumes: Chickpeas (33), Kidney beans (26), Lentils (37), Soybeans (16)

Sweeteners: Coconut sugar (54), Fructose (23), Honey (59), Maple syrup (54), White sugar (91)**Vegetables:** Carrots (boiled) (32), Plantains (boiled) (66), Potatoes (boiled) (87), Pumpkin (boiled) (75), Sweet potatoes (steamed) (71).

2.8.5. The Impact of Preparation and Maturity on GI

The method used to prepare certain foods can alter their Glycemic Index (GI).

Cooking Methods and GI

- Frying typically involves high fat content, which can slow the absorption of sugar into the bloodstream and consequently lower the GI. However, it is critical to recognize that despite lowering the GI, fried foods are often high in calories and unhealthy fats (depending on the oil used), potentially harming overall health. Baking and roasting are generally healthier alternatives as they use significantly less oil.
- Roasting and baking can break down resistant starch (a starch that naturally resists digestion and is found in foods like oats, potatoes, and legumes), thereby raising the GI.
- Boiling, on the other hand, is believed to help retain more resistant starch, resulting in a lower GI compared to other preparation methods.
- Cooking time is also a factor: prolonged cooking of starches like rice or pasta increases how easily the starch is digested, which elevates their GI. Therefore, it is best to cook these items only until they are al dente (firm to the bite).

Ripeness and GI

Beyond cooking, the degree of ripeness can impact the GI of some fruits, such as bananas. As a fruit ripens, its resistant starch content naturally diminishes, causing its GI rating to become higher [37].

2.9. Plantains

The plantain (*Musa paradisiaca*) is a significant variety within the *Musa* genus (banana family) and serves as a staple food across many tropical regions. Unlike the sweet dessert banana, the

plantain's edible fruit contains a much higher starch content, making it unsuitable for raw consumption [40]. The maximum starch level in a plantain occurs before it is fully ripe; consequently, green plantains are usually incorporated into savory dishes by boiling or frying. Ripe plantains, which are slightly sweet, are often cooked with sugar or coconut juice to enhance their flavor. Plantains can also be preserved by drying for later culinary applications or ground into a meal, which can subsequently be refined into flour. Importantly, "plantain" is a common name shared with unrelated plants belonging to the genus *Plantago* (Plantaginaceae family) [41].

2.9.1. The Plantain's Physical Characteristics

A plantain is an enormous herb that grows from an underground rhizome. It can reach heights of 3 to 10 meters and is defined by a tapered, false "trunk" created by the protective leaf sheaths of its spirally arranged foliage. The resulting fruit is borne in clusters and is generally much bigger than the familiar common banana, with a color that ranges from green to a yellowish-brown.

2.9.2. A Historical Look at Plantain

Plantains are generally believed to have originated in Southeast Asia. The two main varieties, the horn plantain and the French plantain, are thought to share a common ancestry. Both of these varieties thrive across various regions, including India, Africa, Egypt, and tropical America. The French plantain specifically is also found in Indonesia and the Pacific islands.

Globally, plantains are a dominant crop, making up approximately 85% of all banana cultivation. In some areas of East Africa, notably central and eastern Uganda and Tanzania, plantains are a significant crop used for making beer [42].

2.9.3. Nutritional Profile of Plantains

Plantains are highly digestible and packed with essential nutrients, including complex carbohydrates, vitamins, and minerals. For centuries, this vegetable has served as the primary food

source for millions of people worldwide. The following data from the United States Department of Agriculture (USDA) details the basic nutritional content for a one cup serving (139 grams) of baked plantains. Note that the method of cooking will cause variations in the final nutrient values [43].

Table 2.2: Nutritional Profile of Plantains

Nutrient Category	Nutrient	Amount per 139g Serving
Energy & Macronutrients	Calories	215
	Carbohydrates	58 g
	Protein	2 g
	Fiber	3 g
	Fat	0.22 g
Minerals	Potassium	663 mg
	Magnesium	57 mg
Vitamins	Vitamin C	23 mg
	Vitamin A	63 ug
	Vitamin B-6	0.29 mg

Like many grains, plantains are nutritionally incomplete, as they are a sparse source of fat and protein. Therefore, they must be combined with other foods to form a healthy, balanced diet.

2.9.4. Plantain and Gastrointestinal Health

Fiber plays a critical role in promoting a healthy digestive tract. It improves bowel regularity by increasing the stool's size and mass while simultaneously softening it, which eases passage and helps avert constipation. Furthermore, consuming a high fiber diet can lower the probability of developing conditions like hemorrhoids or diverticular disease (the formation of tiny pouches in the colon). Systemically, fiber contributes to satiety, slows the overall digestive process, and can be beneficial for controlling cholesterol levels [44].

2.9.5. Plantain Consumption and Body Weight Regulation

Many people mistakenly view carbohydrates as detrimental to weight management, but this isn't necessarily true. The fiber and starch in plantains are complex carbohydrates. Unlike the simple carbohydrates in processed snacks, these complex carbs are less refined and take longer for the body to digest. This slower digestion helps you feel fuller and more satisfied for a longer period, which naturally reduces the desire to snack on unhealthy foods [45].

2.9.6. High Antioxidant Content of Plantain

Plantains are an excellent source of Vitamin C, providing a substantial amount in just one cup. Vitamin C functions as an antioxidant, which is crucial for strengthening immune function. Due to its antioxidant properties, Vitamin C may offer protection against free radical damage a factor implicated in heart disease, aging, and specific cancers. In fact, various studies suggest an inverse correlation between Vitamin C intake and several cancer types (such as lung, breast, and colon). Furthermore, individuals diagnosed with cancer often exhibit lower levels of Vitamin C in their blood [46].

2.9.7. The Cardioprotective Properties of Plantain

Plantains contribute to a healthy heart in two key ways: first, their high potassium concentration is essential for stabilizing both blood pressure and heart rate through the maintenance of body fluids; second, the fiber they provide helps reduce cholesterol levels, ensuring the heart operates efficiently [47].

2.10. The Edible Eggplant

The garden egg, also identified as the African eggplant or by its scientific name, *Solanum aethiopicum*, derives its common name from its physical characteristics and cultivation method. The term "garden egg" refers to the small, oval shaped fruit often white or light green, that bears a resemblance to a chicken's egg. This vegetable is widely and easily grown in home gardens and plots, especially in West African nations where it is consumed as a staple vegetable [48].

Local names for this vegetable in Nigeria include *Igba* (Yoruba), *Afufa* (Igbo), and *Ganyen Gauta* (Hausa). It is reasonable to conclude that the name "garden egg" originated from the fruit's egg like shape combined with its identity as a common, readily cultivated garden crop.

2.10.1. Cultivars and Strains of Edible Eggplant

The garden egg comes in three distinct types: green, white, and yellow, each possessing a unique flavor profile and physical form, and all are distributed across various regions. Striped varieties, such as green on white or green on yellow, can be seen regardless of the primary color [49]. Varieties of Garden Egg are:

White Garden Eggs: These are the most widespread variety, typically appearing white, off-white, or pale green and shaped like small chicken eggs. They have a subtle, slightly bitter taste that leaves an aftertaste. Though frequently consumed raw, they also make a good addition to salads and are used in stews.

Green Garden Eggs: Ranging from light to deep green and appearing either round or oval, this variety is prevalent throughout Nigeria, particularly in the Southern region. They are noticeably more bitter than the white variety. To offset the intense flavor, they are often paired with peanut butter or groundnut paste. Green garden eggs are also a key ingredient in garden egg stew and sauces.

Yellow Garden Eggs: The yellow hue signifies that these garden eggs are ripe. They are generally smaller than the other two types and are often preferred for raw consumption because they are sweeter than both the green and white varieties [50].

2.10.2. Are Garden Eggs Available Year Round?

Garden eggplants are harvested year-round in Nigeria due to the relative ease of their cultivation, maintaining steady distribution even when not in season. However, their highest concentration in markets occurs during the rainy season (typically June through September). This period of peak supply means they are widely abundant and significantly reduced in price [51].

2.10.3 Health Benefits of Scarlet Eggplant

The garden egg is a nutrient dense food that offers several advantages due to its composition:

- **Digestive Support:** Its dietary fiber content speeds up the digestive process, promoting

more efficient food breakdown and better gastrointestinal health.

- **Essential Vitamins:** Garden eggs are a source of Vitamins A, B6, and C. These vitamins are vital for functions such as improving eyesight, supporting cognitive development, and enhancing the body's defenses. Furthermore, Vitamin B6 helps synthesize serotonin, which benefits sleep quality and bone health.
- **Mineral Content:** Essential minerals are provided, including approximately 9 mg of calcium and 114 mg of phosphorus per 100 g serving, alongside magnesium, potassium, and iron.
- **Disease Risk Reduction:** The vegetable provides antioxidants that help counteract oxidative stress in the body, potentially reducing the likelihood of developing serious illnesses like heart disease and certain cancers.
- **Snack for Fitness:** Given their minimal fat and calorie counts, garden eggs are a suitable snack for those watching their weight.

2.10.4. Target Groups for Garden Egg Consumption

Given their rich nutrient profile, garden eggs are a beneficial addition to nearly any diet, whether a person is trying to diversify their meals, cut down on "empty calories" from poor snacks, or simply boost their intake of fresh produce. Specific groups should consider incorporating garden eggs into their eating plans:

- **Diabetics:** When food is consumed, the body converts carbohydrates into glucose, which is then absorbed into the bloodstream, raising blood sugar. Since garden eggs are low in carbohydrates, they cause a gradual, slower rise in blood glucose levels. This makes them an ideal food choice for individuals working to manage their blood sugar.

- **Those with Digestive Concerns:** The significant fiber in garden eggs is beneficial for digestive wellness. It facilitates regular bowel movements and guards against constipation. Furthermore, dietary fiber supports a balanced gut microbiome, which is key to better digestive function.
- **Pregnant Women:** These vegetables supply vital nutrients necessary during pregnancy, such as folate, which is essential for proper fetal development. Additionally, the iron and calcium present in garden eggs help prevent anemia and support strong bone health for the mother.
- **People with Eyesight Concerns:** Garden eggs are a valuable source of Vitamin A, a nutrient crucial for healthy vision. They also contain antioxidants that shield the eyes from damage inflicted by free radicals. Anyone wishing to enhance their vision should consider including garden eggs in their regular diet.
- **Individuals Managing Weight:** Garden eggs are great for those aiming for weight loss or maintenance. Their high fiber content promotes a feeling of fullness (satiety), which helps curb hunger and naturally leads to lower overall calorie consumption [52].

2.10.5. How to Preserve Garden Eggs

It is highly recommended to consume garden eggs, particularly when fresh or raw, immediately or within a short period after they're bought or picked. While some research indicates that storage might be possible for a few months, the general consensus is that the vegetable's quality begins to degrade quickly if not eaten right away [52].

2.11. Physical Activity and Its Role in Glucose Levels and Diabetes

Physical activity has a major impact on health, including the regulation of glucose levels. As a primary contributor to energy use, physical activity strongly affects how the body manages glucose and maintains energy balance and insulin sensitivity. Importantly, it is considered a major, modifiable risk factor that independently offers protection against conditions like type 2 diabetes, stroke, specific cancers, and cardiovascular disease (CVD) [53]. In addition to its metabolic advantages, engaging in physical activity is associated with several positive outcomes, including better mental health, a lower chance of experiencing falls and injuries, and improved overall long term well being.

The lack of physical activity is a widespread and serious public health concern. Current data indicates low engagement, as roughly 66% of men and 75% of women fall short of achieving the national guidelines for exercise [54]. Historically, energy expenditure was closely tied to energy intake because food was less accessible and physical effort was required to obtain it. However, modern technology and industrialization have created an imbalance between abundant food availability and reduced physical demands in daily life. This mismatch has contributed to the current pandemic of obesity and the parallel rise in type 2 diabetes and other chronic diseases [55].

This significant trend of low activity has prompted action from health organizations worldwide. For instance, the World Health Organization has created a comprehensive global strategy for promoting physical activity. Similarly, the Department of Health in England launched the Choosing Activity initiative to boost exercise rates nationally [56]. The financial toll of physical inactivity is enormous. In the UK, the direct expenses borne by the National Health Service (NHS) are estimated at £1.06 billion. When indirect costs like premature death, sick leave, private medical

treatment, and home care are included, the total annual economic burden surges to £8.2 billion. Consequently, boosting Physical Activity Levels (PALs) is essential for preventing diabetes and improving overall public health [57]. However, the most effective strategies remain uncertain, and more research is needed to evaluate existing initiatives. Understanding psychological and environmental barriers is especially important for designing successful interventions to increase activity [58].

The importance of physical activity in diabetes prevention and management is emphasized by growing evidence across different populations. For individuals with impaired glucose tolerance or those already living with type 2 diabetes, regular activity improves glycemic control, enhances insulin sensitivity, and reduces complications [59]. Broader evidence highlights the role of physical activity in preventing weight gain, obesity, CVD, cancer, osteoporosis, mental health challenges, and other metabolic conditions. Its impact across the life course further reinforces the need for population-wide engagement [60]. National recommendations for physical activity provide a foundation, but public health interventions must also address barriers, risks, and the need for sustainable long-term behaviour change [61].

2.11.1 Physiological Effects of Physical Activity on Glucose Levels and Diabetes

As discussed in metabolic equivalents (METs), different activities lead to a wide variability in physical activity, with levels ranging from 1.2 to 2.2–2.5 reported in healthy adults. While increases in total energy expenditure are expected from physical activity, studies show an additional rise in total energy expenditure not directly explained by physical activity energy expenditure (PAEE) [62]. Since physical activity is a major component of total energy expenditure, the energy cost of an activity depends on both the muscle mass engaged and the intensity of

effort, with values ranging from 2 to 18 METs. These

physiological demands directly influence glucose utilization, insulin sensitivity, and overall sugar regulation [63].

Physical activity also promotes gains in lean body mass by increasing skeletal muscle size. Structural adaptations, including greater capillary density and enhanced glycogen storage capacity, further improve glucose uptake and insulin sensitivity [64]. Importantly, exercise can reduce abdominal subcutaneous and visceral fat even in the absence of weight loss, which significantly improves glycemic control and reduces diabetes risk. For instance, resistance and endurance training over several weeks has been shown to lower fat mass by 2.1% in men and 1.8% in women. Nevertheless, epidemiological studies on physical activity and body fat percentage show mixed results, with gender specific differences reported. Some studies found that total energy expenditure was related to body fat percentage in women but not men, while physical activity energy expenditure was significantly linked to body fat percentage in men but not women [65]. These differences may partly explain why exercise related improvements in sugar control can vary between men and women.

Age related differences have also been observed. Accelerometer based studies in young adults revealed strong inverse associations between moderate-to-vigorous activity and fat mass. Among adolescents, activity was inversely associated with fat mass, body fat percentage, and body mass index (BMI) in boys, but not in girls. In middle aged adults, baseline physical activity predicted reductions in fat mass among younger individuals who tended to gain weight, while in older adults who were generally weight stable, baseline activity was linked to gains in both fat and lean mass [66]. These findings highlight that physical activity influences sugar regulation and diabetes risk differently across life stages.

Variations in methodology for measuring activity, energy expenditure, and body composition especially reliance on self reported data, limit consistency in the evidence. Additionally, dietary intake interacts with physical activity; changes in appetite and food choice may influence body composition and blood sugar regulation, adding complexity to outcomes [67].

Physically active individuals are able to consume greater amounts of energy while maintaining balance. This allows for more flexibility in diet composition and supports higher nutrient density, which can help prevent micronutrient deficiencies. In contrast, sedentary individuals on energy restricted diets may struggle to meet micronutrient requirements. For people with or at risk of diabetes, this dietary flexibility is beneficial, as it allows for better alignment of nutrient intake with glucose management [68].

2.11.2 Macronutrient Intake, Glucose Levels, and Diabetes

Although difficult to assess, several reviews have examined the effects of exercise on macronutrient intake in relation to glucose control. Some studies reported differences in macronutrient intake between active and inactive individuals, but overall results were inconsistent [69]. Slight trends were observed: active men tended to consume more carbohydrate and less fat and protein than inactive men, while active women appeared to consume more fat, though these differences were not statistically significant [70]. Short term intervention trials investigating the acute effects of a single exercise session on macronutrient intake also showed mixed results. Overall, there was no conclusive evidence that long term exercise training alters macronutrient intake. However, a few studies indicated an increase in carbohydrate consumption following exercise, likely explained by glycogen depletion and subsequent physiological demand for glucose replenishment, or by the intake of carbohydrate rich foods and fluids during and after activity [71].

During exercise, physiological responses that influence sugar metabolism also affect cardiovascular function. Blood pressure rises, particularly when large muscle groups are activated, yet vasodilation in the exercising muscles reduces peripheral resistance, which moderates this increase. When exercise ceases, cardiac output falls quickly, but vasodilation persists, creating a post exercise hypotensive effect that can last for several hours. Regular exercise therefore helps maintain vascular health, which is essential for improving insulin sensitivity and glucose regulation [82].

A meta-analysis of 72 trials confirmed that the blood pressure lowering effect of exercise was stronger in individuals with higher baseline blood pressure, mechanisms involving both reduced vascular resistance and changes in the sympathetic and renin angiotensin systems. Endurance training for ≥4 weeks reduced plasma noradrenaline by 29% and plasma renin by 20%, resulting in significant reductions in resting and daytime ambulatory blood pressure [73]. Since hypertension commonly coexists with type 2 diabetes, these adaptations are particularly beneficial for reducing cardiovascular complications in diabetic patients.

Exercise also enhances coronary artery capacity by increasing vessel diameter, capillary density, and angiogenesis, which in turn improves blood flow and glucose delivery to tissues [74]. Similarly, endothelial function critical for vascular regulation and glucose uptake is improved through exercise induced nitric oxide production. Physical activity stimulates nitric oxide synthase activity and enhances antioxidant defenses, thereby improving endothelial function and supporting early protection against vascular damage linked to diabetes [75].

In addition to vascular and metabolic benefits, physical activity influences immune function, which is important in people with diabetes who may be more prone to infections.

Evidence from randomized controlled trials shows that near daily physical activity reduces sick days and lowers the risk of upper respiratory tract infections (URTIs) [76]. Moderate intensity exercise prevents excessive rises in stress hormones and inflammatory cytokines, thereby supporting immune surveillance. Over time, this contributes to improved health outcomes in people with or at risk of diabetes. Moderate endurance exercise has been associated with stable or enhanced immunological markers such as T cell count and serum immunoglobulin levels [77].

By contrast, exhaustive or prolonged exercise may impair immune responses, creating a temporary "open window" of increased infection susceptibility. In athletes or individuals who over train, this can elevate the risk of Upper Respiratory Tract Infections (URTIs) within 3 to 72 hours post-exercise due to suppressed immune function [88]. For diabetes management, this underscores the importance of balancing exercise intensity, ensuring regular moderate activity rather than excessive training, to support both sugar regulation and immune health [79].

2.11.3 Physical Activity in Health and Disease

In 2005, the proportion of English men and women classified as obese was 23.1% and 24.8% respectively. Obesity is a major risk factor for type 2 diabetes, cardiovascular disease (CVD), and some cancers. The direct cost of treating obesity in 2002 was estimated at £45.8–49.0 million, rising to £945–1075 million when indirect costs were included. Since increased physical activity enhances overall energy expenditure and contributes to maintaining glucose balance, it is not surprising that physical inactivity has been linked to higher risks of hyperglycemia, insulin resistance, and diabetes [80]. Indeed, many reports have associated the rising epidemic of type 2 diabetes with increasingly sedentary lifestyles. The decline in energy intake alongside the increase in diabetes prevalence lends further support to this relationship [91].

Evidence also shows an association between physical activity and improved sugar level maintenance. A systematic review examining the effects of physical activity on glycemic regulation identified 16 prospective studies with consistent findings: greater levels of activity were associated with better blood sugar control and reduced diabetes risk [82]. These benefits were observed both in individuals who had and had not previously experienced elevated blood sugar. However, the association between baseline physical activity and later glycemic outcomes remained uncertain. The prospective observational studies suggested that an increase in physical activity energy expenditure (PAEE) of approximately 6300–8400 kJ/week was required to achieve significant improvements in maintaining normal sugar levels and reducing diabetes risk [83].

2.12. Physical Activity Needed to Maintain Glucose Level

The World Health Organization (WHO) has assessed the observational and trial evidence and concluded that there is convincing evidence that regular physical activity helps maintain healthy glucose levels, while sedentary lifestyles increase the risk of impaired glucose control and diabetes [84]. WHO recognises that studies measuring physical activity only at baseline, and exercise intervention studies, do not always provide consistent results. Thus, current patterns of physical activity, rather than past physical activity or enrolment in an exercise programme, are considered most relevant for maintaining normal sugar levels [85].

Although there is some uncertainty around the precise amount of physical activity needed to stabilize glucose levels, it is probably greater than the amount required for the prevention of other chronic diseases. The amount of physical activity required to regulate blood glucose may vary between populations and across life stages [86]. However, consensus at the International Association for the Study of Obesity (IASO) 1st Stock conference suggested that at least 60

minutes per day of activity, or a Physical Activity Level (PAL) of 1.7, is necessary to maintain healthy glucose metabolism and prevent insulin resistance. For children, even more activity is recommended to sustain normal glucose levels. Consequently, this has guided both national and international recommendations [87]. The group concluded that, although definitive data are limited, moderate intensity physical activity of approximately 45–60 minutes per day is effective in improving glycemic control. In children, 45 minutes daily has been associated with healthier BMI and better glucose regulation. It is also recommended to reduce sedentary behaviour, such as television viewing, by at least 30 minutes [88].

2.12.1The Effects of Physical Activity on Maintaining Glucose Levels and Preventing Diabetes

Although evidence from exercise intervention trials suggests that physical activity is not always significantly effective as an initial means of reducing high glucose levels, it has been proposed that physical activity is crucial for maintaining long-term glycemic control [89]. In some, but not all studies, physical activity appears to improve glucose regulation by favourably altering body composition, with a greater proportion of fat mass loss and preservation of lean body mass. Since improvements in blood sugar control can be hindered by reductions in total energy expenditure (TEE) that occur with weight loss, physical activity counteracts this effect by sustaining higher energy output and improving insulin sensitivity. In addition, physical activity may predict better long term glycemic outcomes, as individuals who maintain higher activity levels are often more consistent in dietary regulation and adherence to diabetes management strategies [90].

The prevalence of type 2 diabetes in England is estimated at 3.3% for men and 1.5% for women, with costs to the National Health Service estimated at £5.2 billion annually. Since obesity

is a major risk factor for type 2 diabetes, physical activity plays a key role in both prevention and

sugar level regulation. Importantly, there is substantial evidence that physical activity independently reduces the risk of type 2 diabetes. Prospective studies indicate that physically active individuals have a 33–50% lower risk of developing diabetes compared with inactive individuals. For instance, the Iowa Women's Health Study found that women with a high vs. low physical activity index had a 42% (95% CI 34–49%) reduced risk of type 2 diabetes [91].

Energy expenditure is directly linked to reductions in diabetes risk. For example, each 500 kcal increase in weekly leisure time physical activity has been associated with a 6% lower risk of diabetes. In men, an increase of 500 kcal in energy expenditure reduced the risk by 24%. Similarly, the Alumni Health Study showed declining diabetes incidence with greater energy expenditure. Both non randomized and randomized intervention trials confirm that physical activity improves sugar control and reduces diabetes onset. Findings from the Diabetes Prevention Program demonstrated a 46% reduction in diabetes incidence among participants who achieved at least 150 minutes of moderate-intensity physical activity per week [92].

There is also strong evidence that people at high risk of diabetes (those with impaired glucose tolerance) benefit even more. Physical activity in this group can reduce diabetes risk by up to 64%. Exercise enhances insulin sensitivity and glucose tolerance, thereby helping individuals in a pre-diabetic state manage sugar levels more effectively [93].

2.12.2 Psychological Barriers to Physical Activity

Achieving an increase in physical activity in the population is a great challenge. There are a number of psychological barriers to increasing physical activity levels and an understanding of how these operate is crucial to developing effective ways to promote physical activity. The

challenge is often to translate short-term gains into the adoption and maintenance of physically active behaviours across the lifespan [94].

2.12.3 Environmental Determinants of Physical Activity

Physical inactivity is a major public health problem and is linked to a huge burden of chronic disease. It is crucial to tackle this issue at the policy level and therefore consider the environmental factors contributing to low levels of physical activity [95].

- transport system dominated by cars
- use of lifts and escalators and inaccessible stairs
- TV, computer games, internet and other sedentary entertainment
- Household appliances and labour-saving devices.

An increase in the number of physical activity facilities was associated with decreased overweight and increased relative odds of achieving ≥5 bouts per week of moderate to vigorous-intensity physical activity. These findings emphasise the connection between the built environment and physical activity [96].

Local authorities and town planners have an important role to play in helping people to gain the benefits of being more active, both in terms of providing appropriate sport and leisure facilities, but also by ensuring that pavements and recreational areas are of a suitable standard and that walking areas are well lit and maintained. Although there appears to be limited scope for increasing energy expenditure at work or via domestic activities, active transport initiatives offer some scope [97]. The journey to school is a potentially important opportunity for establishing daily physical activity in childhood, and many schemes have been introduced at governmental, national

and local levels to promote active transport to school. This is supported by evidence that children who walk or cycle to school are more physically active. The benefits of active transport are not limited to children. There is an enormous potential to increase walking and cycling over short trips, but perceived danger and inconvenience are barriers to achieving this.

It is of course critical to use an evidence based approach to designing community-based interventions which aim to increase physical activity levels. The National Institute for Clinical Excellence (NICE) has issued guidance on the promotion of physical activity among adults [98].

The current recommendations for physical activity are:

- Children and young people should achieve a total of at least 60minutes of at least moderate-intensity physical activity each day. At least twice a week this should include activities to improve bone health, muscle strength and flexibility.
- All movement contributes to energy expenditure and is important for weight management. It is likely that for many people, 45–60 minutes of at least moderate-intensity physical activity a day, on five or more days a week. For general health benefit, adults should achieve a total of at least 30 minutes of moderate intensity physical activity a day is necessary to prevent obesity. For bone health, activities that produce high physical stresses on the bones are necessary.
- A number of psychological barriers to physical activity have been identified, especially for those who are obese and need to lose weight. These include issues related to body image, poor confidence and lack of immediate rewards from physical activity.
- A number of behaviour change models have been used to identify personal factors that can help change physical activity behaviour. It is also proposed that change in physical activity

behaviour is more likely to be effective when promotion strategies take into account the stage at which an individual is considering or achieving a change in lifestyle.

- There are a number of environmental factors which contribute to low levels of physical activity and these should be tackled if significant changes to population level physical activity are to be achieved. Policies which support active transport initiatives have proved to be effective in other countries and thus have greater potential in the UK.
- NICE offers a range of guidance on the effectiveness of different methods of promoting physical activity. However, current research is limited and ongoing work may provide additional guidance in the coming years.
- There are a small number of risks associated with physical activity, many of which are only linked to contact sports or physical activity at very high intensities. Many of the risks of physical activity can be avoided by building up physical activity levels gradually.

2.13. Summary of Reviewed Literatures

- The synergistic effect of unripe plantain (Musa paradisiacae), okra seeds (Abelmoschus esculentus), and bitter yam (Dioscorea dumetorum) extracts on alloxan-induced diabetic rats was investigated using standard methods. Thirty-six (36) albino rats were induced with hyperglycemia using alloxan. The results obtained showed that body weight increased in groups 3, 4, and 5 after administering the synergistic extract. However, there was a decrease in body weight in group 2 due to hyperglycemia. Glucose concentration decreased in groups 3, 4, and 5 respectively, with the decrease being higher in group 5 due to the higher dosage of extract, and this was compared to glibenclimide. Results of the liver function test showed that the marker enzymes Aspartate aminotransferase (AST), Alanine aminotransferase

(ALT), and Alkaline phosphatase (ALP) as well as total and direct bilirubin were found to be within acceptable limits. Therefore, the synergistic extracts proved to be more effective in controlling blood glucose in rats than glibenclimide without toxic effects on the liver [99].

- Unripe plantain and red banana were processed into flour and were subjected to proximate analysis using standard procedures. Twelve apparently healthy normo-glycaemic adults of normal body weight consumed 50 g digestible carbohydrate from glucose drink and test diets. Blood glucose concentration was measured prior to the consumption of the control and test diets and at 30, 60, 90, and 120 minutes after consumption of the standard and test diets. Glycemic indices of the test diets were calculated. Data obtained were analyzed using descriptive statistics of SPSS version 16 and were presented as means and standard deviations. Unripe plantain and unripe red banana flours contained crude fiber (0.82% and 1.11%) and carbohydrate (85.85% and 86.77%), respectively. Glycemic indices of unripe plantain and unripe red banana flour meals were 52.80 and 54.96, respectively [100].
- Ripe and unripe plantain diets processed by frying, roasting, and boiling were investigated for their effects on blood glucose levels. In the study, 30 human volunteers consumed 161g of different plantain diets individually, prepared to be equivalent to 50g of available carbohydrate or glucose after a 10-12 hour overnight fast. Venous blood samples were collected at 30-minute intervals for 2 hours following a fasting blood glucose test. Blood glucose levels post-feeding were determined using the glucose oxidase method, and the areas under the curve were calculated using the trapezoid method. The glycemic index values for ripe plantain diets were found to be 56, 54, and 55 for fried, boiled, and roasted, respectively. Meanwhile, the glycemic indices for unripe plantain diets were 46, 44, and 46 for fried, boiled, and roasted, respectively. Significant differences ($P < 0.05$) were observed in the

glycemic indices of ripe and unripe plantain diets; however, both were within the low glycemic index range. Among the processing methods, the study suggests that boiled unripe plantain offers more promising control over blood glucose levels and better glycemic management in carbohydrate-related metabolic disorders than other methods [101].

- The nutritional content of selected species of tropical eggplant fruit (Solanum spp) diet attenuates hepatic inflammation in high-fat-fed male Wistar rats induced with streptozotocin. Tropical Solanum species contain a high level of phenolic acids and flavonoids, which were found to inhibit some key enzymes associated with the incidence of type 2 diabetes in in vitro and in vivo models based on earlier studies. This study was further designed to compare the nutritional properties, glycemic index, and hypolipidemic and antioxidant effects of three species of tropical eggplant fruit (Solanum kumba, Solanum aethiopicum, and Solanum gilo) diet on streptozotocin (STZ)-induced nephrotoxicity in male Wistar rats. The animal model was subjected to a high fat diet prior to intraperitoneal administration of streptozotocin (35 mg/kg wt); thereafter, the rats were given a supplemented eggplant fruit diet for 14 days. Determination of lipid content [triglycerides (TG), low-density lipoproteins (LDLs), high density lipoproteins (HDLs), and total cholesterol (TC)] was assessed, while the liver biomarker enzymes alanine aminotransferase (ALT), alkaline phosphatase (ALP), and aspartate aminotransferase (AST), as well as endogenous enzymes such as superoxide dismutase (SOD) and catalase (CAT), were determined. Histopathological assessment of inflammation was carried out on the kidney, while the blood urea nitrogen (BUN), uric acid, and creatinine levels related to kidney function were determined. The results showed that the groups with supplemented eggplant diet had significant ($p < 0.05$) reductions in lipid profile, decreased leakages of liver and kidney function enzymes, and restoration of depleted

endogenous antioxidant enzymes. The inflammatory cells and fat deposits from the histopathological view were reduced. However, S. kumba had the best nutritional output [102].

- Lead is one of the heavy metals humans are often exposed to, either through food, cosmetics, or the environment. A study aimed to investigate the positive effects of Solanum melongena (garden egg), Solanum lycopersicum (tomatoes), and Daucus carota subsp. sativus (carrot) on blood glucose concentration, body weight, and feeding habits of albino rats subjected to lead toxicity. In this research, 35 albino rats weighing 80-120g were divided into five groups. Group 1 served as the normal control, while Group 2 acted as the negative control. The remaining three groups were designated as treatment groups 1, 2, and 3. All groups, except Group 1 (normal control), were administered 50mg/kg of lead acetate. Treatment groups received 200mg/kg of Solanum melongena (garden egg), Solanum lycopersicum (tomatoes), and Daucus carota subsp. sativus (carrot). Group 3 was given Solanum melongena and Daucus carota subsp. sativus, while Group 4 received Daucus carota subsp. sativus and Solanum lycopersicum. Group 5 was administered Solanum melongena, Daucus carota subsp. sativus, and Solanum lycopersicum. Changes in blood glucose concentration, body weight, feed, and water consumption were recorded at intervals. The results demonstrated a significant decrease ($P<0.05$ and $P<0.01$) in blood glucose concentration in the treatment groups compared to the negative control. Additionally, there was a significant increase ($P>0.05$, $P>0.01$, and $P>0.001$) in body weight and feed consumption in the treatment groups compared to the negative control. Combined therapy with any two of Solanum melongena, Daucus carota subsp. sativus, and Solanum lycopersicum juice can aid in managing hyperglycemia and reversing internal abnormalities or injuries resulting in weight loss due to lead-induced toxicity [103].

- A systematic review and meta-analysis titled "Chitosan Nanogel with Mixed Food Plants and Its Relation to Blood Glucose in Type 2 Diabetes: A Systematic and Meta Analysis Review of Observational Studies" evaluated the beneficial effects of certain food plants in type 2 diabetes (T2D) when consumed alone or in combination with chitosan. The primary goal of the study was to examine the relationship between chitosan nanogel and mixed food plants (MFP) in controlling T2D. Data for the review were sourced from Medline, Scopus, PubMed, and Cochrane databases, covering the period between January 1990 and January 2021. Eligibility criteria focused on case controlled studies involving unripe plantain, bitter yam, okra, and chitosan either used alone or in combination with non specified food plants (NSFP). Information retrieval and bias evaluation were conducted independently by two critics. Random effects meta analyses on blood glucose control were performed. Findings from 18 studies included seven examining unripe plantains, one on bitter yam, two on okra, and eight on chitosan. These studies demonstrated a decrease in blood glucose levels. However, meta analysis revealed significant heterogeneity (I^2 = 98%), making combined effect sizes less useful. Consequently, prediction intervals (PI) were used instead of confidence intervals (CI), yielding results such as a mean difference of 4.4 mg/dl (95% PI -6.65 to 15.50) and 3.4 mg/dl (95% PI -23.65 to 30.50). The studies were assessed as having a 50% high risk of bias and a 50% low risk of bias, with an unclear risk due to insufficient information from study protocols. Intervention durations ranged from three to 84 days, indicating effectiveness over both short and long periods. However, due to the moderately low quality of the studies, findings were cautiously interpreted. In conclusion, current evidence supports the relationship between chitosan combined with mixed unripe plantain, bitter yam, and okra in managing T2D. Nonetheless, further high-quality case-controlled animal studies are necessary to

validate whether chitosan nanogel should be cross-linked with specified food plants (SFP) for T2D management [104].

- The research titled *Use of unripe plantain (Musa paradisiaca) in the management of diabetes and hepatic dysfunction in streptozotocin induced diabetes in rats* aimed to investigate the effect of unripe plantain (Musa paradisiaca) on markers of hepatic dysfunction in streptozotocin induced diabetic rats. Methods included determining blood glucose; relative liver weight (RLW); relative kidney weight (RKW); relative heart weight (RHW); relative pancreatic weight (RPW); serum and hepatic serum aspartate transaminase (AST), alanine transaminase (ALT), and alkaline phosphatase (ALP); serum amylase, lipase, total, and conjugated bilirubin; and chemical analysis of the test feed using standard techniques. Results showed that diabetic rats had significant alterations ($P < 0.05$) in blood glucose; RLW; RKW; RPW; serum and hepatic AST, ALT, and ALP; serum total and conjugated bilirubin; and serum lipase activities compared to nondiabetic rats, while these parameters were significantly improved ($P < 0.05$) in rats fed unripe plantain. There were no significant differences ($P > 0.05$) in RHW among the groups, along with significant decreases ($P < 0.05$) in amylase levels of diabetic rats compared to nondiabetic rats, but a nonsignificant increase ($P > 0.05$) in amylase levels was observed in rats fed unripe plantain compared to nondiabetic rats. The test and standard rat feeds contained considerable amounts of proteins, carbohydrates, fats, phenols, and crude fiber. The study concluded that amelioration of acute pancreatitis by unripe plantain could play a key role in its management of diabetes and related complications [105].
- A study aimed to formulate a functional and optimized diet using unripe plantain combined with soycake and rice bran, comparing its antidiabetic potentials to those of cerolina and

unripe plantain in both flour and dough forms, while also examining the impact of cooking on antioxidant and overall antidiabetic properties by comparing dough and flour preparations. Using response surface methodology (RSM), the optimal flour blend was established through proximate analysis and sensory evaluation, from which a dough meal (PSRD) was prepared. The antidiabetic (α-amylase and α-glucosidase inhibition) and antioxidant (DPPH and hydroxyl scavenging, metal chelating activities, and ferric reducing antioxidant power) effects were assessed in vitro. Male Wistar rats subjected to a high-fat diet and low-dose streptozotocin were divided into groups receiving various treatments, including the optimized flour (PSRF) and dough (PSRD), cerolina flour (CERF) and dough (CERD), unripe plantain flour (PLTF) and dough (PLTD), glybenclamide, a positive control, and a negative control. Over 28 days, oral administration of these treatments was followed by histological and biochemical evaluations of the pancreas and liver, focusing on antioxidant markers (GST, GPx, catalase, superoxide dismutase activities; NP-SH, GSH, MDA concentrations) and anti-inflammatory markers (MPO, XO, TNF-α, IL-1β, IL-6). Results demonstrated the interplay between diabetes mellitus, oxidative stress, inflammation, and pro-inflammatory cytokines, with the optimized dough showing superior inhibition of α-amylase and α-glucosidase activities compared to the flour blend. Furthermore, the optimized dough provided enhanced antioxidant and anti-inflammatory protection against pancreatic and hepatic dysfunctions associated with type-2 diabetes mellitus [106].

- The existence of bioactive chemicals in plants is essential for the development of their therapeutic qualities, and it is necessary to test medicinal plants regularly to establish the scientific foundation for their use. An experimental study explored the health and aesthetic benefits of Alchornea cordifolia (ogyama) in preparing cassava fufu, analyzing cassava

plantain fufu, cassava fufu, and cassava ogyama fufu to determine their glycaemic index and glycaemic load, as well as conducting a sensory evaluation of food acceptance using questionnaires. Statistical analysis, including one way analysis of variance and independent sample tests with a significance level of 95%, revealed that all three fufu varieties have high glycaemic indices and loads, with cassava fufu having the highest glycaemic index of 78.3, cassava plantain fufu at 73.9, and cassava ogyama fufu the lowest at 54.3. Sensory evaluation showed cassava plantain fufu was most preferred in terms of color, taste, aroma, mouth feel, aftertaste, and overall acceptability, while cassava fufu was least acceptable. The study recommends cassava ogyama fufu for diabetics seeking to manage their health while enjoying fufu [107].

- A study investigated the antidiabetic potential of a diet supplemented with boiled unripe plantain (Musa paradisiaca) in streptozotocin induced Wistar rats, evaluating its effects and properties using standard methods. The research focused on diets containing boiled unripe plantain (20%–40%) in high fat fed/low dose of streptozotocin-induced diabetic rats, comparing outcomes to acarbose administration. Diabetes was induced in twenty-five male Wistar rats using a high fat diet and a low dose of streptozotocin (25 mg/kg body weight), with five normal rats serving as a control group. The animals were divided into five groups of six rats each, and the experiment lasted for 14 days, assessing blood glucose concentration, enzyme activities (α-amylase, α-glucosidase, angiotensin I converting enzyme), thiobarbituric reaction substance (TBARS), High-density lipoprotein-cholesterol (HDL-c), and antioxidant status. Findings revealed elevated blood glucose levels and increased activities of α-amylase, α-glucosidase, angiotensin I converting enzyme, and TBARS in untreated diabetic rats (Group II), while diabetic rats on diets supplemented with boiled

unripe plantain (Groups IV and V) showed reversed trends, with results comparable to those of acarbose-treated groups. Contrasting biochemical assay results were observed in untreated diabetic rats (Group II). This study underscores the therapeutic potential of boiled unripe plantain as a cost effective strategy for diabetes management, particularly in developing nations [108].

- Various flour blends were evaluated for their glycemic index (GI), glycemic load (GL), and in vivo antidiabetic potentials, including PLT (100% Plantain), PSC (Plantain 70%, Soycake 30%), PSR (Plantain 65%, Soycake 30%, Rice bran 5%), PSO (Plantain 65%, Soycake 30%, Oat bran 5%), PSRO (Plantain 60%, Soycake 30%, Rice bran 5%, Oat bran 5%), and CNL (Cerolina, a wheat and soybean blend). Results indicated that the GI (30.48–35.33) and GL (18.79–21.98) of PSR, PSO, and PSRO were lower than those of PLT, CNL, and the recommended values for low GI (= < 55%) and GL (= 20%). Additionally, PSRO demonstrated the highest blood glucose reducing activity (82.72%) compared to other blends, PLT, and Cerolina. These findings established that PSRO (60% plantain, 30% soycake, 5% rice bran, 5% oat bran) exhibited a low glycemic index, low glycemic load, and high blood glucose lowering potential, suggesting its suitability as a functional food for the prevention and management of Type-2 diabetes [109].

- Dietary habits and lifestyle are major contributors to the increase in diabetes mellitus cases in developing nations. Due to the high cost and limited accessibility of treatments, a study aimed to create affordable, functional dough meals using locally sourced unripe plantain, soybean cake, and rice bran. After initial analysis, three specific blends were chosen for their high protein and crude fiber content. The formulated meals had an essential amino acid content of 40.2% to 41.5%, surpassing the 39% benchmark for ideal protein foods. When

tested on diabetic rats, the dough meals reduced blood glucose levels by about 76% and helped stabilize their lipid profiles within normal ranges. The meals were well received in sensory tests, making them a promising and accessible dietary option for managing diabetes, particularly in rural areas [110].

- Research conducted on the biochemical ameliorating potential of optimized dough meals made from blends of plantain (Musa AAB), soycake (Glycine max), and rice bran (Oryza sativa) flours in streptozotocin induced diabetic rats highlights the growing trend of using food as therapy for managing diseases caused by metabolic derangements, including genetic disorders, through functional and nutritional diets designed to maintain health throughout life. Diabetes Mellitus is one such disease that can benefit from this approach. The study aimed to formulate functional diets from these flour blends, which were processed into dough and referred to as optimized flour blends and dough meals. Using 100% plantain flour (PLTF) and 100% cerolina (CERF) as positive and negative controls respectively, the protein efficiency ratio of the optimized flour blends and dough meal samples fed to rats ranged between 0.73 in PLTF and 3.23 in PSRD. It was observed that the flour blends were less digestible than the dough meal flours, and the dough meal flours (PLTD, CERD, and PSRD) exhibited higher α–amylase inhibitory activity compared to the raw flour samples (PLTF, CERF, and PSRF), with PSRD demonstrating the highest α–amylase inhibition at 30%, significantly greater than the others. Regarding α-glucosidase inhibition, values ranged from 25% in PLTD to 32% in PSRD, with the raw flours showing lower inhibition compared to the dough meal samples. Furthermore, rats fed with the optimized diets showed enhanced endogenous antioxidant status [111].

- Diabetes, a metabolic disease affecting individuals across all age groups worldwide, is linked to oxidative stress caused by reactive free radicals in the human body. In traditional medicine, plant based diets such as unripe plantain and water yam have been utilized for diabetes management. A study aimed at exploring the antioxidant properties, α-amylase and α-glucosidase inhibitory activities, glycemic index, blood glucose concentration, and sensory attributes of dough meals made from flour blends of unripe plantain, water yam, and bitter leaf demonstrated significant findings. The research highlighted remarkable free radical scavenging activity and ferric ion reducing power as water yam supplementation increased. Additionally, the inhibition of α-amylase and α-glucosidase activities by the dough meal was found to be influenced by the percentage of water yam inclusion, underscoring its antihyperglycemic potential. Notably, rats consuming dough meals containing 40% water yam supplementation exhibited significantly lower glycemic indices compared to those consuming 100% unripe plantain dough meals. These findings provide evidence that dough meals formulated from unripe plantain, water yam, and bitter leaf could serve as functional foods to mitigate postprandial hyperglycemia [112].
- Diabetes remains a pressing global health concern, with the number of affected individuals steadily increasing. Conventional antidiabetic therapies, while widely used, often entail high costs and limited effectiveness. As a result, traditional medicine and plant-based treatments have garnered significant attention worldwide, particularly in the Middle East, where there is a longstanding tradition of utilizing herbal remedies for various ailments, including diabetes. A comprehensive review by Abu-Odeh and Talib (2021) explored the antidiabetic potential of Middle Eastern medicinal plants, compiling both in vivo and in vitro studies. Their findings emphasized that plants belonging to the Asteraceae and Lamiaceae families are among the

most extensively researched for their antidiabetic properties. The review seeks to provide scientific validation for the ethnobotanical use of these plants as antidiabetic agents. However, the authors stress the need for further research to elucidate mechanisms of action, pinpoint active compounds, and assess safety and pharmacokinetics [113].

- The review titled "Nonconventional Hydrocolloids' Technological and Functional Potential for Food Applications" aims to explore alternatives to conventional industrial starches, focusing on uncommon sources and their technological characteristics, processing methods, and performance in food products. Minor components left after extraction, such as minerals in tuber starches, can significantly influence starch performance, particularly in gelatinization, which may be tailored to meet diverse food industry requirements. These diversified applications include the production of both plant and animal based products with varied sensory attributes. Moreover, hydrocolloids distinct from starch can alter the technological behavior of the amylaceous fraction, suggesting that combinations should be carefully evaluated to address advantages and disadvantages related to biological origin, consumer perception, and technological outcomes. Starches and nonstarch hydrocolloids are notable modifiers in water based systems, with applications extending beyond food industries into other specialties, presenting an opportunity for a diversified production scheme that could mitigate the challenges posed by current monocrop practices and contribute to the future sustainability of the food system [114].
- Pasta made from durum wheat semolina typically has a medium, high glycemic index, high starch digestibility, and limited nutritional value due to its low fiber, vitamin, and bioactive compound content. To enhance its nutritional and functional qualities, researchers studied the incorporation of Pleurotus eryngii (PE) mushroom powder at various substitution levels into

fresh durum wheat semolina pasta to achieve at least one nutritional claim. This research involved two phases: assessing the chemical/physical, nutritional, functional, and sensory properties of laboratory-scale samples and validating selected formulations through industrial-scale production and shelf life analyses. Their findings revealed that the pasta sample with 8.62% PE substitution (SPE8-P) exhibited significantly improved nutritional qualities, including high fiber content sufficient for a "high fiber content" claim and potential prebiotic activity demonstrated by increased bifidobacterial density during simulated fecal microbiota fermentation. While enhanced riboflavin and antioxidant content were observed, regulatory constraints prevented claims related to vitamin B2 richness and antioxidant activity. Sensory analysis indicated that the color, taste, and odor profiles were affected, yet overall acceptability remained high, supporting the product's potential for consumer acceptance. This study confirms the feasibility of producing innovative, nutritionally enriched pasta with PE powder as a functional ingredient, with future research aimed at in vivo evaluation to determine its classification as a functional food [115].

- Brasenia schreberi (BS), a perennial aquatic plant of the water lily family, is increasingly recognized as a functional food. Polysaccharides extracted from BS have demonstrated antihyperglycemic and antihyperlipidemic activities, suggesting their potential as hypoglycemic agents. In a study aimed at partially clarifying the structural characteristics and evaluating the hypoglycemic potential of Brasenia schreberi polysaccharide (BSP), BSP was isolated from the mucilage covering the surface of BS. Structural analysis using SEM and AFM revealed that BSP molecules were tightly connected, forming a ring-shaped network structure. Further investigation determined that BSP is an acidic heteropolysaccharide with a molecular weight of 2.47×10^4 Da, consisting of a main chain with 1,2,3-linked α-D-Galp,

1,2-linked α-D-Manp, and 1,4-linked β-GlcA residues, and side chains including 1,3-linked α-Galp, 1,3-linked α-Fucp, 1,3-linked α-Xylp, T-Araf, and T-Rhap. Rheological analysis showed that BSP solutions behave as pseudoplastic fluids with shear-thinning properties, while its gel strength and texture improve with increasing BSP and Ca^{2+} concentrations. Notably, BSP exhibited strong inhibitory activity against α-amylase and α-glucosidase, highlighting its promise as a candidate for hypoglycemic functional food [116].

- Historically, unripe plantain has been a staple in traditional medicine for managing diabetes and hypertension, with local communities often using it as a wet paste or powder. A recent study explored the effects of diets made from whole unripe plantain flour on diabetic and hypertensive (DH) rats. The researchers created various cookies (Diet A-E) from the flour and analyzed their sensory qualities, amylose to amylopectin ratio, and glycemic index (GI). They then divided the rats into several groups: a healthy group, an untreated DH group, a DH group treated with standard medication (acarbose/captopril), and DH groups fed the different plantain diets. After 14 days, the study revealed that diets with a higher amylose content, lower amylopectin, and a moderate GI effectively reduced fasting blood glucose (FABG) and blood pressure (BP) in the DH rats. Furthermore, these diets lowered the activity of carbohydrate digesting enzymes, angiotensin-converting enzymes, and arginase, while simultaneously improving antioxidant status compared to the untreated group. These results indicate that diets supplemented with whole unripe plantain flour are safe and offer significant health benefits, suggesting they could be developed into functional foods for managing diabetes and its associated complications [117].

- In patients with chronic kidney disease (CKD), the accumulation of specific gut-derived toxins like indoxyl sulfate (IS), p-cresyl sulfate (pCS), and indole 3-acetic acid (IAA)

contributes to the disease's severity. Prebiotics, which modulate the gut microbiota, are seen as a potential way to reduce these compounds. A randomized, double blind, placebo controlled, crossover trial was conducted to investigate the effect of unripe banana flour (UBF), which contains 48% resistant starch, a prebiotic, on the serum levels of these toxins in individuals undergoing peritoneal dialysis (PD). Forty-three PD patients were randomly assigned to two groups, receiving either 21 g/day of UBF or 12 g/day of placebo (waxy corn starch) for four weeks, with a four week washout period between treatments. The primary goal was to measure changes in total and free serum levels of IS, pCS, and IAA. Secondary outcomes included urine excretion and dialysis removal of these toxins, as well as inflammatory markers and dietary intake. Of the 43 participants, 26 completed the study. The results showed that UBF did not significantly change the overall serum levels of IS, pCS, or IAA. However, a reduction in total serum IS was observed in a smaller subgroup of participants who consistently consumed the full 21 g/day dose of UBF. No changes were noted in the other secondary outcomes. Ultimately, the study concluded that UBF did not significantly alter the serum levels of these toxins, though a modest effect on IS was seen in a subgroup of compliant participants [118].

- Traditionally, various parts of the plantain tree have been used in folklore to manage diabetes and other human illnesses, yet little is known about the specific properties of plantain bulb extract (PBE) and its mechanisms. A study was conducted to evaluate the effects of PBE beverage blends, sweetened with honey and containing either 1% or 2% cocoa powder, on streptozotocin (STZ)-induced diabetic rats. The rats were divided into seven groups: a normal control group, an untreated diabetic group, a group treated with acarbose (a standard diabetes medication), and four groups receiving different PBE formulations (PBE alone, PBE with

honey, PBE with honey and 1% cocoa, and PBE with honey and 2% cocoa). The untreated diabetic rats showed higher blood glucose levels and increased activity of carbohydrate hydrolyzing enzymes, along with significantly reduced levels of both enzymatic and non enzymatic antioxidants. However, rats treated with any of the plantain bulb formulations showed a reversal of these negative effects. The blend containing 2% cocoa powder and honey (CHPBE-2) was found to be slightly more effective than the blend with 1% cocoa (CHPBE-1). The findings suggest that both of these blends could be used as beneficial nutraceutical or functional drinks for managing diabetes [119].

- Vegetables offer significant nutritional and health benefits, making them a crucial component of a healthy diet. They are rich in various bioactive compounds that can help lower the risk of certain diseases. Each type of vegetable and each vegetable family possesses a unique combination of these compounds, so their health benefits shouldn't be attributed to just one kind of vegetable. Research suggests that vegetables have anti oxidative, anti carcinogenic, anti diabetic, and cardiovascular disease lowering effects. Although the precise mechanisms by which these compounds reduce disease risk are complex and not always fully understood, the evidence for their positive impact is clear [120].
- Plantain (*Musa paradisiaca*) fruit peels, both ripe and unripe, have been studied for their nutritional and phytochemical content, as well as their potential as antioxidants and anti hyperglycemic agents. Proximate analysis of the peels revealed that their primary components are moisture, carbohydrates, ash, crude fiber, and crude fat, with a small amount of crude protein. The aqueous extract of the peels was found to contain important phytochemicals like alkaloids, flavonoids, phenols, reducing sugars, and amino acids. Further analysis using High Performance Liquid Chromatography Mass Spectrometry (HPLC/MS) identified 15 specific

compounds, including phenolic compounds, sterols, and sitoindosides, with quercetin making up about half of these compounds. The study found that the unripe peel extract had significantly better 2,2nDiphenyl 1 Picrylhydrazyl (DPPH) radical scavenging activity than the ripe peel extract. The unripe peel extract's effectiveness was comparable to that of a standard, gallic acid. Both ripe and unripe peels demonstrated strong alpha-amylase inhibitory activity, but the unripe peels were more potent. Interestingly, the unripe peel's aqueous extract had an inhibitory value identical to acarbose, a common anti diabetic drug. While the hydroethanolic extract of the unripe peels was less effective at inhibiting alpha-amylase compared to acarbose, it showed significantly superior alpha glucosidase inhibitory activity. These findings suggest that plantain peels can be used in both human and animal nutrition and that unripe plantain peel extracts, particularly, hold great promise for the prevention and management of type 2 diabetes [121].

- While people typically eat *Musa* cultivars after removing the peels, prior research suggests that the peels contain valuable nutrients, phytochemicals, and antioxidants. A comparative study investigated the anti diabetic potential of the flours from the pulp of *M. paradisiaca* and the whole flours (pulp and peel) of three common *Musa* cultivars: *M. paradisiaca, M. sapientum*, and an AAB group hybrid. Aqueous extracts from the pulverized M. paradisiaca pulp (PP), whole hybrid (WH), whole M. sapientum (WB), and whole M. paradisiaca (WP) were analyzed for their glycemic index, in vitro antioxidant properties, and their ability to inhibit the enzymes α-amylase and α-glucosidase. All three whole flour samples exhibited low glycemic index values, similar to that of the PP flour. The WH, WB, and WP flours showed higher levels of total flavonoids, as well as greater DPPH, FRAP, and α-amylase inhibitory activity compared to the PP flour. Conversely, the PP flour demonstrated a better

ability to scavenge OH* radicals and higher α-glucosidase inhibitory activity than the other flours. The findings indicate that all tested samples are low glycemic foods, and the whole hybrid flour (WH) in particular, with its high total phenols, flavonoids, and enzyme inhibitory activities, could be especially beneficial for managing diabetes [122].

- Natural product therapy has been used to treat illness for thousands of years, and modern-day medicines, such as various anticancer, antihypertensive, and antimigraine drugs, have been developed from natural products. Natural medicines are advantageous as they tend to have fewer side effects and are considered a relatively safe option. *Solanum aethiopicum* L. (*S. aethiopicum*) is a vegetable crop of the Solanaceae family and is considered one of the five most important crops in sub-Saharan Africa, alongside tomatoes, onions, peppers, and okra. *S. aethiopicum* has many health benefits as it contains the three major macronutrients (carbohydrates, proteins, and fats) as well as fiber and many essential vitamins. Additionally, much research has been conducted on the medicinal value of *S. aethiopicum* over the past few decades. *S. aethiopicum* has been found to have many pharmacological properties including anti inflammatory, antibacterial, antidiabetic, anti obesity, and antioxidant effects. Currently, to our knowledge, there are no comprehensive reviews of the numerous studies on *S. aethiopicum*. Therefore, in this review, we summarize the nutritional, phytochemical, and pharmacological analyses of *S. aethiopicum*, identify notable effects, and review the results [123].

- Nutrition transition to high energy dense foods has been implicated as the major causes of diet related diseases. Plantain based dough meals supplemented with soybean cake and cassava fibre were developed by combining them in different proportions using response surface methodology. The flour blends were analyzed for the nutritional composition while

the glycaemic index, antidiabetic potentials and protein digestibility of the dough meals were determined in wistar rats. The nutritional and essential amino acid contents of the flour blends were comparable to that of cerolina (a commercially available food product commonly recommended for diabetic patients). The rats fed with the formulated dough meals had lower glycaemic index and glycaemic load, and the blood glucose was significantly reduced compared to cerolina and metformin (a synthetic antidiabetic drug). All the plantain-based dough meals were comparable to cerolina and metformin in terms of nutritional quality and blood glycaemic control activities, respectively. Hence, the formulated plantain based dough meals have potential to be used for the prevention and management of diabetes mellitus [124].

- *Solanum melongena* (*SM*) is commonly known as the garden egg fruit or eggplant. It can be eaten fresh or cooked and has a large history of consumption in West Africa. This study focused on interventions of aqueous extract of *SM* (garden eggs) fruits on Mercury chloride ($HgCl_2$) induced testicular toxicity in adult male Wistar rats. Thirty two adult male Wistar rats were randomly divided into four groups (A-D) of eight (n = 8) rats each. Group A Served as control and was given 10 ml/kg/day of distilled water, Group B 500 mg/kg B.W of *SM*, Group C received 40 mg/kg B.W $HgCl_2$ and Group D- 500 mg/kg B.W of *SM* and 40 mg/kg B.W $HgCl_2$). The administration was done by gastric gavage once a day, for twenty eight consecutive days. Testicular weight, semen analysis revealing the sperm count and sperm motility were assessed, gross parameters of the testis and testicular histology were assessed. Testicular oxidative stress markers viz a viz malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx) and reduced glutathione (GSH) were also assessed. Assessment of the histological profiles of the testes showed a derangement of the cytoarchitecture and deterioration of sperm quality after

$HgCl_2$ administration and a marked improvement was observed after *SM* administration. Similarly, *SM* was associated with increased antioxidant parameters (SOD, CAT, GPx, and GSH) and decreased MDA in SM + $HgCl_2$ rats. It was concluded that *S. melongena* offers protection against free radical mediated oxidative stress of rats with mercury chloride induced testicular toxicity [125].

Endnotes

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Chapter

Three

Methodology

3.1 Materials

The materials used in this research included the plant materials [unripe plantain and garden egg], experimental animals (42 male Wistar rats), chemical reagents, and equipment necessary for extract preparation, diabetes induction, and biochemical analysis.

3.1.1 Plant Materials

Fresh *Musa paradisiaca* (giant horn unripe plantain) and *Solanum melongena* (white garden egg) were selected for this study. The plantain samples were obtained from Ojei Market, Ibadan, Oyo State, while the garden eggs were purchased from Ayeye Market, Ibadan, Nigeria.

Unripe plantains was chosen due to their low sugar and high resistant starch content, which have been associated with improved glycemic control. Garden egg was selected because of its antioxidant rich polyphenols and alkaloid composition, which have been implicated in glucose metabolism modulation.

Immediately after procurement, both plant materials were transported to Human Nutrition and Dietetics Department Lead City University, Ibadan, in sterile polythene bags to avoid contamination. On arrival, they were examined for freshness, uniformity in size, and absence of physical damage. Only healthy samples were retained for processing.

3.1.2 Experimental Animals

The study utilized forty two (42) healthy adult male Wistar rats with initial body weights ranging from 115–200 g. The animals were obtained from the Animal House in Obafemi Awolowo University, ile - ife, osun state, transported to Benin and housed at the Animal house, Department of Science Laboratory Technology, University of Benin, where they were maintained under standard laboratory conditions.

All the rats used for the experiment were housed in clean cages. The room temperature was maintained at 22 ± 2 °C, relative humidity at 55 ± 5%, and a 12 hour light/dark cycle was observed [1]. The rats were provided with standard grower pellet feed (Chikun Feeds, Lagos, Nigeria) and clean drinking water ad libitum throughout the experiment.

A seven day acclimatization period preceded all experimental procedures to allow physiological stabilization. During this period, the wistar rats were closely monitored; feeding pattern, mobility, and general health condition [2]. Any rats showing signs of illness or distress were excluded and replaced.

Ethical clearance was obtained from Lead City University under ethical identification number LCU/-REC/25/282.

3.1.3 Chemicals and Reagents

All chemicals and reagents used were of analytical grade. The following were employed:

- Streptozotocin (STZ) – purchased from *ICO Allied Industry Research Chemical Supplies, Togo* for induction of experimental diabetes.
- Sodium citrate buffer (0.1 M, pH 4.5) – used as solvent for STZ preparation.

- Metformin hydrochloride (500 mg/kg) – obtained from *Emzor Pharmaceutical Industries, Nigeria*, used as standard hypoglycemic reference drug.
- Distilled water – used for solution preparation and rinsing of equipment.
- Biochemical assay – used for serum liver, kidney, and lipid profile analyses.
- Chloroform – used for anesthesia prior to sacrifice.
- 10% formal saline solution – used for fixation and preservation of tissue specimens.

All reagents were properly labeled, stored in accordance with manufacturer specifications, and handled under strict safety protocols, ensuring compliance to laboratory safety regulations.

3.2 Processing of Plant Materials and Extract Preparation

The entire extraction process was conducted under a conducive environment, to ensure procedural accuracy and reproducibility. All glassware were sterilized prior to use, and the working bench was disinfected using 70% ethanol to minimize microbial contamination.

Step I: Rinsing

Freshly purchased unripe plantains and garden eggs were first rinsed thoroughly under running tap water, followed by a final rinse using distilled water to remove surface dirt, pesticides, and other contaminants. This was essential to prevent microbial interference and ensure sample purity prior to further processing. The rinsing was done manually using gloved hands, with the samples arranged in stainless steel trays. The process was repeated until the rinse water appeared clear.

Step II: Peeling and Slicing

Each plantain was peeled using a sterile stainless steel knife, ensuring that minimal pulp was lost. The peeled plantain pulps were then sliced into thin circular rings of approximately 2–3 mm thickness using a calibrated slicing device to maintain uniformity. Similarly, garden eggs were washed, de stemmed, and sliced into thin rings of similar thickness. Uniform slicing was crucial to ensure consistent drying and extract yield.

Step III: Blanching

To inactivate enzymes that could cause browning or nutrient loss, both the sliced unripe plantain and garden egg samples were subjected to blanching. The slices were immersed in hot water at 80 °C for 5 minutes using a laboratory water bath (Gallenkamp Model W83). After blanching, the slices were rapidly cooled under running tap water to halt enzymatic reactions.

This step was performed to reduce microbial load and preserve phytochemical integrity prior to drying [3].

Step IV: Drying

The blanched samples were air shade dried at room temperature (25–28 °C) for 12 hours to remove surface moisture. Subsequently, controlled oven drying was carried out:

- Unripe plantain slices were oven dried at 65 °C for 48 hours using a *Memmert UM400 laboratory oven*.
- Garden egg slices were oven dried at 60 °C for 72 hours.

Samples were spread evenly on clean stainless steel trays to avoid overlapping, which could hinder air circulation. The drying process was continuously monitored until constant weight was

achieved. The dry samples were then allowed to cool to room temperature in a desiccator to prevent moisture reabsorption [4].

Step V: Milling

The dried samples were separately milled into fine flour using a *Kenwood laboratory electric blender (Model BL440)*. The blending was done in batches to prevent overheating. Each batch was sieved using a 1 mm mesh to obtain a uniform particle size. The resulting unripe plantain flour and garden egg flour were weighed using a digital analytical balance (Mettler Toledo AB204) and stored in airtight amber containers until needed for extract formulation.

Step VI: Extract Formulation

To prepare the bi-herbal aqueous extract:

i. 500 g of unripe plantain flour and 500 g of garden egg flour were measured accurately and combined in a large sterile soaking jar (capacity: 10,000 ml).

ii. 25,000 ml of distilled water was added as solvent, maintaining a 1:25 w/v ratio, which ensured efficient extraction of water soluble phytochemicals.

iii. The mixture was stirred thoroughly using a glass rod and allowed to stand for 24 hours at room temperature for maceration.

After maceration, the suspension was filtered using a double layered muslin cloth, followed by Whatman No. 1 filter paper to obtain a clear filtrate. The filtrate was then oven dried at 60 °C for 48 hours to yield a dry dietary extract, which appeared as a light brown powder [5].

The dry extract was collected, weighed, and stored in airtight amber bottles in a refrigerator (4 °C) to prevent degradation before use in the experimental treatments.

3.3 Experimental Design

A completely randomized design (CRD) was adopted for this study. Forty two (42) male Wistar rats were randomly distributed into six groups of seven animals per group (n = 7). Randomization was achieved by labeling each cage and drawing lots under supervision to eliminate bias. The experimental groups were as follows:

Group 1: Diabetic rats treated with 25% extract (12.5% unripe plantain + 12.5% garden egg).

Group 2: Diabetic rats treated with 50% extract (25% unripe plantain + 25% garden egg).

Group 3: Diabetic rats treated with 100% extract (50% unripe plantain + 50% garden egg).

Group 4 (Negative Control): Diabetic rats receiving no treatment, maintained on standard rats feed only.

Group 5 (Positive Control): Diabetic rats treated with Metformin at a dosage of 500 mg per kilogram of body weight.

Group 6 (Normal Control): Non diabetic rats maintained on standard feed only.

Each rats were assigned a unique identification number. The cages were positioned equidistantly to ensure uniform exposure to environmental conditions. Standard grower pellet feed and clean water were given to them daily, their body weight was monitored weekly [6].

The design allowed comparative evaluation of the dose dependent hypoglycemic effects of the bi herbal extract in relation to the standard antidiabetic drug, metformin.

3.4 Experimental Protocol for Type 2 Diabetes Induction

After the seven day acclimatization period, experimental induction of Type 2 Diabetes Mellitus (T2DM) was performed using Streptozotocin (STZ). All preparatory procedures were carried out in Research Laboratory, in a well ventilated area designated for animal injections.

3.4.1. Preparation of Streptozotocin Solution

STZ is a light sensitive compound that rapidly degrades in aqueous solution; therefore, all preparations were done fresh and under dim light to preserve its stability. STZ solution was prepared by dissolving it in 0.1 M sodium citrate buffer (pH 4.5). The buffer was freshly prepared from sodium citrate and citric acid, and its pH was confirmed using a Hanna HI98100 digital pH meter.

The required quantity of STZ powder was weighed using a Mettler Toledo analytical balance inside a fume hood to prevent inhalation. The powder was gently transferred into a sterile beaker and dissolved completely in the citrate buffer by slow stirring using a sterile glass rod. The final concentration was adjusted so that each rat received 38 mg of STZ per kilogram of body weight in a total injection volume of 1 ml.

All syringes and needles were sterilized (autoclaved at 121 °C for 15 minutes) and laid out aseptically prior to injection.

3.4.2. Induction Procedure

Before induction, the rats were fasted overnight for 12 hours with free access to water only. The purpose of fasting was to stabilize basal blood glucose levels and enhance the diabetogenic effect of STZ [6].

Each rat was weighed individually to calculate the precise STZ dose required, and injections were prepared accordingly.

STZ was administered intraperitoneally (IP) using a 1 ml insulin syringe with a 26 gauge needle. The injection site (lower right quadrant of the abdomen) was swabbed with 70% ethanol to prevent infection. The needle was inserted at a shallow angle to avoid internal organ injury.

Following administration, each rat was placed in a clean cage lined with tissue paper to absorb any secretions. The rats were then observed for signs of stress such as lethargy, tremor, or excessive urination.

To prevent sudden hypoglycemia that may occur post STZ injection, 5% glucose solution was provided as drinking water for the next 24 hours. This ensured survival of the rats and facilitated the gradual onset of hyperglycemia typical of Type 2 diabetes models [7].

3.4.3. Confirmation of Diabetes Induction

After 48 hours, fasting blood glucose (FBG) levels were measured to confirm successful induction. Prior to measurement, each rat was fasted again for 8 hours overnight. Blood samples were collected via tail vein puncture, performed aseptically.

The measurement was carried out using an Accu-Chek Active glucometer (Roche Diagnostics, Germany). Before use, the glucometer was calibrated using the manufacturer's control solution to ensure accuracy.

Blood glucose values were recorded in mg/dL, and rats with FBG $\geq$ 200 mg/dL along with clinical signs of polyuria, polydipsia, and glycosuria were confirmed as diabetic and retained for further study [8].

Group 6 (Normal Control) did not receive STZ and was maintained on standard feed and water to serve as baseline reference for non diabetic parameters.

3.5. Treatment Administration

After successful induction and confirmation of diabetes, the treatment phase commenced.

3.5.1. Dosing Regimen and Administration

The treatment period lasted 28 consecutive days. All test substances were administered orally using a stainless steel oral gavage needle attached to a 1 ml syringe, ensuring delivery directly into the stomach without aspiration.

Treatments were administered once daily between 8:00 a.m. and 9:00 a.m., maintaining consistency to minimize diurnal variation in glucose metabolism. The administration schedule for each group was as follows:

- **Group 1:** Diabetic rats treated with 25% extract (12.5% unripe plantain + 12.5% garden egg)
- **Group 2:** Diabetic rats treated with 50% extract (25% unripe plantain + 25% garden egg)
- **Group 3:** Diabetic rats treated with 100% extract (50% unripe plantain + 50% garden egg)
- **Group 4:** Negative control (diabetic with no treatment; standard feed only)
- **Group 5:** Positive control (Metformin 500 mg/kg body weight)
- **Group 6:** Normal control (non diabetic; standard feed only)

Each dose of the bi-herbal extract was freshly reconstituted in distilled water immediately before administration to ensure the stability of phytochemicals.

The dose volume did not exceed 1 ml per 100 g of body weight to prevent gastric distress. After administration, each rat was returned to its respective cage, and feeding behavior was observed for 15 minutes to ensure no regurgitation or intolerance occurred.

3.5.2. Monitoring During Treatment

During the 28-day treatment period, rats were observed daily for signs of toxicity, abnormal behavior, or physical changes [9].

Weekly body weight measurements were taken using a Top-pan digital weighing balance (Camry EK5350), as changes in weight serve as indicators of metabolic stability or deterioration [10].

3.6. Measurement of Blood Glucose

To assess the hypoglycemic efficacy of the bi-herbal extract, both fasting blood glucose (FBG) and postprandial blood glucose (PPBG) levels were monitored periodically throughout the experiment. Measurements were taken at consistent time points and under standardized fasting conditions to guarantee data reliability.

3.6.1. Fasting Blood Glucose Measurement

Fasting blood glucose levels were measured at five intervals: Day 0 (baseline), Day 7, Day 14, Day 21, and Day 28.

Prior to each measurement, the rats were fasted overnight for 8 hours with access to water only. Blood collection was performed by tail vein puncture using a sterile 21G needle [11]. The tail tip was gently massaged to improve blood flow, and the first drop of blood was wiped away to prevent contamination from tissue fluids.

A drop of fresh blood was applied to the glucometer strip, and the glucose reading was recorded in mg/dL. Between each test, the glucometer was cleaned and rechecked using a control solution to maintain precision [12].

All readings were taken in duplicate for each rat, and the average value was used for analysis to minimize random error. These data were plotted against time to evaluate the progressive glucose lowering potential of the treatments.

3.6.2. Postprandial Blood Glucose Measurement

On each test day, postprandial glucose (PPG) levels were determined to monitor glucose clearance efficiency after treatment. The rats were not fasted for this measurement; instead, blood samples were collected at fixed intervals of 0, 30, 60, 90, and 120 minutes after the morning treatment administration.

Tail vein sampling was employed for each time point using the same Accu Chek glucometer. Care was taken to alternate puncture points to minimize tissue irritation and clotting.

This test helped evaluate how effectively the bi-herbal extract modulated glucose spikes following food intake, providing insight into its possible insulin sensitizing or glucose utilization mechanisms.

All readings were immediately documented in my laboratory notebook. Each glucometer strip was discarded into a biohazard sharps container, and the sampling area was cleaned with 70% ethanol after each session.

3.7. Sample Collection and Biochemical Assay

At the end of the 28 day treatment period, all animals were humanely sacrificed for sample collection and biochemical analysis. This entire procedure was done under a conducive environment to ensure compliance with ethical handling and scientific accuracy.

3.7.1. Pre Sacrifice Preparation

Prior to sacrifice, each rat was fasted overnight (approximately 10–12 hours) to standardize metabolic conditions [13]. The following morning, all experimental rats were weighed using the Camry EK5350 digital balance, and their final body weights were recorded.

A separate workbench was prepared for the sacrifice procedure. All necessary equipment, including surgical scissors, forceps, syringes, centrifuge tubes, and collection vials, were sterilized and arranged on sterile trays. A 10% chloroform solution was prepared for anesthesia in a covered glass chamber.

Each rat was anesthetized by placing it gently inside the chloroform chamber until deep sedation was observed, indicated by reduced reflex and immobility.

3.7.2. Blood Sample Collection

Blood samples were collected via cardiac puncture immediately after anesthesia. Using a sterile 5 ml syringe fitted with a 22G needle, blood was drawn directly from the heart into plain sterile centrifuge tubes. The use of cardiac puncture was chosen because it yields an adequate volume of blood for all required analyses and ensures minimal hemolysis when done correctly [14].

The collected blood samples were allowed to stand at room temperature for 20–30 minutes to clot. Thereafter, they were centrifuged at 3,000 revolutions per minute (rpm) for 10 minutes using a

Hettich EBA 200 bench top centrifuge. The resulting clear serum was carefully decanted using a micropipette into labeled Eppendorf tubes and stored at 20 °C until biochemical analysis [15]. To ensure traceability and prevent sample mix up, all specimens were meticulously labeled immediately upon collection, adhering to a strict coding system that specified the experimental group and serial number. Strict aseptic technique and safety protocols were maintained throughout the process. Specifically, disposable gloves were changed between the handling of each individual sample to eliminate the risk of cross-contamination. Furthermore, all used syringes and sharp instruments were directed immediately into designated biohazard sharps containers for safe disposal.

3.7.3. Organ Harvesting and Preservation

Immediately after blood collection, the abdominal cavity was opened through a midline incision using sterilized surgical scissors. The liver, kidneys, and pancreas were carefully excised, rinsed in cold normal saline to remove excess blood, and blotted dry using sterile filter paper.

Representative tissue portions from the liver and pancreas were placed in 10% formal saline solution for histopathological analysis. Each sample was clearly labeled with the animal group number and organ type, and stored in airtight glass bottles at room temperature until processing.

3.7.4 Biochemical Analysis

All biochemical assays were performed using standardized enzymatic methods with diagnostic kits obtained from *Randox Laboratories, UK*. Each assay was conducted in triplicate, and readings were confirmed by my supervisor before final documentation.

The serum biochemical parameters analyzed were grouped as follows:

A. Liver Function Tests

The following parameters were determined to assess hepatic integrity and function:

- Aspartate Aminotransferase (AST): Determined by the Reitman and Frankel method (1957). AST catalyzes the transfer of an amino group between aspartate and α-ketoglutarate, producing oxaloacetate and glutamate. The resulting color complex was read at 546 nm using a UV–Visible Spectrophotometer (Jenway 7315, UK).
- Alanine Aminotransferase (ALT): Measured using the same principle as AST. Elevated ALT levels indicate hepatocellular injury.
- Alkaline Phosphatase (ALP): Determined by the phenolphthalein monophosphate method as described by King and Armstrong (1934). ALP activity reflects biliary obstruction or cholestasis.
- Total Bilirubin: Measured colorimetrically using the Jendrassik and Grof method. The intensity of the azobilirubin complex was read at 578 nm.
- Each sample reading was compared with corresponding standard calibrators to ensure accuracy.

B. Kidney Function Tests

The following renal parameters were determined to evaluate kidney performance:

- Serum Urea: Estimated using the diacetyl monoxime method (Fawcett and Scott, 1960). The reaction produced a colored complex measured at 540 nm.
- Serum Creatinine: Determined by the alkaline picrate method (Jaffe's reaction). Absorbance was read at 520 nm using the spectrophotometer.
- Elevated levels of either parameter suggest impaired renal filtration efficiency, common in

diabetic nephropathy.

C. Lipid Profile Analysis

Lipid profile determination was essential to evaluate the effect of the bi-herbal extract on lipid metabolism. The following parameters were assessed:

- Total Cholesterol (TC): Determined enzymatically by the cholesterol oxidase–peroxidase (CHOD-PAP) method.
- High-Density Lipoprotein (HDL): Measured after precipitation of low-density lipoproteins with phosphotungstic acid and magnesium chloride.
- Low-Density Lipoprotein (LDL): Calculated using the Friedewald formula: LDL-C = Total Cholesterol – HDL-C – (Triglycerides/5)
- Triglycerides (TG): Determined using the glycerol phosphate oxidase method.
- All lipid parameters were read at 500–546 nm using the UV–Visible spectrophotometer, and quality control samples were analyzed concurrently to ensure reliability.

3.7.5. Histopathological Examination

Histological processing of liver and pancreatic tissues was carried out on the experimental animals.

Tissues fixed in 10% formal saline for 72 hours were processed through dehydration (ascending ethanol series: 70%, 90%, 95%, and 100%), clearing (xylene), and embedding in paraffin wax. Sections of 5 µm thickness were cut using a rotary microtome (Leica RM2125RTS) and mounted on grease free glass slides.

The sections were stained using Hematoxylin and Eosin (H&E) to reveal cellular and structural

morphology. Stained slides were examined under a binocular light microscope at varying magnifications (×100 and ×400).

Photomicrographs were examined for histopathological changes, such as hepatocyte degeneration, pancreatic islet distortion, necrosis, and vacuolation, and which were then compared across treatment groups.

3.8. Statistical Analysis

All data gotten from the biochemical and physiological analyses were statistically processed and analyze to ensure correctness.

3.8.1. Data Processing

Data obtained were first entered into Microsoft Excel, for proper organization, error checking, and computation of mean values. Statistical analyses were then carried out using GraphPad Prism (Version 9.5.1). All values were expressed as mean ± standard deviation (SD). The normality of data distribution was assessed using the Shapiro Wilk test.

To determine significant differences among treatment means, One Way Analysis of Variance (ANOVA) was employed, followed by Tukey's post hoc multiple comparison test to separate group means.

A p value < 0.05 was considered statistically significant. Time dependent changes in blood glucose levels were analyzed using Repeated Measures ANOVA to evaluate intra group variations over the 28 day period.

The results were presented in tables and graphs, showing trends of biochemical alterations across groups.

3.9. Ethical Considerations

All experimental procedures involving the use of animals strictly adhered; to the ethical standards of Lead City University, Ibadan. Approval was obtained under the assigned ethical identification number LCU/-REC/25/282

Efforts were made to minimize pain, distress, and the number of animals used. Anesthesia was administered using chloroform to ensure that all animals were unconscious before sacrifice. All waste materials were disposed of following biosafety level 2 (BSL-2) procedures to prevent environmental contamination.

Endnotes

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Chapter Four

Results and Discussion of Findings

4.1. Hyperglycemic Index

Results in Table 4.1 showed a significant decrease in sugar levels from days 7, 14, 21 and 28 but majorly a drastic decrease in the sugar level for days 28 across graded doses of the treatment compared to the diabetic control that had a significant increase.

Table 4.1: Effect of bi-herbal extract on streptozotocin induced hyperglycemia male Wistar rats

Groups	Doses (mg/kg)	Baseline	7 days of Treatment	14 days of Treatment	21 days of Treatment	28 days Treatment
Negative control	55	291.70 ± 30.93[a]	458.30 ± 20.28[a]	560.00 ± 40.00[a]	566.50 ± 33.50[a]	583.00 ± 17.00[a]
Normal control	0.5 ml	67.33 ± 6.01[c]	62.67 ± 6.36[c]	77.00 ± 2.00[c]	71.00 ± 8.00[c]	75.50 ± 1.50[c]
Metformin	10	277.70 ± 12.12[a]	113.70 ± 52.30[b]	62.50 ± 8.50[c]	67.50 ± 4.50[c]	59.50 ± 5.50[c]
Bi-herbal Extract	25	264.30 ± 14.11[a]	107.00 ± 24.56[b]	70.00 ± 9.00[c]	65.50 ± 5.50[c]	73.50 ± 6.50[c]
Bi-herbal Extract	50	296.70 ± 13.91[a]	94.67 ± 36.18[c]	78.00 ± 7.00[c]	64.50 ± 4.50[c]	72.00 ± 5.00[c]
Bi-herbal Extract	100	294.30 ± 13.93[a]	105.30 ± 16.01[b]	62.00 ± 5.00[c]	71.50 ± 7.80[c]	71.50 ± 7.50[c]

Values were expressed as mean ± SEM and ANOVA. *p-value > superscript* [a]*= 0.05,* [b]*= 0.01,* [c]*=0.001* showed the level of significant, DW-----distilled water,

4.2. Body Weight and Postprandial Blood Glucose

As shown in Figure 4.1, the induction of diabetes resulted in a significant loss of body weight compared to the healthy control rats. However, treatment with graded doses (25, 50, and 100 mg/kg) of the bi-herbal extract appeared to counteract this trend, causing a small, yet statistically significant, rise in body weight across the treated groups over the course of days 1, 14, 21, and 28.

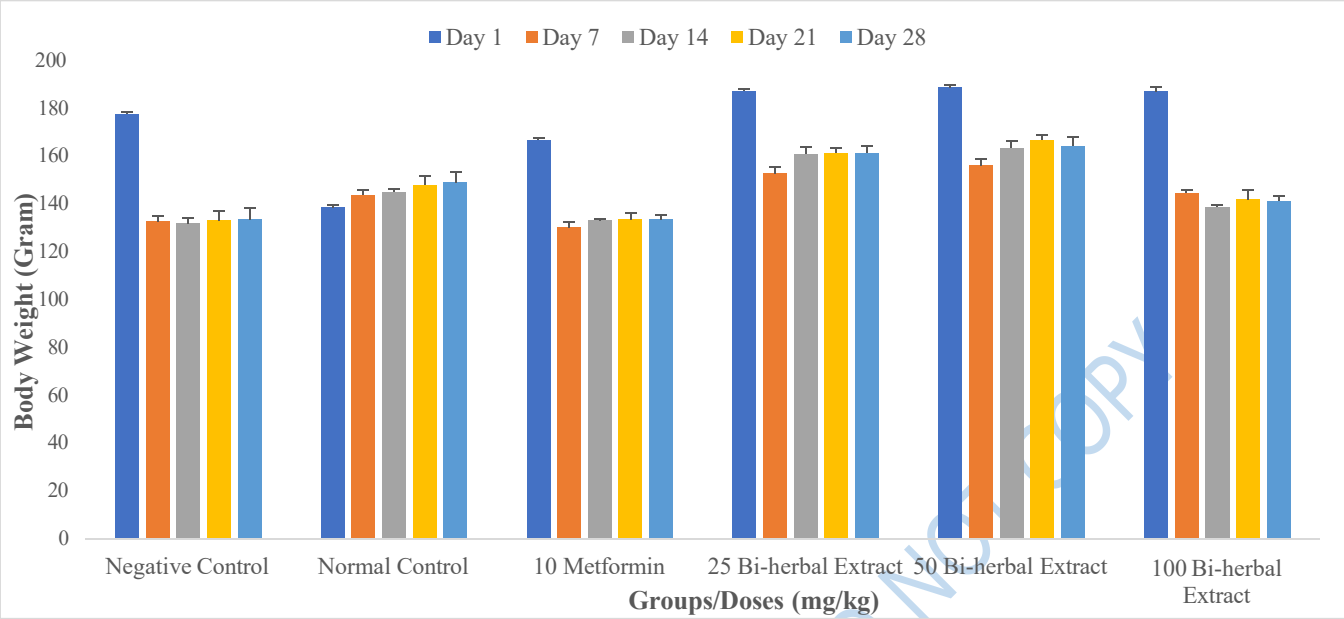

Figure 4.1: Effect of bi-herbal extract on the body weight of streptozotocin induced hyperglycemia male Wistar rats

The results in Figure 4.2 showed a significant decrease in sugar levels from 30, 60, 90 and 120 minutes but majorly a drastic decrease in the glucose tolerance test level for 30 minutes across graded doses of the treatment compared to the diabetic control that had significant increase in day one of the treatments.

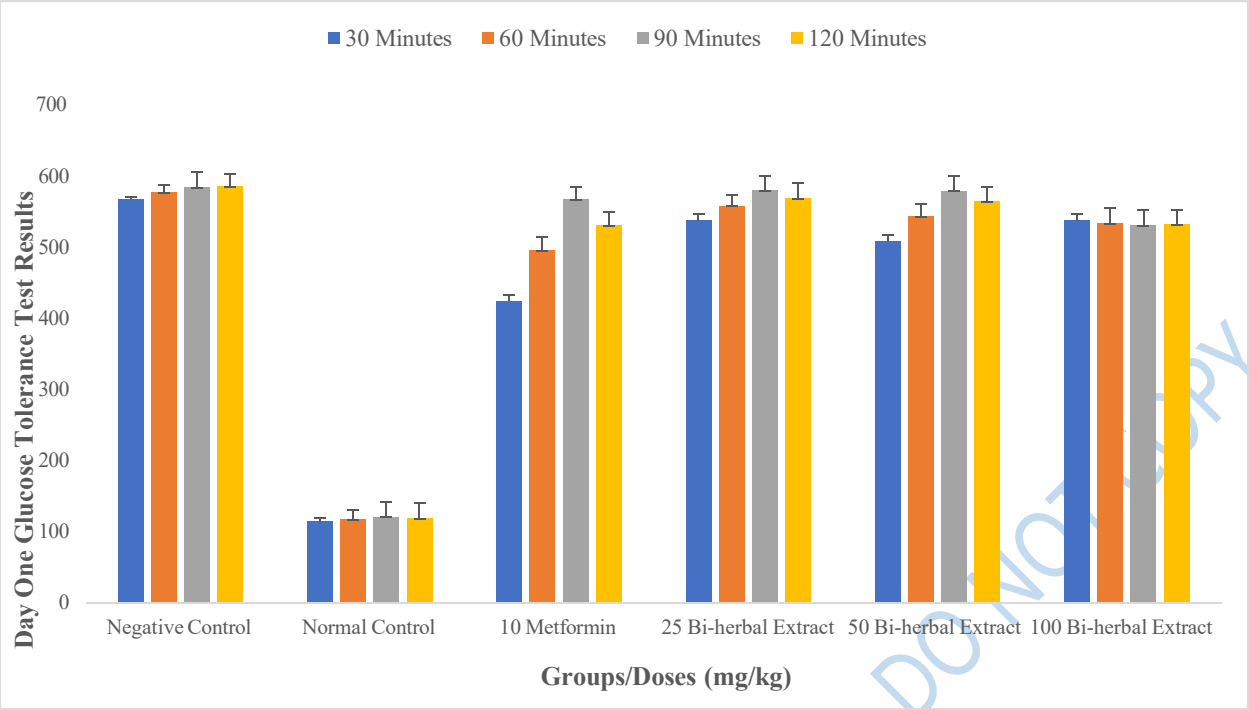

Figure 4.2: Effect of bi-herbal extract on Day one glucose tolerance test in streptozotocin induced hyperglycemia male Wistar rats

The results in Figure 4.3 showed a significant decrease in sugar levels from 30, 60, 90 and 120 minutes but majorly a drastic decrease in the glucose tolerance test level for 30 minutes across graded doses of the treatment compared to the diabetic control that had significant increase in seven days of treatment.

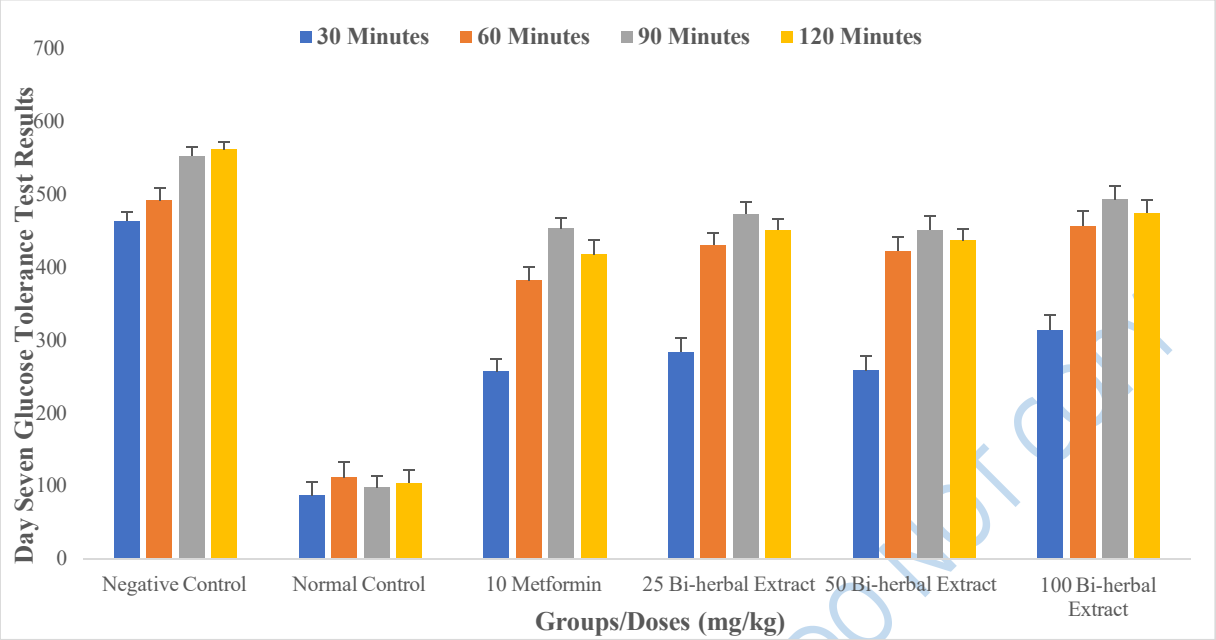

Figure 4.3: Effect of bi-herbal extract on day seven glucose tolerance test in streptozotocin induced hyperglycemia male Wistar rats

The results shown in Figure 4.4 had a significant decrease in sugar levels from 30, 60, 90 and 120 minutes but majorly a drastic decrease in the glucose tolerance test level for 30 minutes across graded doses of the treatment compared to the diabetic control that had a significant increase in 14 days of treatment.

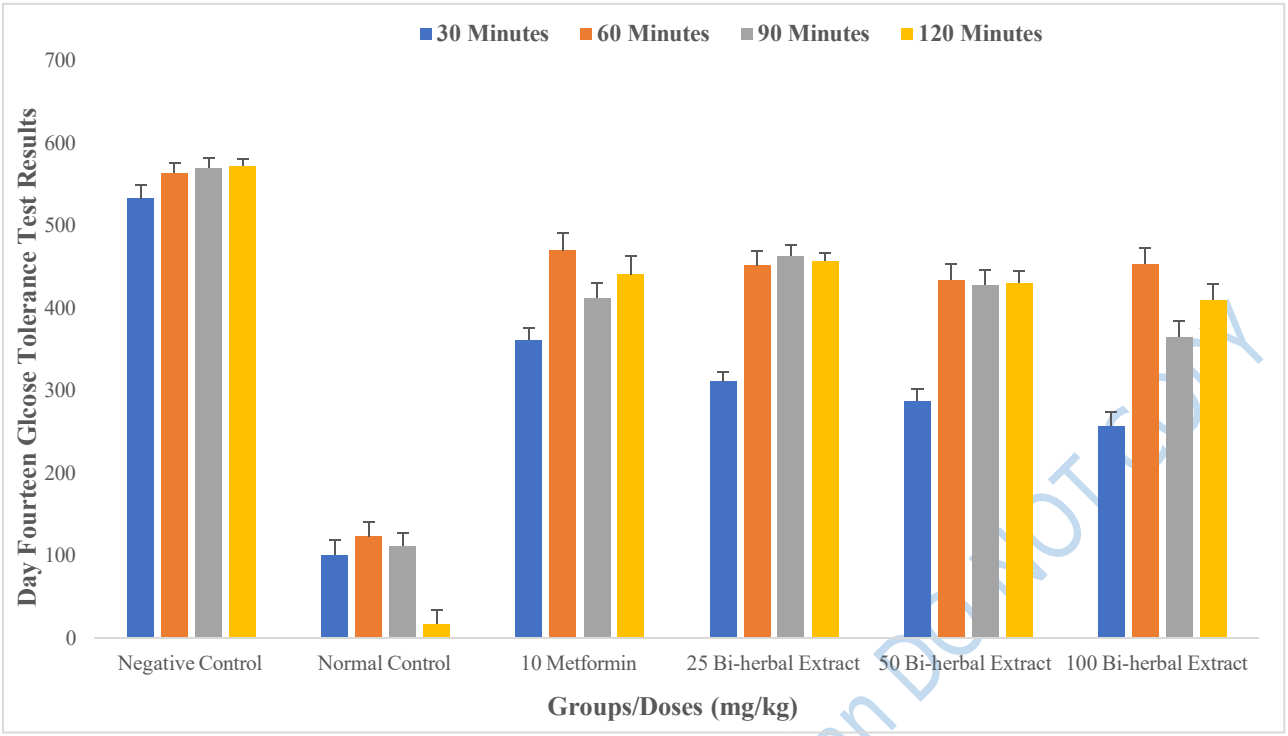

Figure 4.4: Effect of bi-herbal extract on day fourteen glucose tolerance test in streptozotocin induced hyperglycemia male Wistar rats

The results in Figure 4.5 showed a significant decrease in sugar levels from 30, 60, 90 and 120 minutes but majorly a drastic decrease in the glucose tolerance test level for 30 minutes across graded doses of the treatment compared to the diabetic control that had significant increase in twenty-one days of treatment.

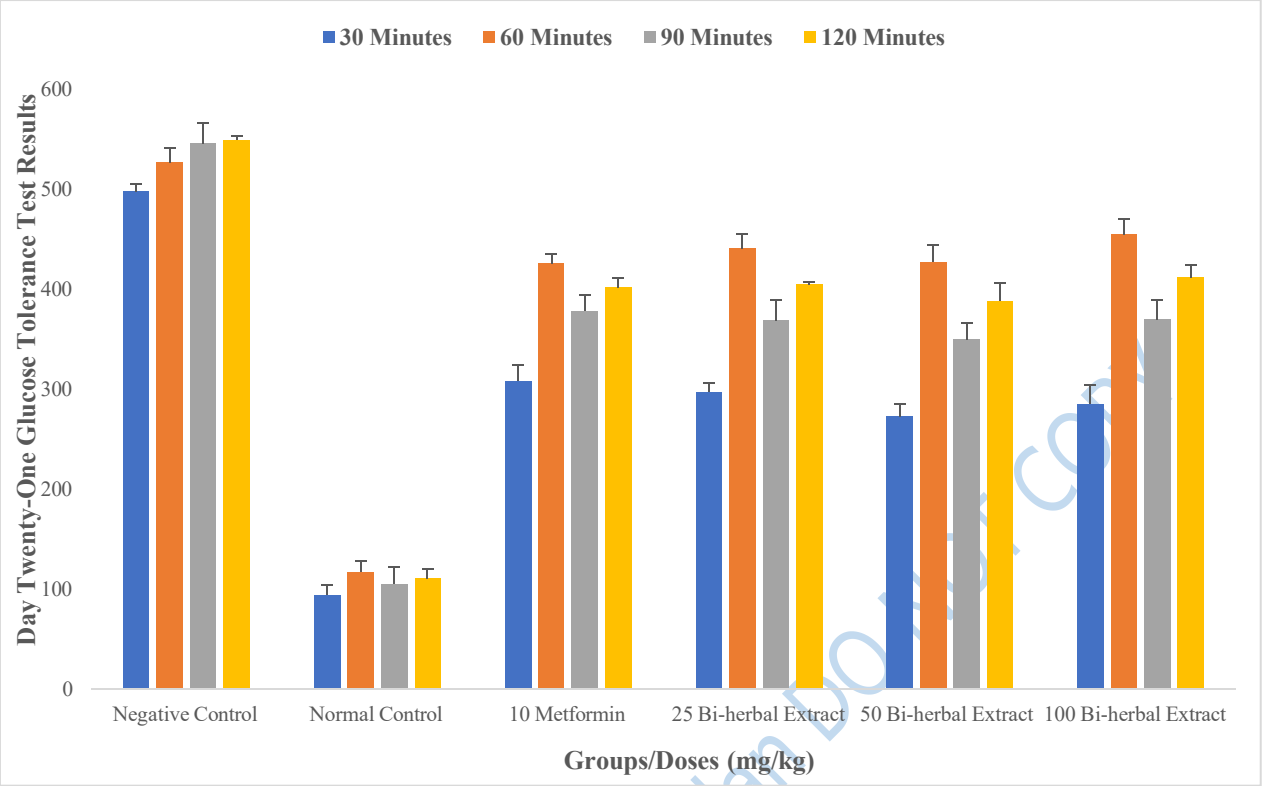

Figure 4.5: Effect of bi-herbal extract on day twenty-one glucose tolerance test in streptozotocin induced hyperglycemia male Wistar rats

The results in Figure 4.6 showed a significant decrease in sugar levels from 30, 60, 90 and 120 minutes but majorly a drastic decrease in the glucose tolerance test level for 30 minutes across graded doses of the treatment compared to the diabetic control that had significant increase in twenty-eight days of treatment.

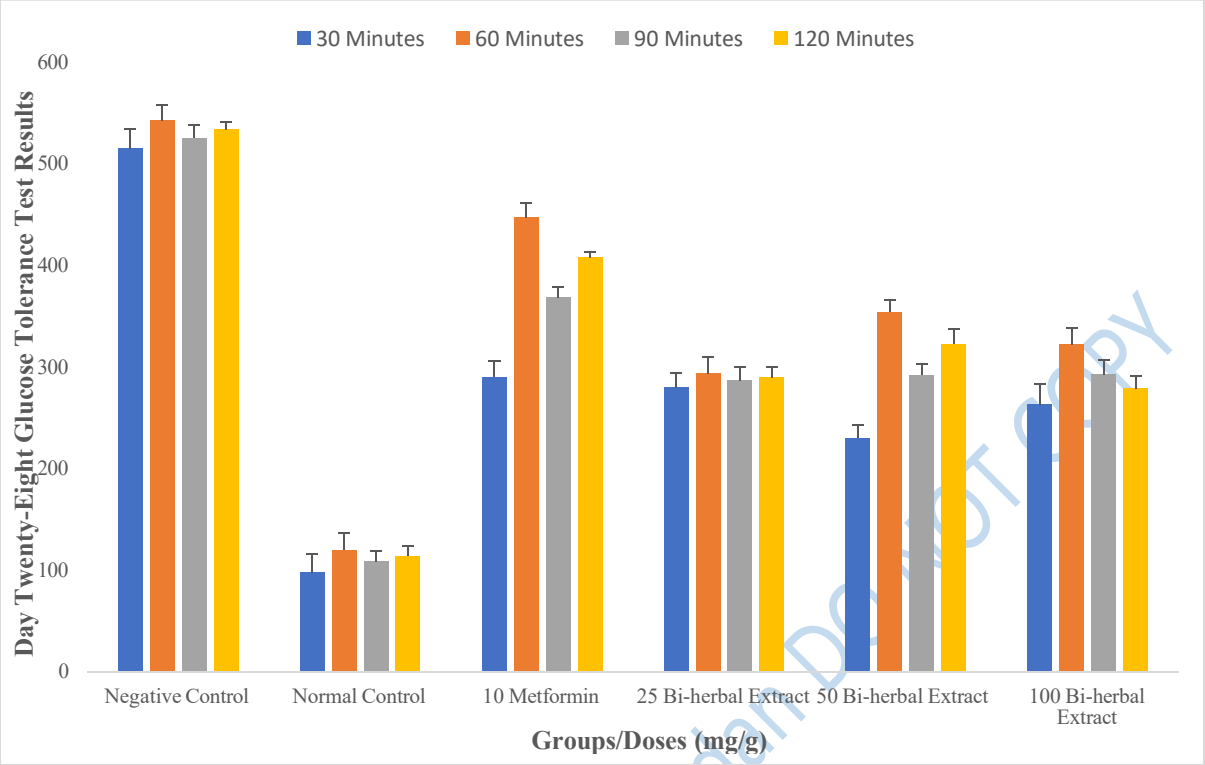

Figure 6: Effect of bi-herbal extract on day twenty-eight glucose tolerance test in streptozotocin induced hyperglycemia male Wistar rats

4.3. Lipid Profile

A cholesterol level above 200 mg/dL is a known trigger for coronary heart disease. High glucose levels negatively affect the body's lipid profile, causing a sharp rise in Total Cholesterol (TC), Triglycerides (TAG), and detrimental Low-Density Lipoproteins (LDL), alongside a drop in protective High-Density Lipoproteins (HDL). As shown in Table 4.2, administering the bi-herbal extract in graded doses (25, 50, and 100 mg/kg) resulted in a significant improvement ($p<0.05$) in the lipid profile. Compared to control groups, the extract significantly lowered TAG, TC, and LDL while raising HDL levels.

Table 4.2: Effect of Bi-herbal extract on lipid profile in streptozotocine induced diabetic male Wistar rats

Groups	Dose mg/kg	Cholesterol (mg/dl)	Triglycerides (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
Negative control	55	156.70 ±6.33[a]	74.33 ± 4.70[a]	49.33 ± 1.76[a]	97.33 ± 4.18[a]
Normal control	0.5 ml	136.70 ± 8.11[b]	67.33 ± 1.45[b]	42.33 ±1.45[b]	77.33 ± 7.42[b]
Metformin	10	138.70 ± 12.57[b]	62.00 ± 7.23[b]	42.67 ± 4.05[b]	84.00 ± 7.10[a]
Bi-herbal Extract	25	129.70 ± 4.63[b]	72.33 ± 1.45[a]	39.00 ± 1.16[b]	75.67 ± 3.84[b]
Bi-herbal Extract	50	142.30 ± 1.45[b]	70.33 ± 0.33[a]	43.00 ± 0.58[b]	85.67 ± 0.88[a]
Bi-herbal Extract	100	130.30 ± 0.33[b]	59.00 ± 3.06[b]	38.33 ± 0.67[b]	80.00 ± 0.58[b]

Data were expressed in Mean±SEM; *P-value* < a 0.05, HDL-----High density lipoprotein, LDL----- Low density lipoprotein, VLDL----Very low density lipoprotein

4.4. Liver Function Test

As shown in Table 4.3, the presence of diabetes resulted in a significant elevation of liver enzymes (AST, ALT, ALP) and their corresponding metabolites. However, the administration of the bi-herbal extract at increasing doses (25, 50, and 100 mg/kg) produced a slight but significant decrease in these markers, bringing the results closer to those of the normal control. This indicates that the different treatments successfully moderated the abnormal values observed in the untreated diabetic subjects.

Table 4.3: Effect of Bi-herbal extract on liver function test in streptozotocine induced diabetic male Wistar rats.

Groups	Dose mg/kg	AST (U/L)	ALT (U/L)	ALP (U/L)	Total bilirubin (mg/dl)	Conjugated bilirubin (mg/dl)
Negative control	50	172.00 ±14.64[a]	90.67 ± 4.37[a]	157.00 ± 6.93[a]	0.37 ±0.03[a]	0.10±0.03[a]
Normal control	0.5 ml	117.00 ± 1.16[b]	75.00 ± 5.03[b]	136.00 ± 8.08[b]	0.40 ±0.06[a]	0.10±0.06[a]
Metformin	10	145.70 ± 14.26[b]	77.00 ± 7.51[b]	132.70 ± 4.33[b]	0.30 ± 0.00[a]	0.10±0.03[a]
Bi-herbal Extract	25	144.00 ± 6.25[b]	75.00 ± 4.58[b]	135.00 ± 7.51[b]	0.40 ± 0.06[a]	0.10±0.06[a]
Bi-herbal Extract	50	164.00 ± 12.50[a]	73.33 ± 0.67[b]	137.30 ± 4.10[b]	0.37 ± 0.07[a]	0.10±0.03[a]
Bi-herbal Extract	100	151.30 ± 3.18[b]	81.33 ± 2.03[a]	133.30 ± 2.40[b]	0.33 ± 0.03[a]	0.10 ±0.03[a]

Data were expressed in Mean±SEM ; *p-value* > [a] 0.05. Aspartate transaminase, AST (U/L), Alanine transaminase, ALT (U/L), Alkaline phosphatase, ALP (U/L)

4.5. Kidney Function Test

The results in Table 4.4 elicited a significant decrease in the level of creatinine, urea and the electrolytes across graded doses (25, 50 and 100 mg/kg) of the bi-herbal extract, exhibited repair across the various treatment when compared with the untreated control.

Table 4.4: Effect of bi-herbal extract on kidney function test in streptozotocine induced diabetic male Wistar rats

Groups	Dose mg/kg	Creatinine (mg/dl)	Urea (mg/dl)	Bicarbonate (mmole/l)	Na+ (mmole/l)	K+ (mmole/l)	Cl^- (mmole/l)
Negative control	55	1.30±0.10[a]	50.33±3.48[a]	20.67±0.33[a]	138.70±0.88[a]	3.77±0.07[a]	100.70±0.33[a]
Normal control	0.5 ml	0.83±0.03[b]	31.00±0.58[b]	21.00±0.58[a]	136.70±0.67[a]	4.10±0.06[a]	102.70±0.67[a]
Metformin	10	1.07±0.12[a]	42.33±4.10[a]	19.67±2.33[a]	140.30±0.88[a]	4.43±0.34[b]	103.70±1.20[a]
Bi-herbal Extract	25	0.97±0.07[b]	39.67±0.33[b]	19.00±0.58[a]	141.70±1.20[a]	4.10±0.06[a]	107.30±0.33[b]
Bi-herbal Extract	50	1.20±0.06[a]	40.33±0.67[b]	22.00±1.16[a]	140.00±0.58[a]	4.10±0.06[a]	102.70±1.45[a]
Bi-herbal Extract	100	1.13±0.03[a]	39.67±1.76[b]	20.33±0.33[a]	137.70±0.88[a]	5.10±0.06[b]	103.70±0.88[a]

Data were expressed in Mean±SEM ; *p-value* > [a] 0.05. Na+ (sodium); K+ (Potassium); Cl- (Chloride)

4.6. Discussion of findings

4.6.1. Effect of Bi-Herbal Extract on Blood Glucose and Body Weight

The effect of the bi-herbal extract on fasting blood glucose (FBG) levels was evaluated over a 28 day treatment period, with values expressed as mean ± SEM. The ANOVA results indicated statistical significance at the following thresholds: $p<0.05$ (a), $p<0.01$ (b), and $p<0.001$ (c).

The successful induction of diabetes was confirmed by the data, which showed that at baseline, every diabetic group including the negative control and all treated animals had significantly higher blood glucose levels compared to the normal (non-diabetic) control group. The negative control group maintained a progressive rise in glucose concentration throughout the experiment from 291.70 ± 30.93 mg/dl at baseline to 583.00 ± 17.00 mg/dl by day 28 indicating persistent hyperglycemia in the absence of treatment.

In contrast, the normal control group treated with distilled water maintained stable glucose values within the normal range (67.33 ± 6.01 to 75.50 ± 1.50 mg/dl), demonstrating normal glycemic regulation.

The Metformin treated group (500 mg/kg) showed a significant ($p < 0.001$) and steady reduction in blood glucose from 277.70 ± 12.12 mg/dl at baseline to 59.50 ± 5.50 mg/dl after 28 days. This decline confirms the efficacy of Metformin as a standard antidiabetic drug that enhances insulin secretion and glucose utilization.

Similarly, the bi-herbal extract caused blood glucose levels to decrease, and this effect was dependent on the dosage; reductions were observed at all tested concentrations (25,50, and 100 mg/kg). The 25 mg/kg group reduced glucose from 264.30 ± 14.11 to 73.50 ± 6.50 mg/dl (p

< 0.001), the 50 mg/kg group from 296.70 ± 13.91 to 72.00 ± 5.00 mg/dl ($p < 0.001$), and the 100 mg/kg group from 294.30 ± 13.93 to 71.50 ± 7.50 mg/dl ($p < 0.001$). These significant declines, comparable to Metformin, indicate that the bi-herbal extract effectively improved glucose regulation in diabetic rats.

The continuous and progressive decrease in glucose levels from day 7 to day 28 suggests a sustained hypoglycemic effect rather than a transient one. This effect may be attributed to the presence of bioactive phytochemicals in the bi-herbal formulation that enhance insulin secretion from pancreatic β-cells, increase glucose uptake by peripheral tissues, or inhibit hepatic gluconeogenesis and intestinal glucose absorption.

Finally, the bi-herbal extract demonstrates strong antihyperglycemic activity due to its ability to regulate blood glucose levels effectively, akin to the standard drug Metformin. Additionally, the formulation prevents hyperglycemia without causing adverse effects, suggesting its safety profile. These results underscore unripe plantain's potential as a consistent option for diabetes management, whether used alone or alongside current treatments. This aligns with previous research on the effects of unripe plantain (*Musa paradisiaca*) and ginger (*Zingiber officinale*) in diabetic rats induced with Streptozotocin. That study observed that diabetic rats fed diets incorporating either unripe plantain alone or a combination of plantain and ginger showed a significant decrease in fasting blood glucose, suggesting that the tested plants possess anti-hyperglycemic properties. However, the study also found that unripe plantain was more effective at reducing elevated blood glucose levels than the plantain-ginger combination at the dosages used. The negative control rats lost weight despite eating more, a consequence of their hyperglycemic condition causing the breakdown (catabolism) of structural proteins. The subsequent reduction in weight loss observed in the groups fed plantain, or the plantain-ginger mix, can be attributed to the

plants' success in lowering hyperglycemia [1]. It also aligns with the study that investigated the ameliorative and antidiabetic effects of diets supplemented with 20–40% boiled unripe plantain in high-fat-fed, low-dose streptozotocin-induced diabetic rats, and found that unripe plantain significantly reduced blood glucose levels [2].

Body weight is an important physiological indicator for evaluating the general health status and metabolic response of experimental animals during treatment. The chart illustrates the changes in body weight of the different groups over a 28-day period of treatment with the bi-herbal extract, Metformin, or control substances.

At Day 1 (baseline), all experimental groups exhibited comparable body weights before treatment. As treatment progressed, distinct patterns emerged across groups. The negative control group showed a continuous decline in body weight from Day 1 to Day 28, indicating the typical weight loss associated with uncontrolled diabetes mellitus. This reduction is likely due to increased protein catabolism and fluid loss resulting from insulin deficiency and persistent hyperglycemia.

In contrast, the normal control group maintained a steady increase in body weight throughout the experimental period, reflecting normal metabolic activity and adequate utilization of nutrients.

The Metformin treated group demonstrated a gradual and consistent increase in body weight after the first week, similar to the normal control. This improvement may be attributed to the restoration of normoglycemia and enhanced glucose uptake in peripheral tissues, thereby improving energy utilization.

Similarly, the bi-herbal extract-treated groups (25, 50, and 100 mg/kg) showed a dose-dependent improvement in body weight. Although a slight initial reduction was observed during the first week, subsequent progressive increases were recorded from Day 14 to Day 28. The 25 mg/kg and

50 mg/kg doses showed better weight recovery than the 100 mg/kg dose, suggesting that moderate doses may have an optimal restorative effect.

The observed improvement in body weight among treated groups correlates with the significant reduction in blood glucose levels, indicating enhanced glucose metabolism, improved nutrient absorption, and possibly stimulation of pancreatic β-cell activity. This pattern implies that the bi-herbal extract, like Metformin, ameliorates diabetic-induced weight loss and helps restore metabolic balance.

The findings suggest that the bi-herbal extract promotes recovery from diabetes-induced weight loss by improving glycemic control and metabolic efficiency. The consistent body weight gain across treatment groups further supports the extract's safety and therapeutic potential during prolonged administration. This aligns with the study on the comparative proximate analysis of pet-ether extracts from bitter leaf and garden egg leaf, as well as their effect on treating diabetes in rats induced by streptozotocin (STZ). The study successfully demonstrated a major reduction in circulating glucose, particularly at higher extract concentrations, confirming that diabetic animals treated with these extracts experienced a notable decrease in blood glucose levels as observed in the study [3]. These results are also consistent with a prior investigation that examined how a beverage containing plantain bulb extract affected diabetic rats induced by streptozotocin. The earlier study demonstrated that administering the extract led to a marked decrease in the fasting blood glucose of the diabetic rats, confirming its efficacy in glucose management [4].

4.6.2 Postprandial Blood Glucose

The results of the postprandial blood glucose test conducted over a 28-day period demonstrated a progressive and dose-dependent antihyperglycemic effect of the bi-herbal extract in diabetic rats.

Throughout the study duration, the negative control group consistently maintained markedly elevated blood glucose levels at all time intervals (30–120 minutes), indicating persistent hyperglycemia and confirming the stability of the diabetic model. In contrast, the normal control group showed consistently low glucose levels, reflecting normal glucose metabolism and tolerance.

On Day 1, there was no significant difference between the bi-herbal extract–treated groups and the negative control, suggesting that the extract did not exhibit an immediate glucose lowering effect. However, metformin, a standard antidiabetic drug, produced a moderate reduction in glucose levels, confirming its expected pharmacological activity. From Day 7 onward, the bi-herbal extract began to demonstrate a measurable reduction in blood glucose levels, particularly at higher doses (50 and 100 mg/kg). This early improvement suggests that the extract may require a period of metabolic adaptation or accumulation before exerting a pronounced antihyperglycemic action.

By Day 14, a significant decline in glucose levels was observed across all extract-treated groups, with the 100 mg/kg dose showing reductions comparable to the metformin group. This trend continued through Days 21 and 28, where both the 50 mg/kg and 100 mg/kg doses produced substantial glucose reductions, approaching near normal levels during the 120-minute post glucose measurement. These findings indicate that prolonged administration of the bi-herbal extract enhances glucose levels in a manner similar to the standard drug, suggesting a potent and sustained antihyperglycemic potential.

The temporal glucose profiles also provide valuable insight into the mechanism of action. In all treated groups, glucose levels peaked around 60 minutes following glucose administration but declined progressively thereafter, indicating improved glucose clearance from the bloodstream.

This effect became more pronounced with increasing treatment duration, implying enhanced insulin sensitivity and/or stimulation of insulin secretion by the bi-herbal extract. The observed improvement in glucose levels over time further suggests possible pancreatic β-cell protection or regeneration, as well as improved peripheral utilization of glucose.

The dose-dependent nature of the bi-herbal extract's effect supports the presence of bioactive phytoconstituents with synergistic or additive hypoglycemic properties. Phytochemicals such as flavonoids, alkaloids, tannins, and saponins commonly found in medicinal plants have been reported to modulate glucose metabolism through antioxidant activity, inhibition of carbohydrate-digesting enzymes, and insulin-mimetic actions. The progressive improvement over the 28-day period further implies that the extract's efficacy may rely on cumulative metabolic modulation rather than acute pharmacological intervention.

In summary, these findings demonstrate that the bi-herbal extract delivers significant anti-hyperglycemic effects in diabetic rats, with its effectiveness increasing over time and with higher dosages. This outcome supports previous research, such as the study on the hypoglycemic activity of the aqueous extract of unripe plantain (*Musa paradisiaca*). That earlier work reported that the *Musa paradisiaca* extract reliably lowered blood sugar in both normal and hyperglycemic rats over a short duration, suggesting that a longer course of treatment could lead to a more pronounced therapeutic benefit [5]. The results of the current study are also consistent with findings from previous research on the leaf extract of the garden egg (*Solanum aethiopicum*). That earlier work, conducted on the beta-cells of streptozotocin-induced diabetic male Wistar rats, demonstrated the plant's anti-diabetic and hypolipidemic (lipid-lowering) characteristics. That study demonstrated that oral administration of the methanolic leaf extract of *S. aethiopicum* reduces blood glucose levels and serum lipid levels, likely due to an improvement in insulin secretion through the

recovery of pancreatic beta-cells. Therefore, *S. aethiopicum* leaf extract may be effective in the therapeutic management of type 1 diabetes due to its antidiabetic and hypolipidemic effects [6]. The 50 mg/kg and 100 mg/kg doses were most effective, producing glucose tolerance profiles comparable to metformin after prolonged administration. These results strongly suggest that the bi-herbal formulation possesses promising therapeutic potential for the management of diabetes mellitus, possibly through mechanisms involving enhanced insulin action, glucose utilization, and β-cell protection.

4.6.3 Effect of Bi-Herbal Extract on the Lipids

Lipid measurements, including total cholesterol, triglycerides, HDL, and LDL, were calculated and reported as the Mean ± SEM. A statistical analysis of these parameters revealed notable differences among the groups, with the results achieving statistical significance ($p<0.05$). Negative control group exhibited the highest levels of total cholesterol (156.70 ± 6.33 mg/dl), triglycerides (74.33 ± 4.70 mg/dl), HDL (49.33 ± 1.76 mg/dl), and LDL (97.33 ± 4.18 mg/dl), indicating possible lipid imbalance or metabolic disturbance. In contrast, the normal control group had significantly lower cholesterol (136.70 ± 8.11 mg/dl) and triglyceride (67.33 ± 1.45 mg/dl) levels, consistent with normal lipid metabolism.

Treatment with Metformin (500 mg/kg) and bi-herbal extract produced notable modulation in serum lipid levels. The bi-herbal extract at 25 mg/kg and 100 mg/kg markedly reduced total cholesterol and LDL concentrations while also decreasing triglyceride levels, indicating a dose dependent hypolipidemic effect. Particularly, the 100 mg/kg dose recorded the lowest triglyceride (59.00 ± 3.06 mg/dl) and LDL (80.00 ± 0.58 mg/dl) levels, comparable to or better than the Metformin group.

Although HDL values showed slight variations across groups, the extract-treated rats maintained relatively stable HDL concentrations, suggesting preservation of beneficial lipoprotein levels despite reductions in total cholesterol and LDL. This pattern implies that the bi-herbal extract may enhance lipid metabolism and promote cardiovascular protection by improving the lipid profile.

consequently, the significant reductions ($p < 0.05$) in total cholesterol, triglycerides, and LDL observed in extract treated groups suggest that the bi-herbal extract possesses lipid lowering (hypolipidemic) potential, comparable to the standard drug, Metformin. These effects may contribute to its antidiabetic or cardioprotective activity by mitigating dyslipidemia often associated with metabolic disorders. The significant reductions in total cholesterol, triglycerides, and LDL observed in the extract-treated groups indicate that the bi-herbal extract has a notable lipid lowering effect. This suggests its potential as a hypolipidemic agent, comparable to the standard drug Metformin. These effects are likely beneficial in addressing dyslipidemia, a common issue in metabolic disorders, and may contribute to its overall antidiabetic or cardioprotective properties. This outcome supports existing literature, such as the study on unripe plantain processing and its influence on lipid profiles in rats with high cholesterol. That earlier work confirmed the anti hypercholesterolemic properties of unripe plantain supplemented diets in experimental animals. The rats on the plantain diet showed notable reductions in weight, total cholesterol, harmful LDL cholesterol, and plasma MDA. This beneficial decrease in poor health markers was accompanied by a clear improvement in their HDL cholesterol levels [7].

4.6.4 Effect of Bi-Herbal Extract on the Liver

The results for biochemical markers including Alkaline phosphatase (ALP), Aspartate transaminase (AST), Alanine transaminase (ALT), total bilirubin, and conjugated bilirubin are

presented as the Mean ± SEM. A difference between groups was considered statistically non-significant if the p-value was greater than 0.05 ($p>0.05$).

These results show that the negative control group exhibited the highest AST (172.00 ± 14.64 U/L), ALT (90.67 ± 4.37 U/L), and ALP (157.00 ± 6.93 U/L) values, suggesting possible hepatic stress or altered liver function in this group. In contrast, the normal control group showed significantly lower enzyme activities (AST = 117.00 ± 1.16 U/L; ALT = 75.00 ± 5.03 U/L; ALP = 136.00 ± 8.08 U/L), indicating normal liver function.

Treatment with Metformin (500 mg/kg) resulted in enzyme levels comparable to the normal control, demonstrating its hepatoprotective potential. Similarly, bi-herbal extract administration at doses of 25 mg/kg, 50 mg/kg, and 100 mg/kg showed a dose-dependent modulation of liver enzymes. The 25 mg/kg and 100 mg/kg doses maintained AST, ALT, and ALP levels close to the normal control, while the 50 mg/kg dose showed a slight increase in AST (164.00 ± 12.50 U/L), possibly reflecting mild hepatic stimulation rather than toxicity.

Total and conjugated bilirubin levels remained statistically unchanged ($p > 0.05$) across all groups, indicating that the bi-herbal extract did not adversely affect bilirubin metabolism or bile excretion.

The bi-herbal extract did not significantly affect liver function biomarkers compared to the control and standard drug due to its composition and mechanism of action, which may lack harmful substances or active compounds that interfere with liver enzyme activity. The absence of significant differences ($p > 0.05$) among treatment groups suggests that the extract does not induce liver toxicity, making it safe at the tested doses. Additionally, its potential hepatoprotective effect may stem from bioactive compounds that support liver health without causing adverse effects. These results align with prior research showing that treating diabetic subjects with unripe plantain

for 28 days successfully increased the activity of the aforementioned enzymes. This indicates that unripe plantain possesses the capacity to repair liver damage, validating its traditional use in folk medicine [8]. Also, this investigation aligns with previous research on the therapeutic effects of plantain flour in diabetic rats, specifically examining its influence on key organs and exploring molecular changes in the kidney's genetic transcription. Type 2 diabetes was experimentally induced in the rats using a combination of streptozotocin (STZ) and a diet high in fat and sugar. The study evaluated the mitigating effects of plantain flour at three different dosages (1 g/kg·Bw, 2 g/kg·Bw, and 4 g/kg·Bw) through several analytical methods, including biochemical assays, histological examination, a homeostasis model, and kidney transcriptome analysis. The results showed that plantain flour intervention successfully lowered the concentrations of alanine aminotransferase (ALT), aspartate aminotransferase (AST), and urea (UREA). Pathological observations further confirmed that plantain flour reduced symptomatic fat accumulation in the liver and kidney tissues. Moreover, the homeostasis model indicated that plantain flour had the ability to decrease insulin resistance in the diabetic rodents [9].

4.6.5 Effect of Bi-Herbal Extract on the Kidney

The measured renal function parameters, which include Na+, K+, Cl−, and bicarbonate electrolytes, along with creatinine and urea, were reported using the Mean ± SEM format. No statistically significant variations ($p>0.05$) were observed among the groups for these markers. Negative control group recorded the highest creatinine (1.30 ± 0.10 mg/dl) and urea (50.33 ± 3.48 mg/dl) values, indicating possible renal impairment or stress. Conversely, the normal control group showed significantly lower values (creatinine: 0.83 ± 0.03 mg/dl; urea: 31.00 ± 0.58 mg/dl), reflecting normal kidney function.

Treatment with Metformin (500 mg/kg) resulted in moderate values of creatinine (1.07 ± 0.12 mg/dl) and urea (42.33 ± 4.10 mg/dl), which were comparable to those of the extract treated groups. Administration of the bi-herbal extract at 25, 50, and 100 mg/kg produced no significant changes ($p > 0.05$) in renal markers compared to the normal control, indicating that the extract did not compromise kidney function.

Bicarbonate levels remained relatively stable (19.00–22.00 mmole/L) across all groups, suggesting maintained acid base balance. Similarly, serum sodium (Na^+) and chloride (Cl^-) concentrations were consistent among groups, implying preserved electrolyte and osmotic homeostasis. Slight variations were observed in potassium (K^+) levels, particularly at 100 mg/kg (5.10 ± 0.06 mmole/L) and with Metformin (4.43 ± 0.34 mmole/L), but these remained within physiological limits, indicating no electrolyte imbalance.

Kidney function remained unaffected by the bi-herbal extract; there were no statistically significant differences ($p>0.05$) between the treated animals and the control group. This conclusion is supported by the observation that renal function and electrolyte balance remained stable, comparable to both the standard drug and normal control groups. These findings suggest the extract is safe for use without causing nephrotoxic effects, reinforcing its potential as a reliable therapeutic option. This finding is consistent with a study designed to assess the influence of extracts derived from *Solanum melongena*, *Solanum lycopersicum*, and *Daucus carota Subsp. Sativus* on key electrolytes following lead toxicity in albino Wistar rats. The experiment quantified changes in potassium, chloride, urea, and creatinine levels in the blood. The final data confirmed the extracts' effectiveness in counteracting the toxicity introduced by lead acetate. The study also revealed the deleterious effect of Lead acetate exposure to kidney and some selected electrolytes of the living system. This was confirmed by the assay of some biomarkers. Reports show that these plants

contain some phytochemical compounds. Thus, the extracts possess anti-nephrotoxic potential which is dependent on its bioactive compounds. This study has shown that the used plants could regulate and reduce elevated renal biomarkers in individuals that are in constant exposure to Lead. It can therefore be assumed that any of these plants is equally effective in ameliorating Lead acetate toxicity [3]. These results also aligns with existing research showing that unripe plantain can normalize key biological indicators, specifically by fixing a compromised lipid profile and stabilizing liver and kidney function. The plant achieves this, in part, by stimulating antioxidant enzyme activity. This is because it has demonstrated protective properties for both the liver and kidneys, unripe plantain is considered a strong candidate for therapeutic interventions targeting diseases of these organs [4].

Endnotes

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Chapter Five

5.1. Summary of Findings

This study investigated the synergistic effects of unripe plantain (*Musa paradisiaca*) and garden egg (*Solanum melongena*) flours on postprandial blood glucose regulation in streptozotocin (STZ)-induced diabetic albino rats. The global rise in diabetes mellitus and related metabolic disorders has heightened the need for safe, affordable, and natural dietary interventions to control blood sugar levels. Current pharmacological therapies, while effective, often present side effects or become less effective over time. Consequently, research has shifted toward exploring food-based and plant-derived alternatives that possess hypoglycemic and antioxidant properties.

Unripe plantain and garden egg are widely consumed in Nigeria and other parts of West Africa, where they have long been used in traditional medicine to manage diabetes and obesity. Both foods are characterized by low glycemic indices and the presence of bioactive compounds that may aid in blood glucose regulation. However, little research has focused on the combined effects of these two functional foods. This study, therefore, aimed to evaluate whether their combination could produce a synergistic effect greater than their individual contributions. The research further examined the influence of this bi-herbal formulation on liver and kidney functions, lipid metabolism, body weight, and overall metabolic balance.

The experimental design involved forty-two (42) healthy male Wistar rats weighing between 115–200 g. The animals were divided into six groups of seven rats each: Group 1 (25% extract: 12.5% unripe plantain + 12.5% garden egg), Group 2 (50% extract: 25% unripe plantain + 25% garden egg), Group 3 (100% extract: 50% unripe plantain + 50% garden egg), Group 4 (diabetic control, untreated), Group 5 (positive control treated with metformin at 500 mg/kg), and Group 6 (normal

control, non-diabetic). Type 2 diabetes mellitus was induced by intraperitoneal injection of streptozotocin (55 mg/kg body weight), and treatment lasted for 28 days. Fasting blood glucose and postprandial glucose levels were monitored weekly, while biochemical assays were conducted to assess liver and kidney functions, lipid profile, and histopathological changes in tissues.

The results showed that all STZ-induced diabetic rats exhibited significantly elevated fasting blood glucose levels at baseline, confirming the successful induction of diabetes. The untreated diabetic control group maintained persistent hyperglycemia throughout the study, with glucose levels rising from 291.70 ± 30.93 mg/dL at baseline to 583.00 ± 17.00 mg/dL by day 28. In contrast, treatment with the bi-herbal extract produced a marked and dose-dependent reduction in blood glucose levels. The 25%, 50%, and 100% extract-treated groups showed significant ($p < 0.001$) reductions in fasting blood glucose by the end of the 28-day period, comparable to those achieved by the standard antidiabetic drug, metformin. This steady decline in glucose levels over time suggests a sustained antihyperglycemic effect of the extract, possibly due to enhanced insulin secretion, improved glucose utilization, or inhibition of gluconeogenesis.

The glucose tolerance test (GTT) further revealed that the bi-herbal extract improved glucose clearance from the bloodstream in a dose- and time-dependent manner. On day 1, no immediate glucose-lowering effect was observed, but by days 14 to 28, significant improvements in glucose tolerance were evident in the 50% and 100% extract-treated groups, with responses closely matching those of the metformin group. This observation implies that the extract may act through gradual metabolic modulation, possibly by stimulating β-cell regeneration or enhancing insulin sensitivity.

Body weight measurements showed that untreated diabetic rats experienced progressive weight loss throughout the experiment due to increased protein catabolism and poor glucose utilization common symptoms of uncontrolled diabetes. Conversely, rats treated with the bi-herbal extract or metformin demonstrated steady weight recovery, indicating restored metabolic balance and improved nutrient absorption. Among extract-treated groups, the 25% and 50% concentrations produced the most significant body weight gains, suggesting an optimal therapeutic window for metabolic restoration.

Liver function analysis revealed that serum enzyme levels (AST, ALT, and ALP) remained within normal limits in extract-treated rats, with values comparable to the normal control and metformin groups. These results indicate that the bi-herbal extract does not exert hepatotoxic effects. Similarly, total and conjugated bilirubin levels were statistically unchanged ($p > 0.05$) across all groups, further confirming hepatic safety. In the kidney function tests, creatinine and urea levels were stable and did not differ significantly between treated groups and controls, demonstrating that the extract preserved renal integrity. Electrolyte balance (Na^+, K^+, Cl^-, and bicarbonate) also remained normal, suggesting that neither dehydration nor electrolyte disturbance occurred during treatment.

The lipid profile analysis showed that the untreated diabetic rats had elevated total cholesterol, triglycerides, and low-density lipoprotein (LDL) levels, indicative of dyslipidemia commonly associated with diabetes. Treatment with the bi-herbal extract significantly reduced total cholesterol, triglycerides, and LDL concentrations while maintaining or slightly improving high-density lipoprotein (HDL) levels. The 100% extract-treated group recorded the lowest triglyceride and LDL values, closely approximating the metformin-treated group. These findings demonstrate

the extract's hypolipidemic and cardioprotective potential, which may further contribute to its antidiabetic efficacy by mitigating cardiovascular risks linked to metabolic disorders.

Histopathological examination of liver and pancreatic tissues supported the biochemical findings. The livers of extract-treated rats showed normal architecture with mild or no degenerative changes, while the pancreatic tissues exhibited partial restoration of islet cells, suggesting possible β-cell protection or regeneration. These results are consistent with the biochemical evidence of improved glycemic control and organ function.

The study concludes that the combination of unripe plantain and garden egg flour possesses potent antihyperglycemic, hypolipidemic, and hepatoprotective effects without inducing toxicity. The observed dose-dependent response and similarity to metformin's activity underscore its therapeutic promise as a natural dietary intervention for diabetes management. The synergistic interaction between the two foods likely arises from the combined actions of their phytochemical constituents, such as flavonoids, alkaloids, tannins, and saponins, which may act through multiple mechanisms enhancing insulin secretion, inhibiting intestinal glucose absorption, improving peripheral glucose uptake, and providing antioxidant protection.

This research provides valuable scientific evidence supporting the use of unripe plantain and garden egg as functional foods for the management of diabetes mellitus and related metabolic conditions. It highlights the importance of exploring food-based synergies in developing safer, cost-effective, and nutritionally beneficial alternatives to synthetic hypoglycemic drugs. The findings could inform dietary recommendations, stimulate further clinical investigations, and contribute to public health strategies aimed at reducing the global burden of diabetes through natural and accessible nutrition-based solutions.

5.2. Conclusion

This study successfully demonstrated that the combined administration of unripe plantain (Musa paradisiaca) and garden egg (Solanum melongena) bi-herbal extract exerts potent and broad-spectrum therapeutic effects in Streptozotocin (STZ) induced diabetic Wistar rats. The findings confirm its significant potential as a natural dietary intervention for managing Type 2 Diabetes Mellitus (T2DM) and its associated metabolic complications.

Fasting Blood Glucose (FBG): The bi-herbal extract produced a significant ($p < 0.001$) and dose-dependent reduction in FBG levels across the 28-day treatment period. By Day 28, the extract's efficacy, particularly at the 50 mg/kg and 100 mg/kg doses, was comparable to that of the standard antidiabetic drug, Metformin. This indicates a sustained and effective glucose-lowering action.

Postprandial Blood Glucose (PPBG): The extract significantly improved glucose tolerance and clearance, with the greatest reductions in postprandial glucose levels observed at 30 minutes across all measured time points (Day 7 through Day 28). This dose- and time-dependent improvement suggests enhanced insulin sensitivity or glucose utilization.

Body Weight: While diabetic control rats experienced continuous weight loss due to catabolism, all groups treated with the bi-herbal extract or Metformin showed a significant and progressive body weight recovery from Day 14 to Day 28, indicating a restoration of metabolic balance and improved nutrient utilization.

Lipid Profile: The bi-herbal extract demonstrated a significant hypolipidemic effect ($p < 0.05$), comparable to Metformin. It successfully lowered detrimental blood lipids by reducing Total

Cholesterol (TC), Triglycerides (TAG), and Low-Density Lipoproteins (LDL), while maintaining or slightly improving beneficial High-Density Lipoproteins (HDL) levels. This modulation is critical for mitigating the cardiovascular risks associated with diabetes.

Liver Function Test (LFT): Treatment with the bi-herbal extract resulted in no significant adverse effects on liver function markers (AST, ALT, and ALP) or bilirubin levels, with values remaining comparable to the normal and Metformin control groups. This establishes the hepatoprotective potential and safety of the extract at the tested doses.

Kidney Function Test: Similarly, the extract did not cause any statistically significant variations ($p > 0.05$) in renal markers, including creatinine, urea, and electrolytes (Na^+, K^+, Cl^-, and bicarbonate). This confirms the nephroprotective potential and overall safety for long-term consumption.

5.3. Recommendations

Based on the findings of this research, several recommendations can be made to guide future studies and practical applications:

i. **Adopt the 100 mg/kg Extract as the Most Effective Dose:** The bi-herbal extract demonstrated a strong dose-dependent antihyperglycemic and hypolipidemic effect, with the 100 mg/kg dose producing the most significant reductions in fasting blood glucose, postprandial glucose, total cholesterol, triglycerides, and LDL. Therefore, this dose is recommended as the optimal therapeutic concentration for future use and formulation.

ii. **Consider the Extract as a Complementary or Alternative Therapy to Standard Antidiabetic Drugs:** Since all doses produced glucose-lowering activity comparable to Metformin and the highest dose matched its performance this bi-herbal

formulation may be used alongside ,or as an alternative to conventional antidiabetic therapy, especially in settings where accessibility and cost are major concerns.

iii. **Prioritize Long-Term Use for Maximum Benefit:** The extract's antihyperglycemic effect became more pronounced from Day 7 to Day 28, suggesting its therapeutic activity improves with time. Thus, extended administration is recommended to achieve full therapeutic benefits, particularly for postprandial glucose control and lipid modulation.

iv. **Promote its Use for Managing Diabetes-Associated Weight Loss:** Since the extract significantly improved body weight in diabetic rats, indicating better nutrient utilization and metabolic recovery, it is recommended for patients experiencing diabetes-induced weight loss as part of a nutritional or therapeutic regimen.

v. **Use Confidently Based on Safety Profile:** The study found no adverse effects on liver or kidney biomarkers, and electrolyte balance remained normal across all treatment groups. The extract is therefore recommended as a safe natural therapeutic agent, even for prolonged administration.

vi. **Investigate Phytochemical Components for Mechanism-Driven Optimization:** Given the dose-dependent effects and likely action of flavonoids, alkaloids, tannins, and saponins, further studies should investigate the specific phytoconstituents responsible for β-cell protection, insulin stimulation, and improved glucose utilization, aiding future drug development.

vii. **Conduct Clinical Trials to Validate Therapeutic Potential in Humans:** Since the extract produced robust metabolic benefits comparable to Metformin in animal models, controlled clinical studies are recommended to validate its efficacy, establish human dosage equivalents, and confirm long-term safety.

viii. **Develop Standardized Preparations for Consistent Therapeutic Outcomes:** To improve reliability and clinical utility, there is a need to standardize extraction methods, dosage forms, and concentration levels, particularly around the 100 mg/kg dose which proved most effective.

5.4. Contribution to Knowledge

This research has made significant contributions to scientific understanding in the field of nutritional biochemistry and diabetes management through the following findings:

i. **Establishment of Dose-Dependent Antidiabetic Efficacy of a Bi-Herbal Extract:** This study provides new evidence that the bi-herbal extract demonstrates a clear, dose-dependent antihyperglycemic effect in streptozotocin-induced diabetic rats. The highest dose (100 mg/kg) produced reductions in fasting and postprandial blood glucose comparable to Metformin, highlighting its potential as a potent natural alternative or complementary therapy.

ii. **Demonstration of Sustained Blood Glucose Regulation Over Prolonged Administration:** Unlike many plant-based extracts that show acute but short-lived effects, this study establishes that the bi-herbal formulation exerts progressive and sustained glucose-lowering activity over a 28-day period. This supports the possibility of cumulative metabolic modulation, pancreatic β-cell protection, and improved peripheral glucose utilization.

iii. **Evidence of Improved Body Weight Recovery in Diabetic Conditions:** The study contributes to existing knowledge by demonstrating that the extract ameliorates diabetes-induced weight loss in a dose-responsive manner, indicating improved nutrient utilization, enhanced insulin activity, and restoration of metabolic balance. This adds to current understanding of plant-based therapies that both regulate glucose and improve systemic health.

iv. **Discovery of Significant Hypolipidemic Effects Comparable to Metformin:** Findings show that the bi-herbal extract significantly reduces total cholesterol, triglycerides, and LDL while maintaining stable HDL levels. This dual effect on both glucose and lipid metabolism suggests a broader therapeutic role in managing metabolic syndrome and preventing cardiovascular complications in diabetes.

v. **Safety Profile and Non-Toxic Effects on Liver and Kidney Function:** A major contribution of this research is the demonstration that the bi-herbal extract does not produce hepatotoxic or nephrotoxic effects at all tested doses. Liver enzymes (AST, ALT, ALP), bilirubin levels, renal biomarkers (creatinine, urea), and electrolytes remained within normal physiological ranges. This confirms the extract's high safety margin and supports its suitability for long-term therapeutic use.

vi. **Integration of Two Medicinal Plants into a Potent Synergistic Antidiabetic Agent:** While the antidiabetic potential of the individual plants has been reported, this research is among the few to experimentally validate the synergistic interaction of the combined (bi-herbal) formulation. The enhanced glycemic, lipid, hepatic, and renal effects observed suggest a stronger therapeutic efficacy than either plant alone.

vii. **Contribution to Evidence Supporting Plant-Based Interventions in Diabetes Management:** This study strengthens scientific support for the traditional use of unripe plantain and related botanicals by providing robust empirical data showing their hypoglycemic, hypolipidemic, hepatoprotective, and renoprotective effects, thereby expanding the pharmacological potential of indigenous medicinal plants.

5.5. Areas for Further Study

While this study has provided valuable insights into the antihyperglycemic and hypolipidemic effects of combined unripe plantain (*Musa paradisiaca*) and garden egg (*Solanum melongena*) flours, further investigations are recommended in the following areas:

i. **Identify Active Ingredients and How They Work:** Although the bi-herbal extract demonstrated strong antihyperglycemic and hypolipidemic effects, the specific phytochemicals responsible for these actions remain unclear. Future research should isolate, characterize, and evaluate individual bioactive constituents to determine their specific mechanisms of action on glucose metabolism, lipid regulation, and organ protection.

ii. **Check Long-Term Safety:** The present study revealed no significant adverse effects on liver and kidney biomarkers at the tested doses. However, extended sub-chronic and chronic toxicity studies are needed to fully assess long-term safety, especially at higher doses or with prolonged use beyond 28 days.

iii. **Find the Best Dose and How the Body Uses It:** The results indicated a clear dose-dependent response for blood glucose and lipid regulation, with the 100 mg/kg dose showing the most potent effect. Further studies should explore optimal dosing ranges, therapeutic windows, bioavailability, and metabolic pathways of the extract to determine the most effective and safest dosage.

iv. **Examine Organ Tissues Under the Microscope:** While biochemical markers indicated preserved liver and kidney function, histological analyses were not included. Future research should incorporate microscopic evaluation of pancreatic, hepatic, renal, and intestinal tissues to confirm tissue-level protection or regeneration.

v. **Study Antioxidant and Anti-Inflammatory Effects:** Given that diabetes is associated with oxidative stress and inflammation, additional studies should explore whether the bi-herbal extract's antihyperglycemic effects are mediated through antioxidant pathways, anti-inflammatory mechanisms, or enhancement of pancreatic β-cell integrity.

vi. **Compare With Standard Diabetes Drugs:** Since the bi-herbal extract showed antihyperglycemic and lipid-lowering effects comparable to metformin, further comparative studies should evaluate synergistic, additive, or antagonistic interactions when the extract is administered alongside standard antidiabetic medications.

vii. **Investigate How It Controls Blood Sugar After Meals:** The extract demonstrated improved glucose tolerance over time, particularly after Day 14. Future studies should investigate its effects on insulin secretion dynamics, carbohydrate-digesting enzyme inhibition, and glucose uptake by skeletal muscle and adipose tissue.

viii. **Assess Pancreatic β-Cell Healing and Protection:** The progressive improvement in glycemic control suggests possible β-cell recovery. Targeted studies using immunohistochemistry and molecular markers are recommended to determine whether the extract promotes β-cell proliferation, survival, or regeneration.

ix. **Explore Fat Metabolism and Heart-Protective Effects:** Because the extract significantly reduced total cholesterol, triglycerides, and LDL, future studies should examine its influence on lipid-modulating enzymes, oxidative status of lipids, and markers of cardiovascular risk in diabetic models.

x. **Test the Extract in Human Clinical Trials:** After full preclinical validation, controlled clinical trials are recommended to determine the extract's effectiveness, tolerability, and safety in human patients with type 2 diabetes or prediabetes.

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Biodata

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FOOD CONSULTANT | NUTRITIONIST |

DIETICIAN EDUCATOR

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E- Mail: lydiaayankoso@gmail.com
Website : https://richlyddietclinic.com
Mobile: +2347032261611

BIO DATA

STATE / LGA: Oyo State / OgbomosoNorth
Date of birth: 13th March, 1990
Sex: Female
Marital Status: Married
Languageskills: English, Yoruba

CAREER PROFILE

Experienced in Medical Nutrition Therapy (MNT) for managing chronic diseases, developing personalized meal plans, and improving patient outcomes in clinical settings.

Skilled in community nutrition, health promotion, and designing nutrition education programs for disease prevention and public health improvement.

Expertise in menu planning, food safety, and quality control, ensuring nutritionally balanced meals in healthcare and institutional settings.

Passionate about teaching and research in clinical and community nutrition, with a focus on evidence-based dietary interventions and maternal nutrition.

Specializes in mental health nutrition, developing dietary interventions for psychiatric conditions, and collaborating with mental health professionals for holistic care.

Experienced instructor in Nutrition and Dietetics, committed to effective teaching, student mentorship, and continuous professional development in a diverse educational setting.

Dedicated to Client relationship management skills to maintain professional communication with customers and maintain a high level of customer satisfaction.

Dedicated to improving dietary habits and long-term health for people of all ages through in-depth knowledge of nutritional program development and delivering impactful presentations on diabetes, cardiac health and sensitive weight-related issues.

Exceptional communication skills and effective teaching of attention-grabbingseminars. Expert atcounselling, food management, treatment planning, leisure, tourism and client-specificdiet plans and

menus.

SKILLS PROFICIENCY

- Managing diseases through tailored nutrition interventions.
- Creating personalized meal plans for health improvement.
- Menu planning, food safety, and quality control expertise.
- Implementing nutrition programs for disease prevention.
- Evaluating nutritional status and recommending interventions.
- Conducting and analyzing nutrition-based research.
- Teaching nutrition principles to diverse audiences.
- Working with healthcare teams for holistic patient care.
- Strong communication and interpersonal skills.
- Ability to work independently and as a team player, with little or no supervision
- A fast learner with a high sense of commitment and diligence
- Commitment to continuous professional development and improvement.
- Dedicated to fostering an inclusive and supportive learning environment.
- Excellent organizational and time-management abilities.
- Scheduling and Calendar Management
- Food counselling, Patient education, Dietary habit evaluation
- Executive and Administrative Support

ACADEMIC QUALIFICATION OBTAINED WITH DATE

1. LeadCity University Ibadan, Oyo State 2024 till date

Master's Degree in Human Nutrition and Dietetics in View

- National Teachers Institute, Kaduna State 2018 - 2019

Post Graduate Diploma in Education

2. ObafemiAwolowo University, Ile-Ife, Osun State 2011-2015

B.Sc Nutrition and Dietetics.
Second Class Honours (Upper Division)

3. Federal Polytechnic Ede, Osun State 2008-2010

OND in Leisure and Tourism Management (Distinction)

4. Baptist Grammar School, Ajaawa, Ogbomoso, Oyo State 2006-2007

Senior **S**chool **C**ertificate

5. Federal Government College, Ogbomoso, Oyo State 2000-2006

West Africa Senior School Certificate

6. Federal Government College Staff School, Ogbomoso, Oyo State1994-2000

Primary **S**chool **L**eaving **C**ertificate

WORK EXPERIENCE WITH DATES

May 2022 - till date: EDO STATE COLLEGE OF NURSING SCIENCES, Benin City, Edo State

Job Title:- Human Nutrition and Dietetics Lecturer

Responsibilities/ Main Achievement

° Design and deliver comprehensive nutrition and dietetics courses for nursing students, integrating practical and theoretical knowledge.
° Provide academic and career guidance to students, offering support in coursework, research projects, and professional development.
° Conduct and publish research in peer-reviewed journals on topics related to nutrition, dietetics, and their impact on patient care and nursing practices.
° Work closely with nursing staff and other healthcare professionals to incorporate current nutritional science into clinical practices and patient care plans.
° Lead community health initiatives and workshops to educate the public on nutritional health, disease prevention, and healthy lifestyle choices.
° Successfully launched a multi-faceted nutritional education program that significantly improved students' understanding and application of nutrition in clinical settings, leading to enhanced patient outcomes and recognition by the nursing school's accrediting body.

January 2021 - October, 2021

Job title : Nutritionist/Dietitian at Ekiti State University Teaching Hospital,Ekiti State, Nigeria.

Responsibilities/Main Achievements:

- Assessed nutritional status of patient in health. Planned and coordinates all aspect of dietary care for patient on both long term and short term.
- Drew up monthly menu plan for in patient (both normal and therapeutic diet)
- Carried out dietary modification based on different disease condition.
- Supervised food items purchased and preparation of meal in the kitchen.

January2018-2023 : RICHLYD DIET CLINIC, Ekehuan, Benin City, Edo State. Job title: Nutritionist / Dietitian

Job Description

- Developing nutrition plan addressing individual patient conditions, including diabetes, weight loss and healthy eating.
- Developing nutrient-dense recipes and flexible meal templates to meet nutritional objectives.
- Coaching individuals via online seminars on managing chronic disease with effective dietary plan.
- Offering weight loss and health education information to patients, families and nutrition practitioners.

May 2016- April 2017: NYSC - ARMY DAY SECONDARY SCHOOL, EkehuanBarrack,

Benin City, Edo State.
Job title: : Class Teacher- Agricultural Sciences

Job Description

- Maintained excellent attendance record, consistently arriving to work on time.
- Prepared lesson plans on topics such as plant science, animal husbandry and technology in farming.
- Conducted assessments of student learning styles and used results to plan instructional activities.

July 2014 - October, 2014 : LAGOS UNIVERSITY TEACHING HOSPITAL, Lagos State.

Job title: Nutritionist

Job Description :

iv. Spoke with pregnant women about nutritional needs and benefit of breastfeeding
v. Managed food quality assurance programme
vi. Completed detailed nutritional assessments of each patient based on health history, medical conditions and energy requirements

July 2010-September2011: PREMIER HOTEL, Mokola, Ibadan
Job title: Bakery and Kitchen Assistant

Job Description :

- Prepared all pastry items in accordance with standards of quality, quantity control, taste and presentation.
- Maintained clean, organized kitchen to maximize efficiency and food safety.
- Followed production chart to keep hot, fresh products available all day.

June 2009 - August, 2009: OgbomosoNorth Local Government, Oyo State
Job title: Environmental Service Officer-***(Industrial Training)***

Job Description

- Inspected municipal and industrial facilities for adherence to environmental and hygienic regulations.
- Maintained excellent attendance record, consistently arriving to work on time
- Conducted and participated in the sensitization programmes at community level for healthy living

HOBBIES

- Teaching, Counseling, Reading, Writing, Travelling, Basketball, Creativity and Volunteering.

PROFESSIONAL LICENSE/MEMBERSHIP

Practice License - 2021 - 2025

Institute for Dietetics in Nigeria

Registered Member

Nutrition Society of Nigeria

September 2022

Registered Member

Institute for Dietetics in Council of Nigeria.

October 2021.

Registered Member

Teachers Registration

Nigeria

June 2021

AWARDS AND HONOURS

- Certificate ofCompletion : Online Course **2020**
  Improveyour Mental Wellness : disasterready.org
- Certificate ofCompletion : Online Course **2020**

  Take care of your Mental Healthatwork : disasterready.org
- Certificate of Completion : Online Course **2014**

  International Malnutrition Task Force, (Southampton University, UK)
- Certificate of Participation (Overweight and Obesity in NigerianChildren: Dietary Intervention) **2014**

  Association of Dietitians in Nigeria

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The University Compliance Certification

This is to certify that this thesis by Lydia Tolulope AYANKOSO with the Matric Number: LCU/PG/006325 in the department of Human Nutrition and Dietetics, Faculty Basic Medical and Health Sciences is in full compliance with the university format and style.

…… ……......

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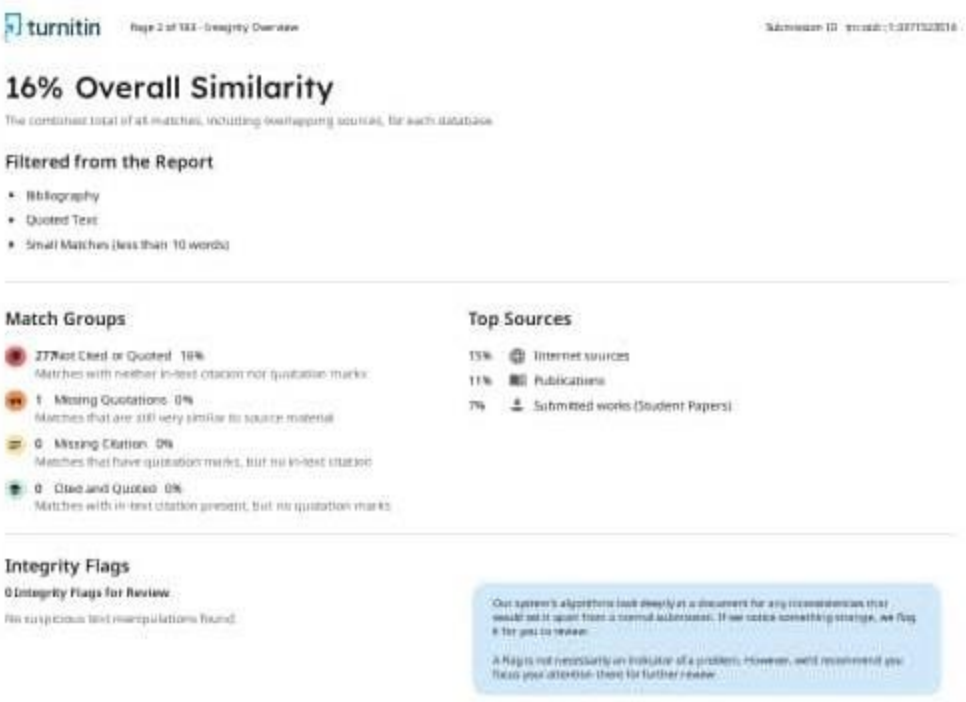
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