CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Diabetes mellitus, a chronic metabolic disorder characterized by hyperglycemia, a ffects millions of people worldwide. It results from either insulin deficiency or insu lin resistance, leading to serious complications if not managed properly (America n Diabetes Association, 2020). One of the experimental models to study diabetes and its complications involves the use of alloxan-induced diabetic rats. stz selecti vely destroys insulin-producing beta cells in the pancreas, mimicking the pathoph ysiology of diabetes (Lenzen, 2008).

Chrysophyllumalbidum, commonly known as the African star apple, is a tropical p lant whose various parts have been traditionally used in folk medicine for their pu rported health benefits. Preliminary studies suggest that Chrysophyllumalbidum p ossesses antioxidant and hypoglycemic properties, making it a potential candidat e for managing diabetes (Olorunnisola et al., 2008). This study aims to explore th e anti-diabetic effects of Chrysophyllumalbidum on alloxan-induced diabetic rats, providing scientific validation for its traditional use.

Diabetes mellitus is a chronic condition characterized by persistent hyperglycemi a due to either insufficient insulin production or ineffective insulin utilization. Glo bally, the prevalence of diabetes has been rising, posing a significant public healt h challenge. The International Diabetes Federation (IDF) reported that approximat ely 463 million adults were living with diabetes in 2019, and this number is project ed to reach 700 million by 2045 if current trends continue (International Diabetes Federation, 2019). This increase underscores the urgent need for effective and ac

cessible therapeutic strategies.

Traditional medicine has been a cornerstone in the management of various diseases, including diabetes, particularly in developing countries where access to modern healthcare may be limited. Medicinal plants, used in folk remedies, offer a reservoir of bioactive compounds that could be developed into modern pharmaceuticals (Patel *et al.*, 2012). Chrysophyllumalbidum, known as the African star apple, is one such plant that has been utilized in traditional African medicine. The various parts of this plant, including its leaves, seeds, and fruits, have been used to treat ailments ranging from malaria to diarrhea and diabetes (Adebayo et al., 2010).

Research into the medicinal properties of Chrysophyllumalbidum has identified several bioactive compounds, such as flavonoids, saponins, tannins, and alkaloids. These compounds are known for their antioxidant, anti-inflammatory, and antimicrobial activities, which may contribute to the plant's therapeutic effects (Adebayo *et al.*, 2011). Flavonoids, in particular, have been shown to have significant anti-diabetic properties by improving insulin secretion and sensitivity, reducing oxidative stress, and modulating carbohydrate metabolism (Adefegha&Oboh, 2012).

Alloxan-induced diabetes in rats is a well-established model for studying diabetes and evaluating the potential anti-diabetic effects of various substances. Alloxan, a beta-cell cytotoxin, selectively destroys insulin-producing cells in the pancreas, leading to hyperglycemia and other diabetic complications (Lenzen, 2008). This model closely mimics the pathophysiology of Type 1 diabetes in humans, making it suitable for preclinical testing of anti-diabetic agents.

Previous studies on the anti-diabetic potential of Chrysophyllumalbidum have yielded promising results. For instance, Adewole and Caxton-Martins (2006) demonst

rated that the leaf extract of Chrysophyllumalbidum significantly lowered blood gl ucose levels in diabetic rats. However, comprehensive studies investigating the m echanisms by which Chrysophyllumalbidum exerts its hypoglycemic effects are s till needed. Understanding these mechanisms could facilitate the development of new, plant-based therapeutic agents for diabetes management.

Given the increasing burden of diabetes and the limitations of current treatments, there is a pressing need to explore alternative therapies. Natural products like Chry sophyllumalbidum offer a promising avenue for the discovery of new anti-diabeti c agents that are both effective and affordable. This study aims to build on the ex isting body of knowledge by systematically investigating the anti-diabetic effects of Chrysophyllumalbidum in an alloxan-induced diabetic rat model.

1.2 Aim of the Study

The primary aim of this study is to investigate the anti-diabetic effect of Chrysoph yllumalbidum in alloxan-induced diabetic rats. This research seeks to determine w hether the plant extract can mitigate hyperglycemia and its associated complicati ons in an established animal model of diabetes.

1.3 Objective of the Study

To evaluate the phytochemical composition of Chrysophyllumalbidum extracts.

To determine the hypoglycemic effect of Chrysophyllumalbidum on STZ-induced diabetic rats.

To compare the efficacy of Chrysophyllumalbidum with standard anti-diabetic dr ugs

1.4 Problem Statement

Despite advancements in diabetes management, there remains a significant need

for effective, affordable, and accessible treatments, particularly in developing cou ntries. Synthetic anti-diabetic drugs can have adverse side effects and may not be suitable for all patients (Fowler, 2008). Natural products, such as those derived fro m medicinal plants, offer a promising alternative. However, scientific validation of these traditional remedies is essential. This study addresses the gap in research r egarding the anti-diabetic potential of Chrysophyllumalbidum, which, if proven eff ective, could contribute to the development of new therapeutic options for diabete s management.

1.5 Scope of the Study

This study focuses on evaluating the anti-diabetic effects of Chrysophyllumalbid um in an alloxan-induced diabetic rat model. It includes the preparation and phyto chemical analysis of plant extracts, administration of these extracts to diabetic ra ts, and subsequent assessment of blood glucose levels, insulin levels, and pancre atic tissue histopathology. The study is limited to the use of laboratory animals a nd may form the basis for future clinical trials in humans.

CHAPTER TWO

LITERATURE REVIEW

2.1 Diabetes Mellitus: An Overview

Diabetes mellitus is a complex metabolic disorder characterized by chronic hyper glycemia resulting from defects in insulin secretion, insulin action, or both (World Health Organization, 2016). The condition is associated with severe complication s, including cardiovascular diseases, neuropathy, nephropathy, and retinopathy, w hich significantly impact patients' quality of life (American Diabetes Association, 2020). Current therapeutic strategies aim to maintain blood glucose levels within a normal range, but there is a constant search for more effective treatments with f ewer side effects (Chawla *et al.*, 2016).

Diabetes mellitus is a multifaceted metabolic disorder characterized by chronic hy perglycemia resulting from defects in insulin secretion, insulin action, or both. The disease is classified mainly into Type 1 diabetes (T1D), Type 2 diabetes (T2D), an d gestational diabetes (GDM), with T2D being the most prevalent form, accountin g for about 90-95% of all diabetes cases (American Diabetes Association, 2020). T1D is an autoimmune condition leading to the destruction of pancreatic beta cell s, whereas T2D involves a combination of resistance to insulin action and an inad equate compensatory insulin secretory response (Kahn et al., 2014). The long-ter m complications of diabetes include cardiovascular diseases, neuropathy, nephro pathy, and retinopathy, which contribute to significant morbidity and mortality am ong affected individuals (Forbes & Cooper, 2013).

2.2 STZ-Induced Diabetes in Rats

STZ, a cytotoxic glucose analog, is widely used to induce diabetes in experimenta l animal models. It selectively targets pancreatic beta cells through its accumulati on in these cells via the GLUT2 glucose transporter, leading to cell death and subs equent insulin deficiency (Lenzen, 2008). This model closely mimics the human c ondition of Type 1 diabetes, making it valuable for studying potential anti-diabetic agents.

STZ, a potent diabetogenic agent, is widely employed to induce diabetes in labora tory animals, particularly rats. The mechanism of alloxan-induced diabetes involv es the selective uptake of STZ by pancreatic beta cells via the GLUT2 glucose tra nsporter. Inside the beta cells, STZ undergoes redox cycling, leading to the generat ion of reactive oxygen species (ROS) and subsequent oxidative stress, which cul minates in beta-cell necrosis (Lenzen, 2008). This model effectively mimics the p athology of T1D and is valuable for evaluating the efficacy of potential anti-diabe tic agents.

2.3 Medicinal Plants in Diabetes Management

Medicinal plants have long been used in traditional medicine for the management of diabetes. Various plants have been scientifically investigated for their hypoglyc emic properties, with some showing promising results (Marles& Farnsworth, 199 5). These plants often contain bioactive compounds such as flavonoids, alkaloid s, glycosides, and terpenoids, which contribute to their therapeutic effects (Patel *e t al.*, 2012).

Medicinal plants have been integral to traditional medicine systems across the w orld, offering a rich source of bioactive compounds for the development of therap eutic agents. Numerous plants have been investigated for their hypoglycemic pro perties, revealing a variety of mechanisms through which they exert their effects, i

ncluding enhancing insulin secretion, improving insulin sensitivity, and inhibiting carbohydrate digestion and absorption (Patel et al., 2012). Some well-studied anti-diabetic plants include Momordicacharantia (bitter melon), Trigonellafoenum-graecum (fenugreek), and Gymnemasylvestre (gymnema), which have shown promise in both preclinical and clinical studies (Bailey & Day, 1989).

2.4 ChrysophyllumAlbidum: Pharmacological Potential

Chrysophyllumalbidum belongs to the Sapotaceae family and is indigenous to tropical Africa. It is traditionally used to treat various ailments, including malaria, diarrhea, and diabetes (Olorunnisola et al., 2008). Phytochemical studies have revealed that Chrysophyllumalbidum contains important bioactive compounds such as flavonoids, saponins, tannins, and alkaloids, which possess antioxidant and anti-inflammatory properties (Ajiboye*et al.*, 2013).

Preliminary studies suggest that Chrysophyllumalbidum extracts can significantly reduce blood glucose levels in diabetic rats, supporting its traditional use as an anti-diabetic agent (Adewole& Caxton-Martins, 2006). However, comprehensive studies are needed to confirm these effects and elucidate the underlying mechanisms.

Chrysophyllumalbidum, commonly known as the African star apple, belongs to the Sapotaceae family and is native to tropical Africa. The plant has been traditionally used in various African countries for its purported medicinal properties. The leaves, seeds, and fruits of Chrysophyllumalbidum are used to treat a range of ailments, including malaria, diarrhea, and diabetes (Olorunnisola*et al.*, 2008).

Phytochemical analyses of Chrysophyllumalbidum have identified several bioactive compounds, such as flavonoids, saponins, tannins, and alkaloids, which are known for their antioxidant, anti-inflammatory, and antimicrobial activities (Adebayo

et al., 2011).

The hypoglycemic potential of Chrysophyllumalbidum has been highlighted in preliminary studies. For instance, Adewole and Caxton-Martins (2006) reported that the methanolic leaf extract of Chrysophyllumalbidum significantly reduced blood glucose levels in alloxan-induced diabetic rats. Additionally, the extract showed protective effects on pancreatic beta cells, suggesting a dual mechanism of action involving both the enhancement of insulin secretion and protection against beta-cell damage. Another study by Olorunnisola et al. (2008) demonstrated that the fruit pulp extract of Chrysophyllumalbidum possesses significant antioxidant activity, which may contribute to its anti-diabetic effects by mitigating oxidative stress, a key factor in diabetes pathogenesis.

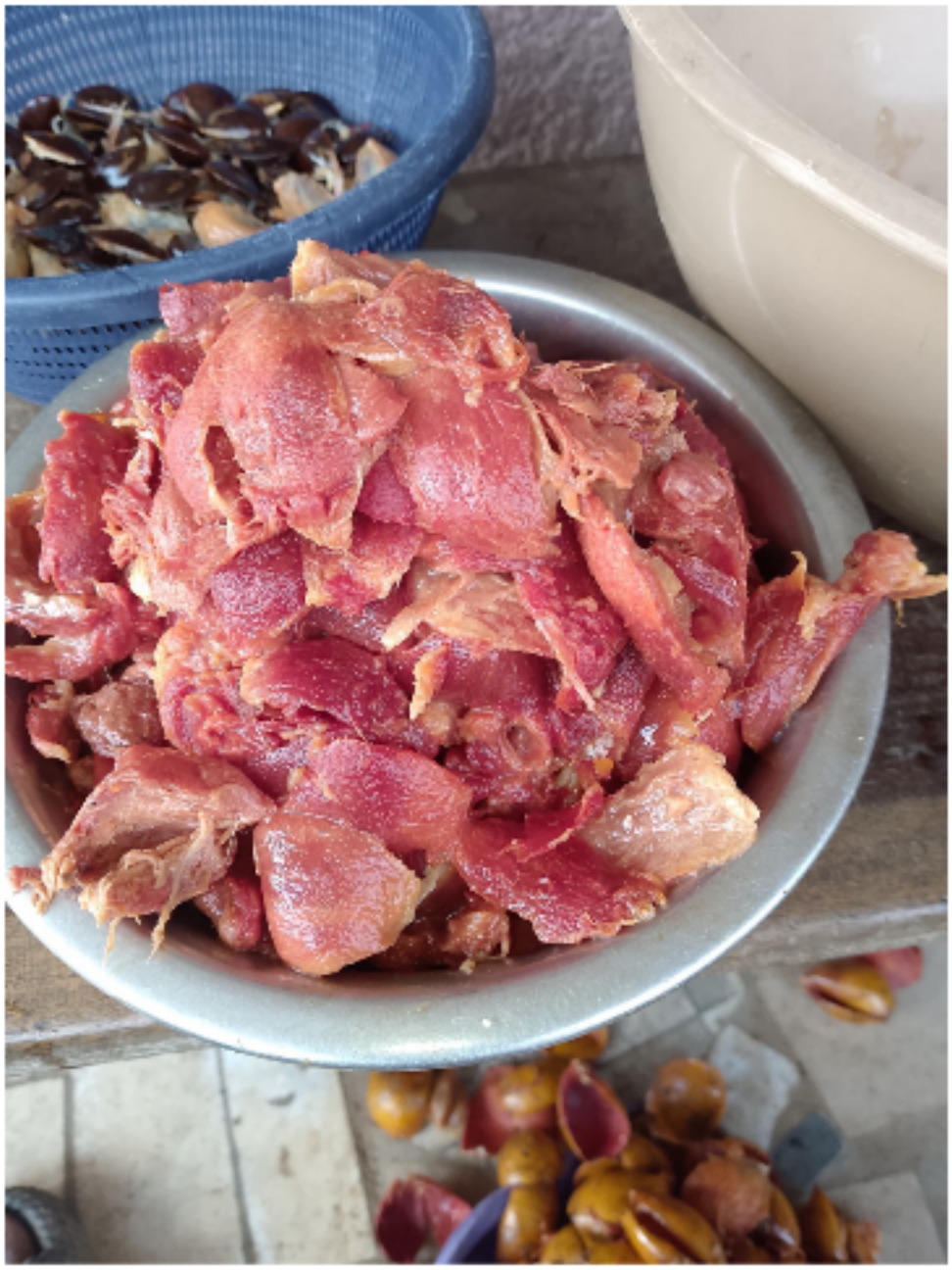

Figure 1: CAP and CAS

2.5 Mechanisms of Action of Anti-Diabetic Plants

The mechanisms through which anti-diabetic plants exert their effects are diverse and multifaceted. Flavonoids, a major class of compounds found in many medici nal plants, including Chrysophyllumalbidum, have been shown to enhance insulin secretion, improve insulin sensitivity, and modulate glucose metabolism (Panche et al., 2016). These compounds exert antioxidant effects by scavenging free radic als and upregulating the activity of antioxidant enzymes, thereby reducing oxidati ve stress and its detrimental effects on pancreatic beta cells and other tissues (Ra himi*et al.*, 2005).

Saponins, another class of bioactive compounds present in Chrysophyllumalbidu m, have been reported to exhibit hypoglycemic effects through various mechanis ms, including inhibition of intestinal glucose absorption, stimulation of insulin sec retion, and modulation of glucose transporters (Lacaille-Dubois & Wagner, 1996). Tannins and alkaloids also contribute to the anti-diabetic effects of medicinal pla nts by inhibiting enzymes involved in carbohydrate digestion, such as alpha-amyl ase and alpha-glucosidase, thereby reducing postprandial hyperglycemia (McDou gall & Stewart, 2005).

2.6 Comparative Studies on Anti-Diabetic Plants

Comparative studies on the efficacy of different anti-diabetic plants have provide d valuable insights into their potential therapeutic applications. For example, a stu dy comparing the hypoglycemic effects of Momordicacharantia and Gymnemasy lvestre found that both plants significantly reduced blood glucose levels in diabeti c rats, but Momordicacharantia exhibited a more pronounced effect on improving insulin sensitivity (Sharma et al., 1990). Similarly, the combined use of multiple pl

ant extracts has been explored to achieve synergistic effects and enhance overall therapeutic efficacy (Marles& Farnsworth, 1995).

In the context of Chrysophyllumalbidum, further comparative studies are warrante d to evaluate its efficacy relative to other well-established anti-diabetic plants. Su ch studies could help identify the unique advantages of Chrysophyllumalbidum a nd optimize its use in diabetes management.

CHAPTER THREE

METHODOLOGY

3.1 Study design: Anti-Diabetic Effect of *Chrysophyllum Albidum* Pulp and See d in STZ-Induced Diabetic Rats

This comprehensive methodology outlines the detailed experimental procedures u ndertaken to evaluate the anti-diabetic potential of *Chrysophyllum albidum* (Afric an Star Apple) pulp (CAP) and seed (CAS) extracts in streptozotocin (STZ)-induce d diabetic rats. The protocol encompasses meticulous plant material collection, ri gorous extraction techniques, precise animal model induction, standardized treat ment administration, and systematic biochemical analysis of blood glucose level s over a defined period.

3.2 Ethical Approval and Animal Care

Prior to the initiation of any experimental work, a comprehensive research propos al detailing all animal procedures will be submitted to and approved by the Institu tional Animal Ethics Committee (IAEC) of the collaborating institution. All animal handling, care, and experimental protocols will strictly adhere to the internationall y accepted guidelines for the humane use and care of laboratory animals (e.g., NI H Guide for the Care and Use of Laboratory Animals or local equivalent regulation s). This commitment ensures that all efforts are made to minimize stress, pain, an d discomfort to the animals throughout the study.

Healthy adult male Wistar or Sprague-Dawley rats, typically weighing between 15 0–200 g, will be procured from a reputable animal breeding facility. Upon arrival, t he rats will undergo a minimum seven-day acclimatization period to adjust to the laboratory environment, during which their general health and behavior will be clo

sely monitored. Animals will be housed in spacious, well-ventilated polypropylene cages (6 rats per cage) equipped with appropriate bedding material (e.g., wood sh avings, changed regularly to maintain hygiene). The animal housing facility will maintain controlled environmental conditions: a consistent temperature of 22±2◦ C, a relative humidity of 50–60, and a strict 12-hour light/dark cycle (lights on at 0 7:00 AM, off at 07:00 PM). Throughout the entire experimental duration, rats will h ave *ad libitum* access to a standard laboratory pellet diet and fresh distilled water, which will be replenished daily. Daily observations will include monitoring for any signs of distress, changes in appetite, water intake, body weight, and general activ ity.

3.3 Plant Material Collection, Authentication, and Preparation

- **Collection:** Fresh, mature, and visually healthy fruits of *Chrysophyllum albi dum* will be meticulously collected during their peak fruiting season from a specific, identified geographical location (e.g., a designated farm or wild ha bitat in a particular region). Care will be taken to select fruits that are fully r ipe, as indicated by their characteristic color and texture, to ensure optimal concentration of bioactive compounds.

- **Authentication:** The collected plant material will undergo rigorous botanica l identification and authentication by a qualified plant taxonomist or botan ist. This crucial step confirms the species and prevents misidentification. A representative voucher specimen (e.g., with flowers and fruits) will be prep ared, properly labeled, and deposited in a recognized institutional herbariu m for future reference and verification.

- **Pulp Separation and Preparation:** Upon collection, the fruits will be thorou

ghly washed under running tap water to remove any dirt, debris, or surface con taminants. The outer pericarp will be carefully peeled, and the fleshy pulp will be manually separated from the seeds. To preserve the integrity of ther molabile bioactive compounds, the pulp will be thinly spread on clean trays and air-dried at ambient room temperature (25–30◦C) in a shaded, well-ven tilated area. This process typically takes several days to a week, or until the pulp reaches a constant weight, indicating complete moisture removal. Alte rnatively, a forced-air oven can be used at a low temperature (e.g., 40–50◦ C) for a shorter duration, provided it does not compromise the active consti tuents. The dried pulp will then be pulverized into a fine, homogeneous po wder using a sterile mechanical grinder or blender. The resulting powder wil l be sieved through a fine mesh (e.g., 60-mesh size) to ensure uniform parti cle size, which aids in efficient extraction.

- **Seed Separation and Preparation:** The seeds, separated from the pulp, will also be thoroughly washed to remove any adhering pulp residues. They wil l then be air-dried under similar conditions as the pulp. Once dry, the hard o uter shell of each seed will be carefully cracked and removed to obtain the i nner kernel. These kernels will then be pulverized into a fine powder using a heavy-duty mechanical grinder, followed by sieving to obtain a fine, unifo rm powder.

- **Storage:** Both the powdered *Chrysophyllum albidum* pulp (CAP) and seed (CAS) materials will be immediately transferred into opaque, airtight contai ners (e.g., dark glass bottles or vacuum-sealed bags) and stored in a cold r oom or freezer at 4◦C until the extraction process to prevent degradation, m

oisture absorption, and microbial contamination.

3.4 Sample Extraction

- **Solvent Selection:** For this study, aqueous extraction (using distilled water) will be employed. This choice is justified by several factors: it mimics traditional methods of preparing herbal remedies, it is generally safe for *in vivo* administration, and water is a polar solvent capable of extracting a wide range of hydrophilic compounds such as polysaccharides, glycosides, and some phenolic compounds and flavonoids, which are often implicated in anti-diabetic activities. While other solvents like ethanol or methanol could extract different sets of compounds (e.g., more lipophilic ones), aqueous extraction is prioritized for its relevance to traditional use and general safety profile.

- **Extraction Method (Aqueous Maceration):**

    - A precise quantity of the powdered *Chrysophyllum albidum* pulp (e.g., 100 g) will be weighed using an analytical balance. This powder will be transferred into a clean, sterile conical flask or an appropriate extraction vessel.

    - A measured volume of distilled water (e.g., 1000 mL, establishing a 1:10 w/v ratio of plant material to solvent) will be added to the flask. This ratio ensures adequate solvent penetration and efficient extraction of soluble components.

    - The mixture will be thoroughly mixed and then sealed. The flask will

be placed on an orbital shaker or agitated intermittently by hand at regu lar intervals (e.g., every 6–8 hours) for a continuous period of 72 ho urs at room temperature. This prolonged maceration with agitation f acilitates maximum dissolution and extraction of the bioactive cons tituents from the plant matrix into the solvent.

- After the maceration period, the crude extract will be initially filtered through several layers of clean muslin cloth to separate the coarse p lant residues.

- The filtrate obtained from the muslin cloth will then be subjected to finer filtration using Whatman No. 1 filter paper under vacuum filtrat ion, if available, to ensure the removal of all fine particulate matter, r esulting in a clear filtrate.

- The clear aqueous filtrate will then be concentrated using a rotary e vaporator. This process involves evaporating the solvent under redu ced pressure and a controlled temperature (typically 40–55◦C) to pre vent thermal degradation of heat-sensitive compounds. The rotary e vaporator allows for efficient solvent removal while preserving the i ntegrity of the extracted compounds.

- The resulting concentrated extract, which will be a viscous liquid, wil l then be subjected to lyophilization (freeze-drying). This process inv olves freezing the extract and then reducing the surrounding pressur e to allow the frozen water to sublimate directly from the solid phas e to the gas phase. Lyophilization is preferred as it effectively remov

es water without using high temperatures, thus preserving the biologica l activity and stability of the extracted compounds and yielding a dr y, highly concentrated powdered extract.

- The final dry powdered extract will be weighed accurately using an analytical balance to determine the extraction yield.

- The identical extraction procedure, from maceration to lyophilizatio n, will be meticulously followed for the powdered *Chrysophyllum alb idum* seed (CAS) material to ensure consistency and comparability between the two extracts.

- **Storage of Extracts:** The lyophilized CAP and CAS extracts, being highly hy groscopic and potentially sensitive to light and oxidation, will be immediat ely transferred into opaque, airtight, amber-colored glass bottles. These bot tles will be tightly sealed and stored in a deep freezer at −20∘C until require d for *in vivo* administration. This low-temperature, dark, and anaerobic stor age condition is critical for maintaining the stability, potency, and integrity of the bioactive compounds over the study duration.

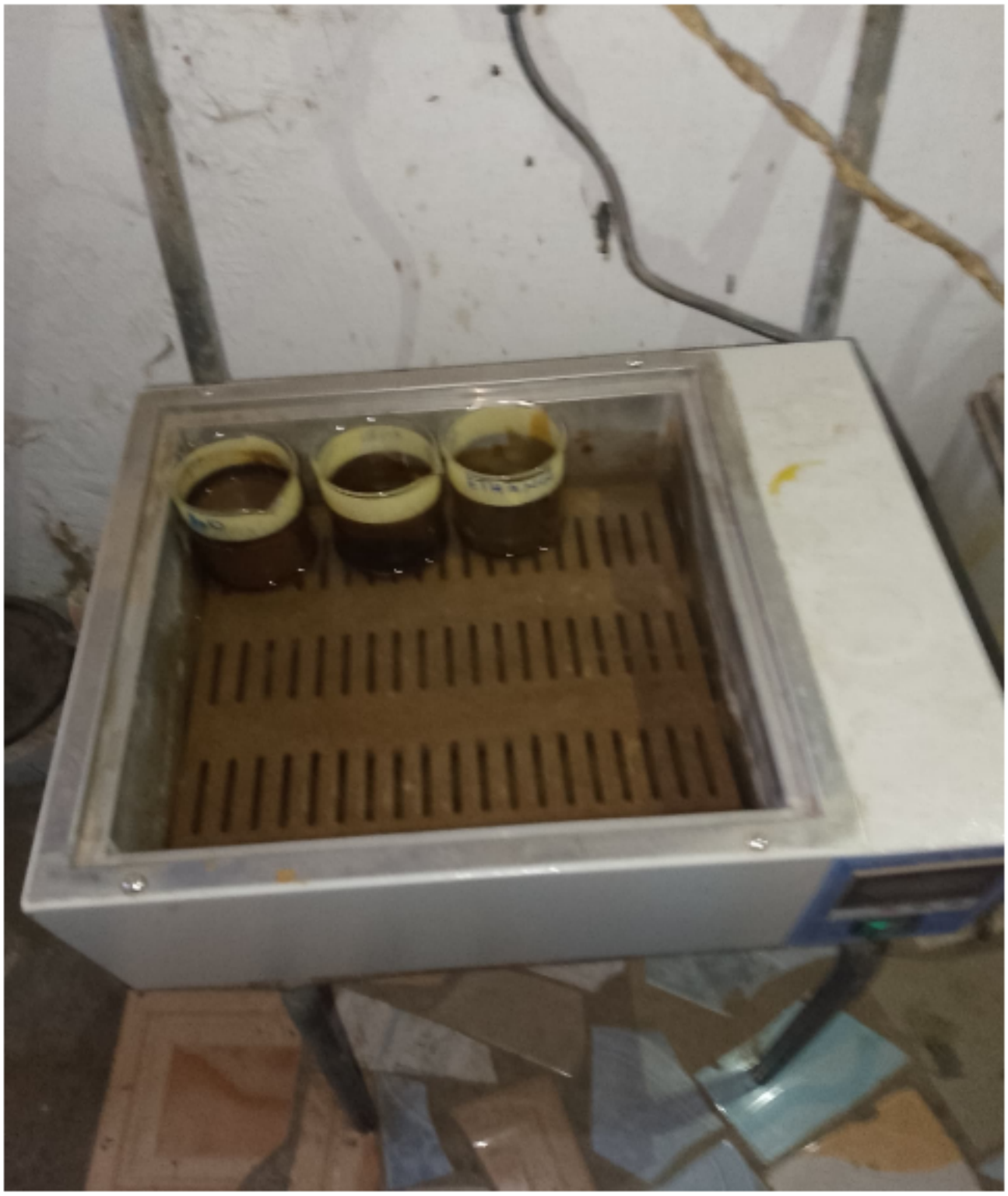

Figure 2: Extraction process

3.5 Chemicals and Reagents

All chemicals and reagents utilized in this study will be of analytical grade or higher purity to ensure accuracy and reproducibility of results. Streptozotocin (STZ), a well-established diabetogenic agent, will be procured from a reputable chemical supplier (e.g., Sigma-Aldrich, Merck). Metformin hydrochloride, a widely used oral anti-diabetic drug, will serve as the positive control and will be obtained from a certified pharmaceutical supplier. Citrate buffer (0.1 M, pH 4.5) will be freshly prepared using sodium citrate and citric acid. Blood glucose levels will be measured using a commercially available, calibrated glucometer (e.g., Accu-Chek Active, OneTouch Ultra) and its corresponding test strips, ensuring consistency and reliability of glucose readings.

3.6 Animal Model and Induction of Diabetes

- **Animal Selection:** Male rats are typically preferred in diabetes research to avoid hormonal fluctuations associated with the estrous cycle in females, which could potentially influence glucose metabolism. Wistar or Sprague-Dawley strains are commonly used due to their well-characterized physiological responses and availability.

- **Diabetes Induction:** Type 1 diabetes will be induced in the experimental rats by a single intraperitoneal (i.p.) injection of streptozotocin (STZ). STZ is a glucose analogue that selectively targets and destroys pancreatic β-cells, leading to insulin deficiency and subsequent hyperglycemia. To ensure its stability and efficacy, STZ will be freshly dissolved in cold 0.1 M citrate buffer (pH 4.5) immediately prior to administration. The chosen dose of 60 mg/kg body weight is a standard dose known to reliably induce stable and se

vere hyperglycemia in rats. Normal control rats will receive an equivalent volu me of the citrate buffer vehicle alone via i.p. injection.

- **Confirmation of Diabetes:** After a 72-hour post-STZ injection period, which allows for the full diabetogenic effect to manifest, fasting blood glucose (F BG) levels will be measured from blood samples collected from the tail vei n of each rat. Only rats exhibiting consistent FBG levels ≥200 mg/dL (or 11. 1 mmol/L) will be considered successfully diabetic and included in the stu dy. This threshold ensures a clear distinction between diabetic and non-dia betic animals and a uniform baseline of hyperglycemia across the treatme nt groups.

3.7 Experimental Design and Grouping

A total of 42 rats will be randomly allocated into the following seven distinct expe rimental groups. Randomization will be performed using a random number gener ator or a similar unbiased method to minimize selection bias and ensure group co mparability at baseline.

- **Group 1: Normal Control (ND + water):** Non-diabetic (ND) rats receiving an equivalent volume of distilled water orally daily via gavage. This group ser ves as a baseline for normal physiological parameters.

- **Group 2: Diabetic Control (D control):** STZ-induced diabetic rats receiving an equivalent volume of distilled water orally daily via gavage. This group r epresents the untreated diabetic state and demonstrates the progression of hyperglycemia without intervention.

- **Group 3: Standard Drug Control (D +** 50 **mg/kg body weight metformin):** STZ-induced diabetic rats receiving 50 mg/kg body weight of metformin hydrochloride orally daily. Metformin, a well-established anti-diabetic drug, serves as a positive control to validate the experimental model's responsiveness and provide a benchmark for the efficacy of the plant extracts.

- **Group 4: *Chrysophyllum albidum* Pulp (D +** 100 **mg/kg body weight CAP):** STZ-induced diabetic rats receiving a low dose of 100 mg/kg body weight of the *C. albidum* pulp extract orally daily.

- **Group 5: *Chrysophyllum albidum* Pulp (D +** 200 **mg/kg body weight CAP):** STZ-induced diabetic rats receiving a high dose of 200 mg/kg body weight of the *C. albidum* pulp extract orally daily.

- **Group 6: *Chrysophyllum albidum* Seed (D +** 100 **mg/kg body weight CAS):** STZ-induced diabetic rats receiving a low dose of 100 mg/kg body weight of the *C. albidum* seed extract orally daily.

- **Group 7: *Chrysophyllum albidum* Seed (D +** 200 **mg/kg body weight CAS):** STZ-induced diabetic rats receiving a high dose of 200 mg/kg body weight of the *C. albidum* seed extract orally daily.

- **Treatment Administration:** All oral administrations will be performed once daily at a consistent time each morning (e.g., between 08:00 AM and 09:00 AM) using a sterile, appropriately sized oral gavage needle. The CAP and CAS extracts, as well as metformin, will be freshly prepared by dissolving the lyophilized powder in distilled water immediately before administration to e

nsure stability and accurate dosing. The treatment period will span 13 consec utive days, a duration deemed sufficient to observe significant changes in blood glucose levels based on preliminary data.

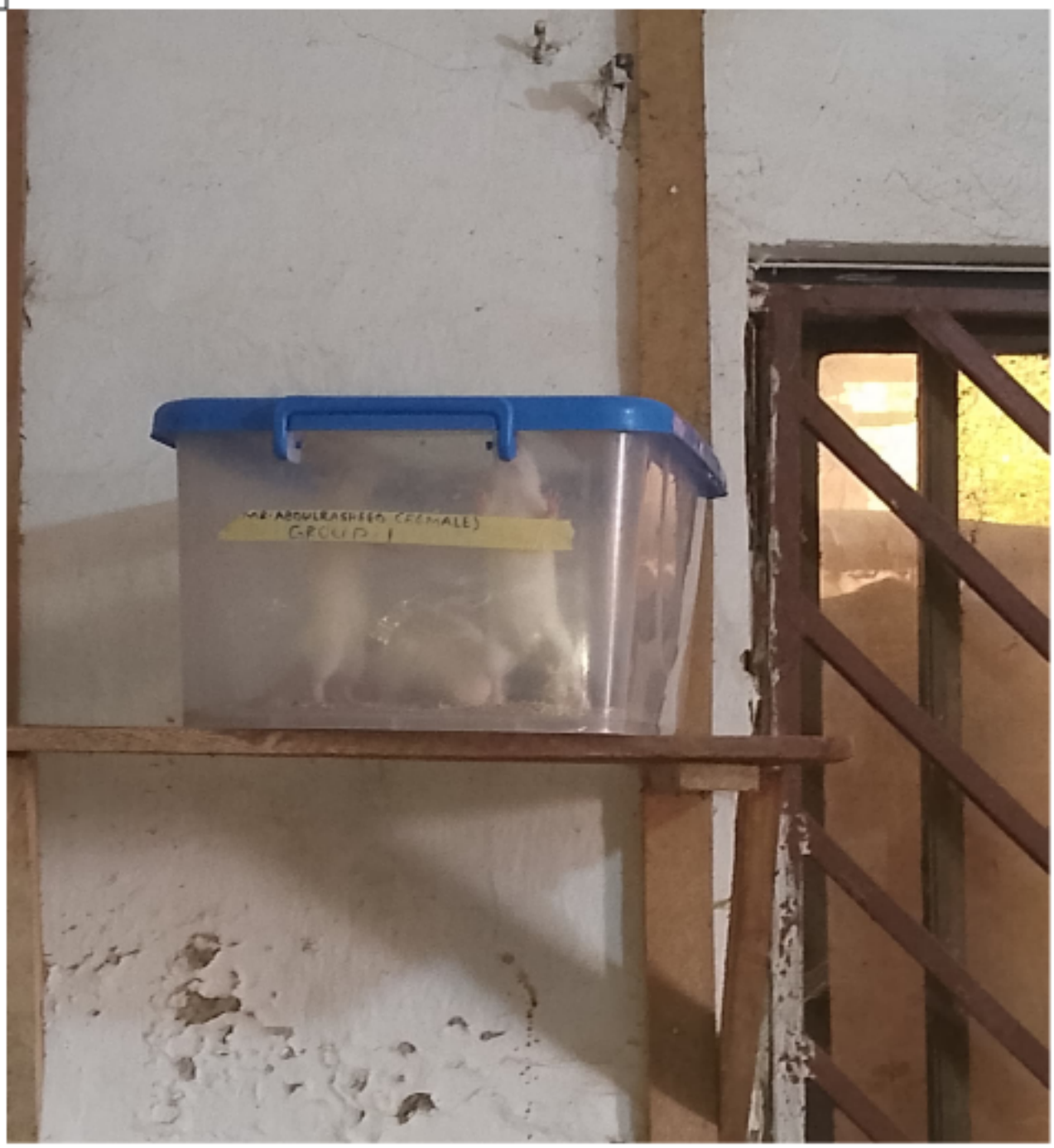

Figure 3: rat grouping