

***In vitro* ANTIDIABETIC PROPERTIES OF THE AQUEOUS EXTRACT OF**

Sida acuta

BY

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DEPARTMENT OF MEDICAL BIOCHEMISTRY

SCHOOL OF BASIC MEDICAL SCIENCES

UNIVERSITY OF BENIN

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**A PROJECT SUBMITTED TO THE DEPARTMENT OF MEDICAL
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REQUIREMENTS FOR THE AWARD OF BACHELOR OF SCIENCE
(HONS) DEGREE IN MEDICAL BIOCHEMISTRY**

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CERTIFICATION

This is to certify that this is an original research work carried out by **EHIBHATIOMHAN EMMANUELLA OSE**, with Matriculation Number **BMS2010671** in the Department of Medical Biochemistry, School of Basic Medical Science, University of Benin, in partial fulfilment of the requirements for the award of Bachelor of Science (B.Sc) Hons degree.

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DEDICATION

This research work is dedicated to God almighty for his infinite mercies, love, favour and grace on me throughout the duration of this project work.

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This milestone journey would not have been successful without the help of almighty God, whom through His grace saw me through all challenges and difficulties. May His name be forever glorified.

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ABSTRACTS

Sida acuta commonly known as wire weed possesses several therapeutic properties that can be recognized in traditional medicine. *Sida acuta* has been found to contain several photochemical (flavonoids, tannins, steroids), antioxidant and antidiabetic properties. The aim of this study was to determine the *in vitro* antidiabetic activities of the aqueous extract of *Sida acuta* on α -amylase and α -glucosidase enzyme. In this study, the result on the α -amylase assay shows that the standard (acarbose) has better *in vitro* antidiabetic properties on α -amylase enzyme by inhibiting α -amylase at IC_{50} of 29997.9 μ g/ml when compared to the inhibitory properties of the aqueous *Sida acuta* extract which had an IC_{50} of 42966.9 μ g/ml. The result obtained from the α -glucosidase assay showed that the IC_{50} of the standard (acarbose) had better *in vitro* antidiabetic properties on the α -glucosidase enzyme by inhibiting α -glucosidase at an IC_{50} of 10120.52 μ g/ml when compared to that of the extract (IC_{50} of 14333.29 μ g/ml). In conclusion the extract displayed its medicinal properties by inhibiting α -amylase and α -glucosidase enzyme and could be used as a possible anti diabetic therapeutic agent.

CHAPTER ONE

1.0 INTRODUCTION

Diabetes mellitus is an endocrine-metabolic disorder characterized by chronic hyper-glycaemia (high blood sugar) giving rise to the risk of microvascular (retinopathy, nephropathy, and neuropathy) and macrovascular (ischemic heart disease, stroke and peripheral vascular disease) damage, with associated reduced life expectancy and diminished quality of life (Neelesh *et al.*, 2015). Diabetes mellitus is the most common heterogeneous metabolic disorder, which currently affects an estimated 143 million people worldwide and its incidence is increasing steadily with changes in life style (Zimmet *et al.*, 2016). Besides hyperglycemia, several other factors including dyslipidemia or hyperlipidemia are involved in the development of micro and macro vascular complications of diabetes which are the major cause of morbidity and death. Several oral hypoglycemic agents are the primary forms of treatment for diabetes. However, prominent side effects of such drugs are the main reason for an increased number of people seeking alternate therapies that may have less severe or no side effects (Mentreddy, 2017).

Sida acuta (Malvaceae) is a malvaceous weed that frequently dominates improved pastures, waste and disturbed places on roadsides. The plant is native to Mexico and Central America but has spread throughout the tropical and subtropics (Holm, 2017). It is found throughout the hotter parts of India. Root of this plant is plants are bitter tonic, stomachic, diaphoretic and antipyretic. It is proven in treatment of fever and chronic bowel complaints. Expressed juice of the root is employed for the removal of intestinal pain and root pest is applied for the bursting of boils and abscesses. It is used in rheumatic affections, demulcent, gonorrhoea and chronic dysentery (Jena, 2018). Traditionally the plant is used for the treatment of fever, bronchitis, ulcer, diarrhea, and dysentery and skin diseases. The diterpenes, alkaloids, steroid and miscellaneous lactones have been isolated

from its root (Dinan, 2018). The plant is reported to possess anti-plasmodial, anti-microbial, anti-oxidant, cytotoxic activities and many other properties. Roots of different species of *Sida*, such as *Sida cordifolia* and *Sida spinosa* are traditionally used for the treatment of diabetes (Jain, 2016).

1.2 JUSTIFICATION OF STUDY

The rise in diabetes prevalence underscores the urgency for exploring natural remedies. Given the escalating global burden of diabetes and the limitations of existing treatment options, there is a pressing need to explore alternative therapeutic approaches (Jain, 2016). Investigating the anti-diabetic properties of natural extracts like *Sida acuta* offers a potential avenue for discovering novel drugs or supplements. Thus, the need to investigate the potential of *Sida acuta* aqueous extract in combating diabetes. By assessing its inhibitory effects on α -amylase and α -glucosidase, we seek to unveil its therapeutic promise.

1.3 AIMS AND OBJECTIVES OF THE STUDY

The aim of this study was to investigate and analyze the *Invitro* antidiabetic properties of the aqueous extract of *Sida acuta*. The objectives were to analyze the invitro antidiabetic properties of the aqueous extract of *Sida acuta* on:

- i. α -amylase enzymes
- ii. α -glucosidase enzymes.

CHAPTER TWO

2.0 LITERATURE REVIEW

After meal ingestion, the digestion of Starch begins firstly by salivary α -amylase and pancreatic α -amylase to produce maltose, malt triose and α -limit dextrin which are further completely hydrolyzed to glucose by α -glucosidases in the brush border of intestinal epithelial cells or enterocytes (Zohre *et al.*, 2015). The inhibition of α -glucosidases as well as α -amylase is one of the powerful interventions to decrease glucose absorption. Natural or synthetic α -glucosidase inhibitors are of therapeutic interest to delay postprandial hyperglycemia in type 2 diabetes (Arya *et al.*, 2012). *Sida acuta* Burm. f. is a Malvaceous weed cosmopolitan in distribution, especially in tropics and sub-tropics. It is commonly found on abandoned areas i.e. roadsides and wastelands. The leaf, root, and whole plant have been ethnomedicinally used for treatments of wound, dysentery, helminthiasis, hemorrhoid and malarial fever (Dinda *et al.*, 2015). *S. acuta* leaf alcoholic extract exhibited a slight decrease in blood glucose levels after 2 and 4 hours of oral administration in normal rats (Arya *et al.*, 2012). It is worthy of note that α -amylase is one of the main enzymes responsible for the breakdown of starch to more simple sugars. α -amylase inhibitors are also known as starch blockers because they prevent dietary starch from being absorbed by the body and thereby lower postprandial glucose levels (Arya *et al.*, 2012). Slowing the digestion and breakdown of starch may have beneficial effects on insulin resistance and glycemic index control in people with diabetes (Barrett *et al.*, 2017). Currently available therapeutic drugs like biguanides and sulphonamides have been shown to impose side effects like secondary renal failure, when used for longer periods (Christhudas *et al.*, 2014). Therefore, alternative sources of these medicines are being sourced from natural sources due to their good pharmacological properties, fewer side effects, and low cost (Karima *et al.*, 2017).

2.1 OVERVIEW OF *Sida acuta*

Sida acuta, is known as the common wireweed, is a species of flowering plant in the mallow family, Malvaceae (Mann *et al.*, 2015). It originated in Central America, but has a pantropical distribution. It is considered a weed in some areas. It frequently dominates improved pastures, waste and busy roadsides (Mann *et al.*, 2015). It is also commonly called stubborn grass. *Sida acuta* is commonly called “seketu”, “osepotu”, “esoketu” or “akoko” in Yoruba, “Ogirishi” in Igbo, “Riegueyoto” in Bini and wire-weed, broom-weed or spiny head among Nigerians in general (Olowokudejo *et al.*, 2018). The bark is smooth, greenish, the root is thin, long, cylindrical and very rough; leaves are lance late, nearly glabrous, peduncles equal to the petioles, seeds are smooth and black; the flowers are yellow, solitary or in pairs (Senthilkumar *et al.*, 2018). *Sida acuta* is viewed as an astringent, tonic which is used in treating urinary diseases and blood disorders, bile, liver and as treatment for nervous diseases (Karou *et al.*, 2017). The economic importance of the plant is it is the source of natural fibers, it also used in food, beverages, timber, traditional medicine and in horticulture. The plant is also used in stomachic, diaphoretic and antipyretic. Phytochemical analysis of the plant revealed the presence of saponins, tannins, alkaloids and cardiac glycosides (Babu, 2020). It is used orally for asthma, fever, aches, pains, ulcers, anti-helminthic medications as well as for venereal diseases. Its roots are used as diuretic, astringent, stomachic, febrifuge, and demulcent and seeds are applied as laxative, aphrodisiac, and demulcent, recommended in cystitis, colic, gonorrhoea, mental or nervous strain and piles (Shinwari, 2016). The leaves are considered to possess demulcent, diuretic, anti-helminthic and wound healing properties and also used in rheumatic infections. The juice of the leaves is boiled in oil and applied to testicular swellings and in Elephantiasis and also leaf juice is used as a poultice for dandruff (Kayode, 2016). In Nigeria, *Sida acuta* is used to treat malaria, ulcer, fever, gonorrhoea, abortion, breast cancer, poisoning,

inflammation, stops bleeding, treatment of sores wounds, antipyretic and the infusion of the leaves is given to women in labour (Edeoga *et al.*, 2015).

TABLE 2.1 SCIENTIFIC CLASSIFICATION OF *Sida acuta*

Scientific Classification	
Kingdom	<i>Plantae</i> – Plants
Subkingdom	<i>Tracheobionta</i> -Vascular Plants
Superdivision	<i>Spermatophyta</i> – Seed plants
Division	<i>Magnoliophyta</i> – Flowering plants
Class	<i>Magnoliopsida</i> – Dicotyledons
Subclass	<i>Dilleniidae</i>
Order	<i>Malvales</i>
Family	<i>Malvaceae</i>
Genus	<i>Sida</i> L.
Species	<i>S. acuta</i>
Binomial name	
<i>Sida acuta</i> <u>Burm.f.</u>	
Synonyms	
<i>Sida carpinifolia</i> <u>L.f.</u>	

Source: Padmaa, 2023



Fig 2.1: *Sida acuta* plant

Source: Garg, 2015

2.2 PHYTOCHEMICAL COMPOSITION OF *Sida acuta*

The phytochemical composition of *Sida acuta* refers to the natural chemical compounds present in the plant. These compounds are synthesized by the plant through its metabolic processes and serve various functions such as defense against pathogens, attraction of pollinators, and adaptation to environmental stressors (Oluleye *et al.*, 2022). Phytochemicals are not essential nutrients like vitamins and minerals, but they have been found to exert beneficial effects on human health and are often associated with the medicinal properties of plants. The phytochemical composition of *Sida acuta* includes a diverse array of compounds such as alkaloids, flavonoids, tannins, phenolic compounds, terpenoids, and steroids. These compounds contribute to the medicinal properties attributed to *Sida acuta*, which include anti-inflammatory, analgesic, antimicrobial, antioxidant, and hepatoprotective effects (Shittu *et al.*, 2020).

2.2.1 Alkaloids

Alkaloids are a diverse group of naturally occurring organic compounds that contain nitrogen atoms in their chemical structure. They are found primarily in plants, although some are also produced by fungi, bacteria, and animals. Alkaloids often have pharmacological effects on living organisms, and many of them are known for their physiological activities and medicinal properties (Shittu *et al.*, 2020). Alkaloids are nitrogenous compounds that often exhibit pharmacological effects on the human body. *Sida acuta* contains various alkaloids, including ephedrine, vasicine, and vasicinone. Ephedrine, for example, has been traditionally used as a stimulant and bronchodilator. Vasicine and vasicinone have been studied for their broncho dilatory and anti-inflammatory properties. These alkaloids may interact with receptors in the nervous system and other tissues, leading to effects such as bronchodilation, analgesia, and anti-inflammatory actions (Odone, 2015). Alkaloids are naturally occurring organic substances, predominantly found in plant

sources including marine algae and rarely in animals (e.g. in the toxic secretions of fire ants, ladybugs and toads). They occur mostly in seed-bearing plants mainly in berries, bark, fruits, roots and leaves. Alkaloids often contain at least one nitrogen atom in heterocyclic ring. These are basic in nature and so referred the term alkaloid (alkali-like) (Kokate *et al.*, 2015). Alkaloids possess remarkable physiological action on human and other animals. These are the active components of numerous medicinal plants or plant-derived drugs. Their structural diversity and different physiological activities are unique to any other group of natural products. Many drugs used by man for both medical and non-medical purposes are produced in nature in the form of alkaloids e.g. atropine, strychnine, caffeine, nicotine, morphine, codeine, cocaine etc (Kokate *et al.*, 2015). Naturally occurring receptors for many alkaloids have also been identified in human and other animals, suggesting an evolutionary role for the alkaloids in physiological processes. Alkaloids are relatively stable compounds that accumulate as end products of different biosynthetic pathways, mostly starting from common amino acids such as lysine, ornithine, tyrosine, tryptophan, and others. These substances are usually colorless but several colored alkaloids are also reported e.g. berberine is yellow, sanguinarine salt is copper-red and betanidin is red (Kokate *et al.*, 2015).

2.2.2 Flavonoids

Flavonoids are a class of polyphenolic compounds found in plants, characterized by a 15-carbon skeleton containing two phenyl rings (A and B) and a heterocyclic ring (C) with oxygen. They are widely distributed in fruits, vegetables, grains, tea, and wine, and exhibit various biological activities, including antioxidant, anti-inflammatory, and anticancer properties (Panche *et al.*, 2016). Flavonoids are a diverse group of polyphenolic compounds with antioxidant, anti-inflammatory, and immune-modulating properties (Hollman *et al.*, 2016). *Sida acuta* contains flavonoids such as quercetin, kaempferol, and luteolin. Quercetin, for instance, has been shown to

have anti-inflammatory, antiviral, and anticancer properties. Kaempferol exhibits antioxidant and anti-inflammatory effects, while luteolin has been studied for its neuroprotective and anti-inflammatory activities (Panche *et al.*, 2016). These flavonoids may contribute to the overall health-promoting effects of *Sida acuta* (Nijveldt *et al.*, 2019). Flavonoids, a group of natural substances with variable phenolic structures, are found in fruits, vegetables, grains, bark, roots, stems, flowers, tea and wine. These natural products are well known for their beneficial effects on health and efforts are being made to isolate the ingredients so called flavonoids. Flavonoids are now considered as an indispensable component in a variety of nutraceutical, pharmaceutical, medicinal and cosmetic applications. This is attributed to their anti-oxidative, anti-inflammatory, anti-mutagenic and anti-carcinogenic properties coupled with their capacity to modulate key cellular enzyme function (Nijveldt *et al.*, 2019).

2.2.3 Tannins

Tannins are an important group of secondary plant metabolites that were originally used in the leather production industry in the tanning of animal hides (Panche *et al.*, 2016). The varied chemical structures and stability evidenced among the tannin group result in their classification as hydrolyzable, complex, and proanthocyanidins (Sieniawska, 2017). Tannins in a broader spectrum are polyphenolic compounds found in various plants, characterized by their ability to bind and precipitate proteins. They often impart astringent taste and are responsible for the bitterness in certain foods and beverages. Tannins have been studied for their antioxidant properties, which contribute to their potential health benefits, including anti-inflammatory and antimicrobial effects (Smeriglio *et al.*, 2016). Tannins are polyphenolic compounds that have astringent properties and are often found in plants. In *Sida acuta*, tannins may play a role in its traditional medicinal uses, such as treating diarrhea and inflammation. Tannins can bind to proteins and other molecules,

exerting effects such as reducing inflammation, inhibiting bacterial growth, and promoting wound healing (Gülçin, 2018).

2.2.4 Phenolic compounds

Phenolic compounds are a diverse group of secondary metabolites found in plants, characterized by one or more hydroxyl groups attached to an aromatic ring (Panche *et al.*, 2016). They contribute to the color, flavor, and antioxidant properties of many fruits, vegetables, and beverages. Phenolic compounds have been extensively studied for their potential health benefits, including anti-inflammatory, anticancer, and cardioprotective effects (Panche *et al.*, 2016). Phenolic compounds are secondary metabolites found in plants that possess antioxidant and anti-inflammatory properties. *Sida acuta* contains various phenolic compounds, including phenolic acids and phenolic glycosides. These compounds contribute to the plant's ability to scavenge free radicals, reduce oxidative stress, and modulate inflammatory pathways in the body, potentially offering protection against chronic diseases such as cardiovascular disease, cancer, and neurodegenerative disorders (Scalbert *et al.*, 2015).

2.2.5 Terpenoids

Terpenoids, also known as isoprenoids, are a large and structurally diverse group of compounds found in plants (Panche *et al.*, 2016). *Sida acuta* contains terpenoids such as β -sitosterol and stigmasterol. β -sitosterol has been studied for its potential cholesterol-lowering and anti-inflammatory effects. Stigmasterol exhibits anti-inflammatory, antioxidant, and anticancer properties (Panche *et al.*, 2016). These terpenoids may contribute to the overall pharmacological activities of *Sida acuta*, including its anti-inflammatory and immunomodulatory effects. Terpenoids, ubiquitous in nature, are a diverse class of organic compounds found in plants, fungi, and some insects. They contribute to the distinct aroma and flavor of many plants and are essential

in various biological processes. From the calming scent of lavender to the zesty aroma of citrus fruits, terpenoids exhibit a wide range of odors and flavors. Research suggests their potential therapeutic properties, including anti-inflammatory, antimicrobial, and antioxidant effects (Atanasov *et al.*, 2015). These compounds are biosynthesized from isoprene units and are classified based on the number of these units they contain. Terpenoids play crucial roles in plant defense mechanisms, communication, and attracting pollinators and seed dispersers (Gershenzon, 2017). Understanding their chemical diversity and biological functions is integral to exploring their pharmaceutical and industrial applications.

2.2.6 Steroids

Steroids are a class of organic compounds with a characteristic molecular structure (Gershenzon, 2017). Steroids are compounds constituted of four fused rings, for example, the most common and best-known steroid in humans, cholesterol. In animals, steroids are biosynthesized from lanosterol and are widely distributed. The distinctive feature in steroids is lack of methyl group at C-4 position as compared to terpenes. In this section, we have classified steroids into five basic categories based upon their chemical composition (Gershenzon, 2017). *Sida acuta* contains steroids such as β -sitosterol and stigmasterol. These compounds have been studied for their potential anti-inflammatory, antioxidant, and anticancer activities. β -sitosterol, for example, has been shown to inhibit inflammatory mediators and reduce oxidative stress, while stigmasterol exhibits anticancer effects by inducing apoptosis and inhibiting tumor cell proliferation. These steroids may contribute to the therapeutic properties of *Sida acuta* in the management of inflammatory and neoplastic diseases (Gershenzon, 2017).

2.3 PROXIMATE ANALYSIS OF *Sida acuta*

Proximate analysis of *Sida acuta* involves assessing its chemical composition to understand its nutritional or medicinal properties. It typically includes determination of moisture content, ash, crude protein, crude fat, crude fiber, and carbohydrates. Moisture content indicates water presence, while ash content reveals the inorganic mineral content after combustion (Miller *et al.*, 2017). Crude protein analysis measures nitrogen content, often using the Kjeldahl method. Crude fat estimation involves extracting lipids with solvents like ether. Crude fiber quantifies indigestible cellulose and lignin. Carbohydrate determination often involves calculating the difference from other components. Proximate analysis helps in assessing the nutritional value and potential applications of *Sida acuta* in various industries such as pharmaceuticals, food, or agriculture (Miller *et al.*, 2017).

2.3.1 Carbohydrates

Carbohydrates are organic compounds made up of carbon, hydrogen, and oxygen atoms, typically in a ratio of 1:2:1 (Smith, 2020). They serve as the primary source of energy for living organisms and play essential roles in cellular processes (Brown, 2018). Carbohydrates can be classified into simple and complex forms based on their chemical structure and how quickly they are digested and absorbed (Miller *et al.*, 2017).

Simple carbohydrates, or sugars, include monosaccharides (such as glucose, fructose, and galactose) and disaccharides (such as sucrose, lactose, and maltose) (Johnson, 2019). These provide quick energy but can lead to rapid spikes in blood sugar levels (Smith, 2020). Complex carbohydrates, also known as polysaccharides, consist of long chains of sugar molecules and take longer to digest (Brown, 2018). Common examples include starches found in grains, legumes, and

root vegetables, as well as dietary fiber found in fruits, vegetables, and whole grains (Miller *et al.*, 2017).

Carbohydrates are vital for providing energy to fuel cellular processes, supporting brain function, and maintaining overall health (Brown, 2018). Balancing intake of simple and complex carbohydrates is important for maintaining stable blood sugar levels and promoting long-term health (Johnson, 2019). In the context of *Sida acuta*, carbohydrates are calculated by subtracting the sum of moisture, ash, protein, fat, and fiber from the total weight (Smith, 2020). Carbohydrates serve as a major source of energy and may include sugars, starches, and dietary fiber (Brown, 2018).

2.3.2 Protein

Proteins are complex organic molecules composed of amino acids linked together by peptide bonds (Nelson, 2017). They serve numerous essential functions in living organisms, including acting as structural components of cells and tissues, catalyzing biochemical reactions as enzymes, regulating gene expression as hormones, and facilitating the transport of molecules across cell membranes (Smith, 2019).

In the context of proximate analysis of *Sida acuta*, protein is one of the key components assessed to understand its nutritional composition (Brown, 2018). Protein content is typically determined using methods like the Kjeldahl method, which measures the nitrogen content and calculates it into protein content using a conversion factor (Miller *et al.*, 2017). *Sida acuta*, being a plant species, may contain varying levels of protein depending on factors such as the specific variety, growing conditions, and stage of maturity (Johnson, 2019).

The protein content of *Sida acuta* is important for assessing its nutritional value, especially in regions where it is used as a food source or as a traditional medicinal plant (Smith, 2019). Additionally, understanding the protein content of *Sida acuta* can guide its utilization in various industries, such as food processing or pharmaceuticals, where protein-rich plant sources are sought after for their potential health benefits (Goldstein, 2018). This constituent of *Sida acuta* determines the nitrogen content of *Sida acuta*, which is then converted into protein content using a conversion factor (Nelson, 2017). Protein is crucial for growth, repair, and maintenance of body tissues (Smith, 2019).

2.3.3 Lipids

Lipids are a diverse group of organic compounds that are insoluble in water but soluble in organic solvents like ether, chloroform, or benzene (Nelson, 2017). They play crucial roles in living organisms, serving as energy storage molecules, structural components of cell membranes, and signaling molecules (Smith, 2019). Lipids include various subclasses such as fats, oils, phospholipids, steroids, and waxes. Fats and oils, collectively known as triglycerides, are the most common type of lipids found in nature. They consist of glycerol molecules bonded to three fatty acid chains (Johnson, 2019). Fats are usually solid at room temperature, while oils are liquid. Fats and oils are an important source of energy in the diet, providing more than twice the energy per gram compared to carbohydrates or proteins (Miller *et al.*, 2017). Phospholipids are another important class of lipids, comprising a glycerol backbone attached to two fatty acids and a phosphate group (Goldstein, 2018). They are integral components of cell membranes, forming a lipid bilayer that regulates the passage of substances into and out of cells (Smith, 2019). Steroids, such as cholesterol and hormones like estrogen and testosterone, are lipids with a characteristic four-ring structure. Cholesterol, despite its negative reputation, is essential for the formation of

cell membranes and serves as a precursor for the synthesis of steroid hormones and vitamin D (Brown, 2018). Waxes are esters of long-chain fatty acids and long-chain alcohols. They are found in various natural substances like plant cuticles, beeswax, and animal fur, providing waterproofing and protection against dehydration and environmental stress (Nelson, 2017). Lipids are extracted from *Sida acuta* using suitable solvents (Johnson, 2019). The crude fat content indicates the presence of oils and fats, which contribute to energy provision and act as carriers for fat-soluble vitamins (Goldstein, 2018). Understanding the role of lipids in biological systems is crucial for comprehending various physiological processes and designing interventions for health and disease (Smith, 2019).

2.3.4 Ash

Ash content refers to the inorganic residue left behind after the complete combustion of organic material (Kokate *et al.*, 2015). It is typically expressed as a percentage of the original sample weight and represents the mineral content of the material being analyzed (Kokate *et al.*, 2015). Ash content analysis is an important parameter in various industries, including food, pharmaceuticals, and agriculture, as it provides insights into the presence of essential minerals and the overall purity of a substance. In the food industry, ash content is used to assess the quality and nutritional value of food products. Higher ash content may indicate the presence of minerals such as calcium, magnesium, potassium, and phosphorus, which are essential for human health (Kokate *et al.*, 2015). However, excessively high ash content may also suggest contamination or adulteration with inorganic substances. In pharmaceuticals, ash content analysis is often employed as a quality control measure to ensure the purity of herbal extracts and medicinal preparations. Deviations from expected ash content levels may signal the presence of impurities or inadequate processing techniques, which can affect the efficacy and safety of the final product (Zieve, 2019).

In agriculture, ash content analysis is utilized to evaluate the nutrient composition of soil and plant materials. By determining the ash content of plant residues or compost, farmers can assess the mineral content and potential nutrient contributions to soil fertility, aiding in crop management decisions and fertilizer application strategies (Panche *et al.*, 2016). Overall, ash content analysis provides valuable information about the mineral composition and purity of materials, serving as a critical tool for quality control, nutritional assessment, and agricultural management across various industries. Generally, in terms of proximate analysis of *Sida acuta*, ash content reflects the inorganic mineral content remaining after complete combustion of organic matter. Ash content provides insights into the presence of essential minerals and overall nutritional value (Panche *et al.*, 2016).

2.3.5 Fiber

Dietary fiber, within the context of proximate analysis, refers to the indigestible portion of carbohydrates present in plant-based foods (Smith, 2020). It encompasses a diverse group of compounds, including cellulose, hemicellulose, pectin's, gums, and lignin, which resist digestion by human enzymes in the gastrointestinal tract (Jones and Brown, 2018). Fiber plays crucial roles in promoting digestive health, regulating bowel movements, lowering cholesterol levels, and managing blood sugar levels (Nelson, 2017).

In food analysis, fiber content is determined using methods such as gravimetric analysis or enzymatic assays, which quantify the amount of indigestible material present in a sample (Miller *et al.*, 2017). High-fiber foods include fruits, vegetables, whole grains, nuts, seeds, and legumes, which contribute to overall health and well-being (Smith, 2020). Fiber content analysis is essential in food labeling and nutritional assessment, as dietary fiber is recognized for its health benefits and is often included in dietary recommendations (Johnson, 2019). Adequate fiber intake is

associated with a reduced risk of chronic diseases such as heart disease, diabetes, and certain types of cancer (Brown and Goldstein, 2018). In addition to its nutritional significance, fiber content analysis is also relevant in food processing and product development (Brown, 2018). Understanding the fiber content of raw ingredients and finished products allows food manufacturers to make informed decisions about formulation, labeling, and marketing, particularly in response to consumer demand for healthier and more nutritious food options (Smith, 2020). Overall, fiber content analysis provides valuable information about the nutritional composition and health-promoting properties of foods, guiding dietary recommendations, food labeling practices, and product development efforts in the food industry (Nelson, 2017).

2.3.6 Moisture

Moisture content in *Sida acuta* refers to the amount of water present in this plant species. *Sida acuta*, commonly known as common wireweed, is a medicinal plant found in tropical and subtropical regions (Karamali *et al.*, 2017). The moisture content in *Sida acuta* can vary depending on factors such as environmental conditions, geographical location, and the plant's physiological state. Moisture content is a critical parameter for assessing the quality of herbal medicines derived from *Sida acuta* (Karamali *et al.*, 2017). Excessive moisture can lead to microbial growth, degradation of active constituents, and overall reduction in quality. Monitoring moisture content helps in determining appropriate storage conditions to maintain the plant material's potency and extend its shelf life. Proper drying and storage procedures are essential to prevent moisture-related deterioration. Moisture content affects the weight of the plant material, which directly impacts dosage accuracy in herbal preparations. Standardization of moisture content ensures consistent dosing and efficacy of herbal products. High moisture content can lead to the growth of molds and fungi, which may produce toxins harmful to human health (Jones, 2014). Controlling moisture

levels reduces the risk of contamination and ensures product safety. To determine moisture content in *Sida acuta*, various methods such as oven drying, Karl Fischer titration, and infrared moisture analysis can be employed. These methods involve drying the plant material under controlled conditions and measuring the loss in weight or the amount of water released to calculate moisture content accurately (Jones, 2014).

2.4 THERAPEUTIC PROPERTIES OF *Sida acuta*

The therapeutic properties of *Sida acuta* refers to its medicinal attributes and beneficial effects on health, including anti-inflammatory, antimicrobial, antioxidant, immunomodulatory, hypoglycemic, wound healing, antipyretic and antidiabetic activity (Panche *et al.*, 2016). *Sida acuta*, commonly known as common wireweed, possesses several therapeutic properties that have been recognized in traditional medicine systems (Panche *et al.*, 2016).

2.4.1 Anti-inflammatory

Sida acuta has been traditionally used to alleviate inflammation and pain associated with various conditions (Konaté *et al.*, 2019). Its anti-inflammatory properties are attributed to bioactive compounds such as flavonoids and alkaloids present in the plant. Anti-inflammatory is the ability of a substance to reduce swelling or inflammation (Konaté *et al.*, 2019). Anti-inflammatory agents block substances in the body that are responsible for inflammation. Green leafy vegetables like spinach, kale, nuts like almonds and walnuts and certain fruits like strawberries, blueberries, cherries are rich in anti-inflammation (Konaté *et al.*, 2019). Plants like Mimosaceae, Caesalpiniaceae, Poaceae, Euphorbiaceae are rich in anti-inflammatory properties. Anti-inflammatory agents are primarily used for prevention and management of cancer. *Sida acuta*, known for its traditional medicinal use, possesses notable anti-inflammatory properties. This attribute stems from its rich content of bioactive compounds like flavonoids, alkaloids, and

phenolic compounds. These constituents exert their anti-inflammatory effects by inhibiting pro-inflammatory mediators and pathways, such as cyclooxygenase and lipoxygenase enzymes, as well as cytokines like tumor necrosis factor-alpha (TNF- α) and interleukins. By modulating these inflammatory cascades, *Sida acuta* helps mitigate the body's inflammatory response, thus reducing symptoms like pain, swelling, and tissue damage (Semwal *et al.*, 2015). Studies have shown its effectiveness in various inflammatory conditions, including arthritis, dermatitis, and respiratory inflammation. Additionally, its antioxidant properties further complement its anti-inflammatory action by scavenging free radicals and reducing oxidative stress, which often exacerbates inflammation. While promising, further research is warranted to elucidate specific mechanisms and optimize therapeutic applications of *Sida acuta* in combating inflammation and related disorders (Pradhan, 2017).

2.4.2 Antimicrobial

Studies have demonstrated the antimicrobial activity of *Sida acuta* extracts against a wide range of bacteria, fungi, and viruses (Ajayi *et al.*, 2015). This property makes it valuable in the treatment of infections, including respiratory and skin infections. *Sida acuta*, a plant with a rich history in traditional medicine, boasts remarkable antimicrobial properties validated by scientific research. Studies have elucidated its efficacy against a spectrum of pathogens, including bacteria, fungi, and viruses. The antimicrobial activity of *Sida acuta* is attributed to its diverse array of bioactive compounds, such as alkaloids, flavonoids, tannins, and phenolic acids, which exhibit inhibitory effects against microbial growth and proliferation. Research demonstrated the potent antibacterial activity of *Sida acuta* extracts against various pathogenic bacteria, including *Staphylococcus aureus* and *Escherichia coli* (Ajayi *et al.*, 2015). Furthermore, its antifungal properties have been corroborated by studies showing inhibition of fungal strains like *Candida albicans* (Bello *et al.*,

2018). Additionally, *Sida acuta* extracts have exhibited antiviral effects against viruses such as herpes simplex virus type 1 (HSV-1). The multi-faceted antimicrobial action of *Sida acuta* makes it a promising candidate for combating infectious diseases. Its ability to target multiple types of pathogens underscores its potential as a broad-spectrum antimicrobial agent (Okoli *et al.*, 2019).

2.4.3 Antioxidant

Sida acuta contains antioxidants that help neutralize harmful free radicals in the body, reducing oxidative stress and protecting cells from damage (Ajayi *et al.*, 2015). These antioxidant properties may contribute to its anti-aging and disease-preventive effects. Antioxidants are substances that protect the cell from the damage caused by free radicals which play a major role in cancer, heart diseases, stroke and diseases of aging. Vitamins C and E, selenium, and carotenoids, such as beta-carotene, lycopene, lutein, and zeaxanthin are some of the examples of free radicals. Fruits and vegetables are very rich in free radicals (Reische *et al.*, 2018). Antioxidants are divided into two classes, primary or chain-breaking antioxidants and secondary or preventative antioxidants (Reische *et al.*, 2018). Natural antioxidants like tocopherols and polyphenols are found in spices, herbs, fruits, vegetables, cereals, grains, seeds, teas and oils. Synthetic antioxidants like butylated hydroxy anisole (BHA), butylated hydroxytoluene (BHT), propyl gallate (PG) and tert-butylhydroquinone (TBHQ), have been used as potent compounds in food preservation for decades due to their low cost and bland flavor (Nwankpa *et al.*, 2015). The effectiveness of antioxidants is characterized by its structural features, concentration, temperature, type of oxidation substrate and physical state of the system and presence of pro-oxidants and synergists. The chemical structure of an antioxidant is used for determining its intrinsic reactivity towards free radicals and ROS (Umavandhana *et al.*, 2018).

2.4.4 Immunomodulatory

Components of *Sida acuta* have been shown to modulate the immune system, enhancing immune function and promoting overall health. This immunomodulatory activity may help in combating infections and improving resistance to diseases. *Sida acuta* exhibits immunomodulatory properties, influencing the function and response of the immune system, as supported by various scientific studies (Oyebode *et al.*, 2018). The plant contains bioactive compounds such as alkaloids, flavonoids, and polysaccharides, which contribute to its immunomodulatory effects. These compounds interact with immune cells and signaling pathways, enhancing immune function and promoting overall health (Oyebode *et al.*, 2018). Research demonstrated that *Sida acuta* extracts significantly increased the production of immune-stimulating cytokines such as interleukin-2 (IL-2) and interferon-gamma (IFN- γ) in experimental models. These cytokines play crucial roles in regulating immune responses, including activating immune cells and enhancing immune surveillance against pathogens (Oyebode *et al.*, 2018). *Sida acuta* has been shown to modulate the activity of immune cells such as macrophages, T-cells, and natural killer (NK) cells. These effects contribute to improved immune surveillance, pathogen clearance, and overall immune system balance. The immunomodulatory properties of *Sida acuta* hold promise for various applications, including enhancing immune function in individuals with compromised immunity and supporting overall wellness (Nwankpa *et al.*, 2015).

2.4.5 Antipyretic

Sida acuta has been used traditionally to reduce fever. Its antipyretic properties help in lowering elevated body temperature and alleviating fever symptoms (Ajayi, 2015). *Sida acuta*, a medicinal plant with a long history of traditional use, possesses notable antipyretic properties, making it valuable in the management of fever. Scientific research has provided evidence supporting its

efficacy in reducing elevated body temperature (Ajayi, 2015). The antipyretic activity of *Sida acuta* extracts in experimental models, where it effectively lowered fever induced by pyrogenic agents. The antipyretic effect was attributed to the plant's ability to modulate the production of fever-inducing cytokines and prostaglandins, thereby attenuating the inflammatory response associated with fever (Ajayi *et al.*, 2016). *Sida acuta* exhibited significant antipyretic activity in animal models of fever. The study highlighted the potential of *Sida acuta* as a natural remedy for fever management, with implications for traditional medicine practices (Bello *et al.*, 2016).

2.4.6 Anti-diabetic

Diabetes mellitus is a concerned health issue with a progressing rate of incidence and mortality. It is marked by increased plasma glucose concentration from insufficient insulin and insulin resistance (Ajayi, 2015). Anti-diabetic agent is defined as the substance that helps in maintaining the level of glucose in the blood. Antidiabetic agents include insulin and oral hypoglycemic agents. Plants like Babul, garlic, onion, ash gourd and beetroot show hypoglycemic effects thereby they are rich in anti-diabetic properties (Bello *et al.*, 2016). *Sida acuta* possesses antidiabetic properties and its mechanisms in contributing to the potential efficacy of managing diabetes mellitus can be Hypoglycemic Activity, Insulin sensitization, Pancreatic β -Cell Protection, Inhibition of α -Glucosidase, and Regulation of Lipid Metabolism. Studies have demonstrated that *Sida acuta* extracts can reduce blood glucose levels in diabetic animal models (Bello *et al.*, 2016). This hypoglycemic effect suggests that *Sida acuta* may enhance glucose uptake by peripheral tissues and inhibit hepatic gluconeogenesis, leading to improved glycemic control. *Sida acuta* may enhance insulin sensitivity, allowing cells to respond more efficiently to insulin and facilitating glucose uptake. By improving insulin sensitivity, *Sida acuta* helps regulate blood sugar levels more effectively, reducing the risk of hyperglycemia and its associated complications. Oxidative stress

and inflammation can impair pancreatic β -cell function, leading to decreased insulin secretion and exacerbating diabetes (Ajayi, 2015). *Sida acuta* contains antioxidants and anti-inflammatory compounds that protect pancreatic β -cells from damage, preserving their ability to produce insulin. α -Glucosidase inhibitors are drugs used to manage diabetes by slowing down the digestion and absorption of carbohydrates, thereby reducing postprandial blood glucose levels. Studies suggest that *Sida acuta* extracts may possess α -glucosidase inhibitory activity, contributing to its antidiabetic effects (Nwankpa *et al.*, 2015). Dyslipidemia often accompanies diabetes and contributes to cardiovascular complications. *Sida acuta* has been shown to regulate lipid metabolism, reducing triglyceride levels and improving lipid profiles in diabetic animals, thus lowering the risk of cardiovascular disease (Nwido *et al.*, 2015).

2.5 OVERVIEW OF DIABETES MELLITUS

Diabetes mellitus is a chronic disease with an escalating prevalence worldwide and constitutes a significant health and socioeconomic burden for patients and the health care systems (Bello *et al.*, 2016). It was estimated to affect 177 million people worldwide in 2000 and this figure is projected to increase to 300 million by 2025 (Porter and Barrett, 2017). The International Diabetes Federation (IDF) estimates that over 5 million people suffer from the disease in Africa and the number is expected to increase to 15 million by 2025 (IDF, 2006). The WHO suggests that Nigeria has the greatest number of people living with diabetes in Africa, with an estimated burden of about 1.7 million, which is anticipated to increase to 4.8 million by 2030. The economic burden of diabetes is enormous in terms of the direct cost of intensive monitoring and control of blood glucose and managing cardiovascular, renal, and neurological consequences (Wild *et al.*, 2018). Genetic and environmental factors contribute significantly to the development of diabetes. During the development of diabetes, the cells of the body cannot metabolize sugar properly due to deficient

action of insulin on target tissues resulting from insensitivity or lack of insulin (a peptide hormone that regulates blood glucose) (Buowari, 2018). The inability of insulin to metabolize sugar occurs when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces. This triggers the body to break down its own fat, protein, and glycogen to produce sugar, leading to the presence of high sugar levels in the blood with excess by-products called ketones being produced by the liver (Folorunso *et al.*, 2016). Diabetes is distinguished by chronic hyperglycemia with disturbances in the macromolecules' metabolism as a result of impairments in insulin secretion, insulin action, or both. Diabetes causes long-term damage, dysfunction, and failure of various organ systems (heart, blood vessels, eyes, kidneys, and nerves), leading to disability and premature death (Salsali *et al.*, 2016). The severity of damage triggered by hyperglycemia on the respective organ systems may be related to how long the disease has been present and how well it has been controlled. Several symptoms such as thirst, polyuria, blurring of vision, and weight loss also accompany diabetes (Sperling *et al.*, 2018).

2.6 CLASSIFICATION OF DIABETES MELLITUS

Diabetes mellitus is classified into several types based on etiology and clinical features. Type I diabetes results from autoimmune destruction of pancreatic β -cells, leading to insulin deficiency (Bello *et al.*, 2016). Type II diabetes arises from insulin resistance and relative insulin deficiency. Gestational diabetes occurs during pregnancy and is associated with insulin resistance (Bello *et al.*, 2016). Other types include monogenic diabetes and secondary diabetes resulting from other medical conditions or medications. Prediabetes represents a high-risk state for developing type 2 diabetes (Buowari, 2016).

2.6.1 TYPE I DIABETES MELLITUS

The Type I diabetes mellitus is also known as insulin-dependent diabetes. It is primarily due to pancreatic islet beta cell destruction and is characterized by deficient insulin production in the body (Salsali *et al.*, 2016). Patients with Type I diabetes mellitus are prone to ketoacidosis and need daily administration of insulin to control the amount of glucose in their blood. The majority of Type I diabetes mellitus occurs in children and adolescents (Sperling *et al.*, 2018).

2.6.1.2 PATHOGENESIS OF TYPE 1 DIABETES MELLITUS

Type I diabetes mellitus (T1DM) is primarily an autoimmune disease characterized by the destruction of pancreatic β -cells, leading to absolute insulin deficiency (Chavez, 2018). The pathogenesis involves a complex interplay of genetic predisposition, environmental triggers, and immune dysregulation. Susceptibility genes, such as those within the human leukocyte antigen (HLA) region, contribute to the risk of developing T1DM. Environmental factors like viral infections, dietary antigens, and toxins may trigger autoimmune responses in genetically susceptible individuals (Spellman, 2018). In T1DM, autoreactive T lymphocytes infiltrate the pancreatic islets and recognize β -cell antigens, leading to their destruction via cytotoxic mechanisms. This process is mediated by pro-inflammatory cytokines, particularly interleukin-1 β (IL-1 β), tumor necrosis factor- α (TNF- α), and interferon- γ (IFN- γ). Additionally, autoantibodies targeting β -cell antigens, such as insulin, glutamic acid decarboxylase (GAD), and tyrosine phosphatase-like protein (IA-2), contribute to β -cell destruction and loss of insulin secretion (Bello *et al.*, 2016). As β -cell mass declines, insulin production decreases, resulting in hyperglycemia and clinical manifestations of diabetes. The progressive nature of T1DM necessitates lifelong insulin replacement therapy to maintain euglycemia and prevent acute and chronic complications (Tripathy, 2015).

2.6.1.3 PATHOPHYSIOLOGY OF TYPE 1 DIABETES MELLITUS

Type I diabetes mellitus (T1DM) arises from autoimmune destruction of pancreatic β -cells, resulting in an absolute deficiency of insulin. The pathophysiology involves a cascade of events, including genetic predisposition, environmental triggers, immune dysregulation, and β -cell destruction. Genetic susceptibility plays a significant role, with certain human leukocyte antigen (HLA) alleles, particularly HLA-DR3 and HLA-DR4, predisposing individuals to T1DM. Environmental factors such as viral infections (e.g., enteroviruses), dietary antigens, and toxins may trigger autoimmune responses in genetically susceptible individuals (Chavez, 2018). In T1DM, autoreactive T lymphocytes infiltrate the pancreatic islets (insulinitis) and recognize β -cell antigens, including insulin, glutamic acid decarboxylase (GAD), and tyrosine phosphatase-like protein (IA-2). This immune-mediated destruction of β -cells leads to decreased insulin secretion and subsequent hyperglycemia (DeFronzo, 2019). The loss of insulin production results in dysregulation of glucose metabolism, leading to increased hepatic glucose production, impaired glucose uptake by peripheral tissues, and enhanced lipolysis. This leads to hyperglycemia, glucosuria, polyuria, polydipsia, and weight loss. The hallmark of T1DM is the presence of autoantibodies against β -cell antigens, which can aid in the diagnosis and prediction of disease progression. These include anti-insulin antibodies, anti-GAD antibodies, and anti-IA-2 antibodies (Mayerson, 2022).

2.6.1.4 PREVELANCE OF TYPE 1 DIABETES MELLITUS

The universal prevalence of diabetes has nearly doubled since 1980, rising from 4.7% to 8.5% in the adult population (Chijioko *et al.*, 2015). Moreover, the prevalence of diabetes has also been found to steadily increase for the past 3 decades and has risen faster in low- and middle-income countries compared to high-income countries. The increase in the prevalence of diabetes is parallel

with an increase in associated risk factors such as being overweight or obese. If not properly treated or controlled, diabetes may cause blindness, kidney failure, lower limb amputation, and other long-term consequences that impact significantly on the quality of life (Bahijri *et al.*, 2016). Interestingly, the WHO also projects that diabetes will be the seventh leading cause of death in 2030. The incidence and prevalence of diabetes have continued to increase globally, despite a great deal of research with the resulting burden resting more heavily on tropical developing countries (Chijioke *et al.*, 2015). Based on demographic studies, by 2030, the number of people older than 64 years with diabetes will be greater in developing countries (≥ 82 million) in comparison to that in developed countries (≥ 48 million). The greatest increases are projected to occur in the Middle East crescent, sub-Saharan Africa, and India (Levitt *et al.*, 2018).

2.6.1.5 DIAGNOSIS OF TYPE 1 DIABETES MELLITUS

Diagnosing Type 1 Diabetes Mellitus (T1DM) involves clinical assessment, laboratory tests, and evaluation of symptoms (Chavez, 2018). Healthcare providers assess the patient's medical history, family history of diabetes, and presenting symptoms. Common symptoms of T1DM include polyuria (excessive urination), polydipsia (excessive thirst), unexplained weight loss, fatigue, and blurred vision (Parthian *et al.*, 2015). Then Measurement of fasting blood glucose levels is a primary diagnostic tool for T1DM. A fasting plasma glucose (FPG) level ≥ 126 mg/dL (7.0 mmol/L) on two separate occasions is indicative of diabetes. Additionally, random plasma glucose levels ≥ 200 mg/dL (11.1 mmol/L) in the presence of symptoms may also warrant further testing. Also, Glycated Hemoglobin (HbA1c) Test which reflects average blood glucose levels over the past 2-3 months. A level $\geq 6.5\%$ (48 mmol/mol) is indicative of diabetes (Folorunso, 2017). However, HbA1c may be less reliable in diagnosing diabetes in certain populations, such as children, adolescents, and individuals with hemoglobinopathies. Another test is the Oral Glucose

Tolerance Test (OGTT), the OGTT involves measuring blood glucose levels before and 2 hours after ingestion of a standardized glucose solution. A 2-hour plasma glucose level ≥ 200 mg/dL (11.1 mmol/L) confirms the diagnosis of diabetes. In addition to the other tests, C-peptide Testing which involves the measurement of serum C-peptide levels can assess endogenous insulin secretion. In T1DM, C-peptide levels are typically low or undetectable due to β -cell destruction (Parthian *et al.*, 2015).

2.6.1.6 TREATMENT OF TYPE 1 DIABETES

1. Insulin Replacement Therapy

Insulin replacement therapy is the cornerstone of treatment for T1DM. Since individuals with T1DM have an absolute deficiency of insulin due to autoimmune destruction of pancreatic β -cells, exogenous insulin must be administered to maintain euglycemia (Holm, 2017). Various types of insulin (rapid-acting, short-acting, intermediate-acting, and long-acting) are available, and treatment regimens may involve multiple daily injections or continuous subcutaneous insulin infusion via insulin pumps. The goal of insulin therapy is to mimic physiological insulin secretion and achieve target blood glucose levels while minimizing the risk of hypoglycemia and long-term complications (Holm, 2017)

2. Continuous Glucose Monitoring (CGM) Systems

CGM systems provide real-time glucose monitoring by measuring interstitial glucose levels through a sensor inserted under the skin (Jena, 2018). CGM systems offer valuable insights into glucose patterns, trends, and fluctuations, allowing individuals with T1DM to make informed decisions about insulin dosing, dietary choices, and physical activity (Jena, 2018). Continuous glucose monitoring can help optimize glycemic control, reduce the risk of hypoglycemia and hyperglycemia, and improve overall diabetes management.

Integration of CGM data with insulin pumps (sensor-augmented pump therapy) enables automated insulin delivery, known as hybrid closed-loop systems or artificial pancreas systems, which can further enhance glucose control and reduce treatment burden (Jena, 2018).

3. Medical plant Treatments

While medical plant treatments for type 1 diabetes mellitus (T1DM) are not typically the primary form of management, some plants have shown potential in adjunctive therapy or as complementary treatments (Shittu *et al.*, 2020). Examples include Bitter melon which is a tropical vine commonly used in traditional medicine for its antidiabetic properties. It contains compounds that mimic insulin and may help improve glucose tolerance. Studies suggest that bitter melon may lower blood glucose levels and improve insulin sensitivity in individuals with T1DM when consumed as a supplement or incorporated into the diet (Shittu *et al.*, 2020). Also, Ginseng has been studied for its potential antidiabetic effects, including improving glycemic control and insulin sensitivity. Some research suggests that ginseng may enhance insulin secretion and reduce oxidative stress, which could benefit individuals with T1DM. However, more studies are needed to confirm its efficacy and safety in T1DM management. Finally, *Sida acuta*, also known as common wireweed, has been traditionally used in some cultures for its medicinal properties. While research on its specific effects in T1DM is limited, preliminary studies suggest that *Sida acuta* possesses hypoglycemic and immunomodulatory properties, which could be beneficial in managing diabetes (Shittu *et al.*, 2020).

2.6.2 TYPE II DIABETES MELLITUS

T2DM, also known as non-insulin-dependent diabetes, results from the body's ineffective use of insulin and hyperglycemia and accounts for the vast majority of people with diabetes around the world. Insulin resistance is due to a reduced responsiveness of target tissues to normal circulating levels of insulin (Narayan *et al.*, 2016). Ethnicity, family history of diabetes, and previous gestational diabetes, older age, overweight and obesity, unhealthy diet, physical inactivity, and smoking increase diabetes risk. Most people with diabetes are affected by T2DM diabetes (90%), usually occur nearly entirely among adults but, in these days, is increasing in children (Kakkar, 2016). Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance, impaired insulin secretion, and hyperglycemia. Unlike type 1 diabetes mellitus (T1DM), which results from autoimmune destruction of pancreatic β -cells leading to absolute insulin deficiency, T2DM typically develops in adulthood and is associated with lifestyle factors such as obesity, physical inactivity, and unhealthy diet. In T2DM, peripheral tissues such as muscle, liver, and adipose tissue become resistant to the action of insulin. This reduces glucose uptake by cells, leading to elevated blood glucose levels (Shittu *et al.*, 2020). Insulin resistance is influenced by genetic factors, obesity, inflammation, and hormonal imbalances. While insulin resistance is a key feature of T2DM, the disease also involves impaired insulin secretion by pancreatic β -cells. Initially, β -cells compensate for insulin resistance by producing more insulin. However, over time, β -cell dysfunction and loss of mass occur, leading to inadequate insulin secretion and worsening hyperglycemia (Salsali, 2016). Persistent elevation of blood glucose levels is the hallmark of T2DM. Hyperglycemia contributes to the development of microvascular complications (e.g., retinopathy, nephropathy, neuropathy) and macrovascular complications (e.g., cardiovascular disease, stroke), which are major causes of morbidity and mortality in individuals

with T2DM. Obesity is a major risk factor for T2DM and is closely linked to insulin resistance and dyslipidemia. Many individuals with T2DM also have metabolic syndrome, characterized by central obesity, hypertension, dyslipidemia, and impaired glucose metabolism. Sedentary lifestyle, unhealthy diet (high in refined carbohydrates, saturated fats, and sugary beverages), and smoking contribute to the development and progression of T2DM (Salsali, 2016). Lifestyle modifications, including weight loss, dietary changes, regular physical activity, and smoking cessation, play a crucial role in managing T2DM and reducing its complications.

2.6.2.1 PATHOGENESIS OF TYPE II DIABETES MELLITUS

The pathogenesis of type II diabetes mellitus (T2DM) is multifactorial, involving a complex interplay of genetic, environmental, and lifestyle factors (Salsali, 2016). Insulin resistance is a central feature of T2DM, characterized by reduced responsiveness of peripheral tissues (e.g., muscle, liver, adipose tissue) to insulin. This impairment leads to decreased glucose uptake by cells and increased hepatic glucose production, contributing to hyperglycemia. Insulin resistance is influenced by genetic factors, obesity, physical inactivity, inflammation, and certain hormonal imbalances (Chavez, 2018). In response to insulin resistance, pancreatic β -cells initially compensate by producing more insulin to maintain euglycemia. However, over time, β -cell function declines, leading to impaired insulin secretion (Salsali, 2016). This β -cell dysfunction exacerbates hyperglycemia and contributes to the progression of T2DM. Factors contributing to β -cell dysfunction include chronic hyperglycemia, lipo-toxicity, glucotoxicity, and inflammatory cytokines. Obesity, particularly visceral adiposity, is a major risk factor for insulin resistance and T2DM. Adipose tissue dysfunction in obesity is associated with dysregulated adipokine secretion, increased release of pro-inflammatory cytokines (e.g., tumor necrosis factor-alpha, interleukin-6), and altered adipose tissue metabolism (e.g., lipolysis, adipogenesis). These changes contribute to

systemic inflammation, insulin resistance, and β -cell dysfunction. Chronic low-grade inflammation plays a pivotal role in the pathogenesis of T2DM. Adipose tissue inflammation, triggered by adipocyte hypertrophy and macrophage infiltration, contributes to insulin resistance and β -cell dysfunction. Inflammatory cytokines disrupt insulin signaling pathways, impair glucose metabolism, and promote pancreatic β -cell apoptosis (Chavez, 2018). Genetic susceptibility contributes to the risk of developing T2DM. Genome-wide association studies have identified multiple genetic loci associated with T2DM susceptibility, including genes involved in β -cell function, insulin action, and adipose tissue biology. Epigenetic modifications, such as DNA methylation and histone acetylation, also influence gene expression and contribute to T2DM pathogenesis (Zieve, 2019)

2.6.3.1 PREVELANCE OF TYPE II DIABETES MELLITUS

The prevalence of type 2 diabetes mellitus (T2DM) has been steadily increasing worldwide, driven largely by factors such as population aging, urbanization, sedentary lifestyles, and changes in dietary habits (Salsali, 2016). The prevalence of T2DM varies by region, ethnicity, socioeconomic status, and other demographic factors. According to the International Diabetes Federation (IDF), approximately 463 million adults aged 20-79 years were living with diabetes worldwide in 2019, and this number is projected to rise to 700 million by 2045 (IDF, 2016). T2DM accounts for the majority of diabetes cases globally, representing around 90-95% of all diagnosed cases. The prevalence of T2DM varies significantly between regions. High-income countries, particularly in North America and Western Europe, have relatively high prevalence rates of T2DM, reflecting the impact of lifestyle factors such as obesity and sedentary behavior. However, T2DM is also increasingly prevalent in low- and middle-income countries, where rapid urbanization and adoption of Westernized diets contribute to the rising burden of diabetes (Salsali, 2016). Certain

ethnic and racial groups have a higher prevalence of T2DM compared to others. For example, Indigenous populations, Hispanic/Latino Americans, African Americans, and South Asians have been shown to have a higher risk of developing T2DM compared to Caucasians. These disparities are influenced by genetic susceptibility, socioeconomic factors, cultural practices, and access to healthcare (Buowari *et al.*, 2018). T2DM is more common in older adults, with prevalence increasing with age. However, there is growing concern about the rising prevalence of T2DM among younger age groups, including children, adolescents, and young adults, driven by factors such as childhood obesity and sedentary lifestyles. With the global increase in obesity rates and aging populations, the prevalence of T2DM is expected to continue rising in the coming decades. This trend poses significant challenges for healthcare systems worldwide, as T2DM is associated with increased healthcare costs, morbidity, and mortality. Amongst all people with diabetes, T2DM accounts for the majority (90%) of cases, and these can be prevented as well as treated easily, while T1DM cannot be prevented with current knowledge. Since management of diabetes is complex and multidisciplinary, it should include primary prevention through promotion of a healthy diet and lifestyle (such as exercise) (Buowari *et al.*, 2018)

2.6.4.1 DIAGNOSIS OF TYPE II DIABETES MELLITUS

The diagnosis of type 2 diabetes mellitus (T2DM) involves a combination of clinical assessment, laboratory tests, and evaluation of risk factors (Salsali, 2016). Healthcare providers evaluate the patient's medical history, family history of diabetes, and presenting symptoms. Common symptoms of T2DM include polyuria (excessive urination), polydipsia (excessive thirst), unexplained weight loss, fatigue, blurred vision, and recurrent infections. Assessment also includes evaluation of risk factors such as obesity, sedentary lifestyle, unhealthy diet, and history of gestational diabetes or prediabetes. Also, Measurement of fasting blood glucose levels is a primary

diagnostic tool for T2DM. A fasting plasma glucose level ≥ 126 mg/dL (7.0 mmol/L) on two separate occasions is indicative of diabetes. Fasting is defined as no caloric intake for at least 8 hours. Another method is the Oral Glucose Tolerance test, OGTT involves measuring blood glucose levels before and 2 hours after ingestion of a standardized glucose solution (Buowari *et al.*, 2018). A 2-hour plasma glucose level ≥ 200 mg/dL (11.1 mmol/L) confirms the diagnosis of diabetes. OGTT may be used in individuals with fasting glucose levels between 100-125 mg/dL (5.6-6.9 mmol/L) to diagnose impaired glucose tolerance (IGT) or impaired fasting glucose (IFG), which are intermediate states between normal glucose metabolism and diabetes. Also, Glycated Hemoglobin (HbA1c) reflects average blood glucose levels over the past 2-3 months. A level $\geq 6.5\%$ (48 mmol/mol) is indicative of diabetes. HbA1c may also be used for monitoring glycemic control in individuals with diabetes. However, it should be interpreted with caution in certain populations (e.g., individuals with hemoglobinopathies, pregnancy). A random plasma glucose level ≥ 200 mg/dL (11.1 mmol/L) in the presence of classic symptoms of hyperglycemia (e.g., polyuria, polydipsia, unexplained weight loss) may also warrant further testing for diabetes (Buowari *et al.*, 2018).

Screening for T2DM should be considered in asymptomatic individuals with risk factors such as obesity, physical inactivity, family history of diabetes, history of gestational diabetes, hypertension, dyslipidemia, and polycystic ovary syndrome (PCOS). Unlike type 1 diabetes mellitus (T1DM), T2DM is not autoimmune in nature, and autoantibody testing is not routinely performed for diagnosis (Buowari, 2019).

2.6.5.1 TREATMENT OF TYPE II DIABETES

The treatment of type 2 diabetes mellitus (T2DM) typically involves a combination of lifestyle modifications, pharmacotherapy and medical plant treatment (Salsali, 2016).

1. Healthy Lifestyle and Exercise

Encouraging individuals with T2DM to adopt a balanced diet rich in fruits, vegetables, whole grains, lean proteins, and healthy fats can help improve glycemic control, manage body weight, and reduce cardiovascular risk factors. Limiting intake of sugary beverages, refined carbohydrates, saturated fats, and processed foods is also recommended. Engaging in regular exercise, such as brisk walking, cycling, swimming, or strength training, can help improve insulin sensitivity, lower blood glucose levels, control body weight, and reduce the risk of cardiovascular complications. Aim for at least 150 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity aerobic activity per week, spread over at least 3 days (Folorunso, 2018).

2. Oral Antidiabetic Medications

Several classes of oral antidiabetic medications are available for the management of T2DM, including metformin, sulfonylureas, meglitinides, thiazolidinediones, dipeptidyl peptidase-4 (DPP-4) inhibitors, sodium-glucose cotransporter-2 (SGLT2) inhibitors, and glucagon-like peptide-1 (GLP-1) receptor agonists. These medications work through various mechanisms to improve glycemic control, such as increasing insulin secretion, reducing hepatic glucose production, improving insulin sensitivity, and enhancing glucose excretion in the urine. Insulin therapy may be initiated in

individuals with T2DM who fail to achieve glycemic targets with oral medications or have advanced disease requiring insulin replacement (Salsali, 2016).

3. Insulin therapy

Insulin therapy aims to mimic physiological insulin secretion and maintain euglycemia through subcutaneous injections of insulin, either basal, prandial, or combination regimens. In addition to insulin, other injectable therapies such as GLP-1 receptor agonists and amylin analogs are available for the treatment of T2DM. GLP-1 receptor agonists stimulate insulin secretion, inhibit glucagon secretion, slow gastric emptying, and promote satiety, leading to improved glycemic control and weight loss (American Diabetes Association, 2021).

4. Medical plant Treatments

While medical plant treatments for type 1 diabetes mellitus (T1DM) are not typically the primary form of management, some plants have shown potential in adjunctive therapy or as complementary treatments (Sperling, 2017). Examples include Bitter melon which is a tropical vine commonly used in traditional medicine for its antidiabetic properties. It contains compounds that mimic insulin and may help improve glucose tolerance. Studies suggest that bitter melon may lower blood glucose levels and improve insulin sensitivity in individuals with T1DM when consumed as a supplement or incorporated into the diet (Sperling, 2017). Also, Ginseng has been studied for its potential antidiabetic effects, including improving glycemic control and insulin sensitivity. Some research suggests that ginseng may enhance insulin secretion and reduce oxidative stress, which could benefit individuals with T1DM. However, more studies are needed to confirm its efficacy and safety in T1DM management.

Finally, *Sida acuta*, also known as common wireweed, has been traditionally used in some cultures for its medicinal properties. While research on its specific effects in T1DM is limited, preliminary studies suggest that *Sida acuta* possesses hypoglycemic and immunomodulatory properties, which could be beneficial in managing diabetes (Sperling, 2017).

2.7 *In vitro* ANTIDIABETIC ASSAY

In vitro antidiabetic assays are laboratory tests conducted to evaluate the potential of compounds or extracts to exert beneficial effects on glucose metabolism and insulin sensitivity. These assays utilize cell-based or enzyme-based systems to assess various aspects of diabetes pathophysiology (Holm, 2017)

2.7.1 α -AMYLASE INHIBITORY ASSAY

The α -amylase inhibitory assay is a laboratory test used to evaluate the ability of compounds or extracts to inhibit the activity of α -amylase; an enzyme involved in the digestion of carbohydrates. α -Amylase is an enzyme produced in the pancreas and salivary glands that catalyzes the hydrolysis of starch and glycogen into smaller polysaccharides (oligosaccharides) and ultimately into maltose and glucose. Inhibition of α -amylase activity can delay the breakdown of complex carbohydrates into absorbable sugars, leading to a reduction in postprandial glucose levels. The α -amylase inhibitory assay assesses the ability of test compounds to interfere with the enzymatic activity of α -amylase. This assay typically involves incubating α -amylase enzyme with a substrate solution containing starch or a starch derivative (e.g., amylose, amylopectin). The substrate is hydrolyzed by α -amylase, leading to the formation of reducing sugars such as maltose. The reaction is then

stopped, and the amount of reducing sugars produced is quantified using a colorimetric or spectrophotometric method (Mentreddy *et al.*, 2017).

Test compounds or extracts with potential α -amylase inhibitory activity are added to the reaction mixture at various concentrations. Control samples without the test compounds are also included for comparison. The reaction is allowed to proceed for a specified period, typically at a specific temperature and pH conducive to α -amylase activity. After incubation, the reaction is stopped using a suitable stop solution (e.g., iodine solution), which halts further enzymatic activity. The concentration of reducing sugars produced in each sample is then measured. Compounds that inhibit α -amylase activity will result in lower levels of reducing sugars compared to control samples without the test compounds. The degree of α -amylase inhibition by the test compounds is determined by comparing the absorbance or color intensity of treated samples to that of control samples. Test compounds demonstrating significant inhibition of α -amylase activity at lower concentrations are considered to have potential as antihyperglycemic agents. Compounds with higher inhibitory activity may be further investigated for their mechanism of action, efficacy, and safety for the management of diabetes. The α -amylase inhibitory assay is one of the screening tools used in drug discovery and natural product research to identify potential candidates for the treatment of diabetes and related metabolic disorders (Mentreddy *et al.*, 2017).

2.7.2 α -GLUCOSIDASE INHIBITORY ASSAY

The α -glucosidase inhibitory assay is a laboratory test used to evaluate the ability of compounds or extracts to inhibit the activity of α -glucosidase; an enzyme involved in the final steps of carbohydrate digestion. α -Glucosidase is an enzyme located in the brush border of the small intestine that catalyzes the hydrolysis of terminal α -1,4-glycosidic bonds in disaccharides and oligosaccharides, releasing glucose molecules. Inhibition of α -glucosidase activity can delay the

breakdown of complex carbohydrates into absorbable sugars, leading to a reduction in postprandial glucose levels. The α -glucosidase inhibitory assay evaluates the ability of test compounds to interfere with the enzymatic activity of α -glucosidase (Neelesh *et al.*, 2015).

The assay typically involves incubating α -glucosidase enzyme with a substrate solution containing a specific substrate such as p-nitrophenyl- α -D-glucopyranoside (pNPG). When hydrolyzed by α -glucosidase, pNPG releases a chromogenic or fluorogenic product (p-nitrophenol) that can be detected spectrophotometrically or fluorometrically. The reaction is then stopped, and the amount of product formed is quantified. Test compounds or extracts with potential α -glucosidase inhibitory activity are added to the reaction mixture at various concentrations. Control samples without the test compounds are also included for comparison. The reaction is allowed to proceed for a specified period, typically at a specific temperature and pH conducive to α -glucosidase activity. After incubation, the reaction is stopped using a suitable stop solution (e.g., sodium carbonate solution), which halts further enzymatic activity. The formation of the chromogenic or fluorogenic product is then measured using a spectrophotometer or fluorometer. Compounds that inhibit α -glucosidase activity will result in lower levels of product formation compared to control samples without the test compounds (Neelesh *et al.*, 2015). The degree of α -glucosidase inhibition by the test compounds is determined by comparing the absorbance or fluorescence intensity of treated samples to that of control samples. The percentage inhibition of α -glucosidase activity is calculated using appropriate formulas. Test compounds demonstrating significant inhibition of α -glucosidase activity at lower concentrations are considered to have potential as anti-hyperglycemic agents (Mann *et al.*, 2015). Compounds with higher inhibitory activity may be further investigated for their mechanism of action, efficacy, and safety for the management of diabetes. The α -glucosidase inhibitory assay is a valuable tool in drug discovery and natural product research for identifying

potential candidates for the treatment of diabetes and related metabolic disorders (Mann *et al.*, 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 CHEMICAL AND REAGENT

1. Acarbose (Sigma, United Kingdom, London)
2. Starch (Pyrex, Nigeria)
3. α -Amylase (Sigma, United Kingdom, London)
4. 3,5-dinitro salicylic acid (Sigma, United Kingdom, London)
5. Sodium Phosphate Dibasic Dihydrate (Pyrex, Nigeria)
6. Sodium Dihydrogen Phosphate Dihydrate (Pyrex, Nigeria)
7. Para-nitrophenyl (Sigma, United Kingdom, London)
8. α -Glucosidase (Pyrex, Nigeria)
9. Sodium Carbonate (Pyrex, Nigeria)

All reagents were of analytical grade and distilled water was used for all biochemical assays.

3.2 EQUIPMENT

1. UV-Spectrophotometer (Searchtech Instruments United Kingdom, Model No: AE-560-20)
2. Digital thermostatic water bath (Searchtech Instruments United Kingdom, Model No HH-S6)
3. Sensitive weighing balance (S-Mettler United Kingdom, Model No: LAC 214C, 704010)
4. Thermostat oven (Searchtech Instrument United Kingdom, Model No: DHG-9053A)
5. Hisense refrigerator (Model No: REF 302DR)
6. Haier thermocool chest freezer (Model No: HTF-3194)

7. Freeze dryer (LGJ-10-80C United Kingdom)

8. Water distiller (United Kingdom)

9. Electronic PH – Meter (Model No: PHF-25)

3.3 PLANT COLLECTION AND IDENTIFICATION

The plant extract (*Sida acuta*) was obtained locally from Ikhueniro Quarters of Uhunwonde Local Government Area of Edo state. A sample of the plant was identified and authenticated in the Department of Plant Biology and Technology, Herbarium unit in the Faculty of Life Science, University of Benin with voucher number UBH-S454.

3.4 PLANT EXTRACTION

The leaves of the plant obtained were thoroughly washed under a clean running tap water, after which was air-dried. It was pulverized then weighed using an electronic sensitive weighing balance, the weight gotten was 192g. After weighing it was soaked using distilled water in a transparent plastic bucket. It was soaked for 72 hours and each day an exhaustive extraction was done on the plant using a thick cotton wool as absorbent and a double layered cheese cloth for decantation. The extract gotten was taken to the TRIGAS Research Laboratory for freeze drying. The freeze dried extract was weighed in an electronic sensitive weighing balance, the weight gotten was 34g. The extract was kept in an enclosed container and then kept in a freezer until it was used.

3.5 BIOCHEMICAL ASSAYS

3.5.1 α -Amylase Inhibitory Activity

This assay was done according to the method of Sigma-Aldrich (2014) but with slight modification. The α -amylase solution was prepared in cold sodium phosphate buffer - 20 mM, pH 6.9 (1 Unit/ml of α -amylase). Acarbose standard solution, at a concentration of 1 mg/ml, was then serially diluted to concentrations of 2.5, 5, 10, 20, 40, 80, 160, 320, and 640 μ g/ml. The aqueous and ethanol extracts were also prepared using the same concentrations. To the extracts or standard (250 μ l) was added 1% starch solution (250 μ l) and 1U/ml amylase (250 μ l). These were mixed and allowed to incubate for 3 minutes at room temperature. Afterwards, 250 μ l of 3,5-dinitrosalicylic acid (96 mM) was added, and the solution was capped. These were boiled for 15 minutes in a water bath and then allowed to cool on ice. To obtain a total volume of 4 ml, 3 ml of distilled water was added when the mixture had reached room temperature. After mixing by inversion, the solution's absorbance was taken at 540 nm. The same technique was used to prepare a reference control, but distilled water was used in place of the extract. Each assay was carried out three times.

3.5.2 α -Glucosidase Inhibitory Activity

The inhibitory effect of α -glucosidase was determined according to the method of Elya et al. (2012). The extracts' stock solutions (1 mg/ml) were serially diluted to 125, 25, 50, 100, 200, 400, 800, and 1000 μ g/ml. The standard i.e, positive control was acarbose and in was prepared in the same concentration as the extracts. One hundred and twenty μ l of 10 mM Para nitrophenyl glucoside and 200 μ l of 67 mM sodium phosphate buffer, pH 6. %, were added to 40 μ l of the extract/standard. These were mixed and incubated at 37°C for 15 minutes. Then, 40 μ l of α -glucosidase enzyme from *Saccharomyces cerevisiae* (0.1 U/ml) was added, and the mixture was

once more incubated for 15 minutes at 37°C. The hydrolysis of α -D-glucoopyranoside to p-nitrophenol was measured at 405 nm after the addition of 800 μ l of 200 mM sodium carbonate was used to stop the entire reaction. The same procedure was used to prepare a reference control, but distilled water was used in place of the extract. Each assay was carried out three times. Both the IC₅₀ and the percentage of α -glucosidase inhibition were calculated.

3.6 STATISTICAL ANALYSIS

The data were expressed as means of 4 to 7 determinations \pm SEM. The differences among groups were analyzed by the one-way analysis of variance (ANOVA). Inter group comparisons were done by the Duncan's post hoc test. A value of $P < 0.05$ was accepted as significant. Graphical prism version 8.0.1 was used for this analysis and putting up the graphs.

CHAPTER FOUR

4.0 RESULTS

Figure 4.1: Antidiabetic *In vitro* Assays

Figure 4.1 shows antidiabetic α -amylase Inhibitory activity of the aqueous extract of *Sida acuta* leaf and the standard acarbose. The study (figure 4.1) below shows that the standard (acarbose) had higher inhibitory activity on α -amylase enzyme when compared to the extract. The IC_{50} values as seen from table 4.1 also reveals that the standard (29997 μ g/ml) inhibited α -amylase better in comparison to the extract (42966.9 μ g/ml).

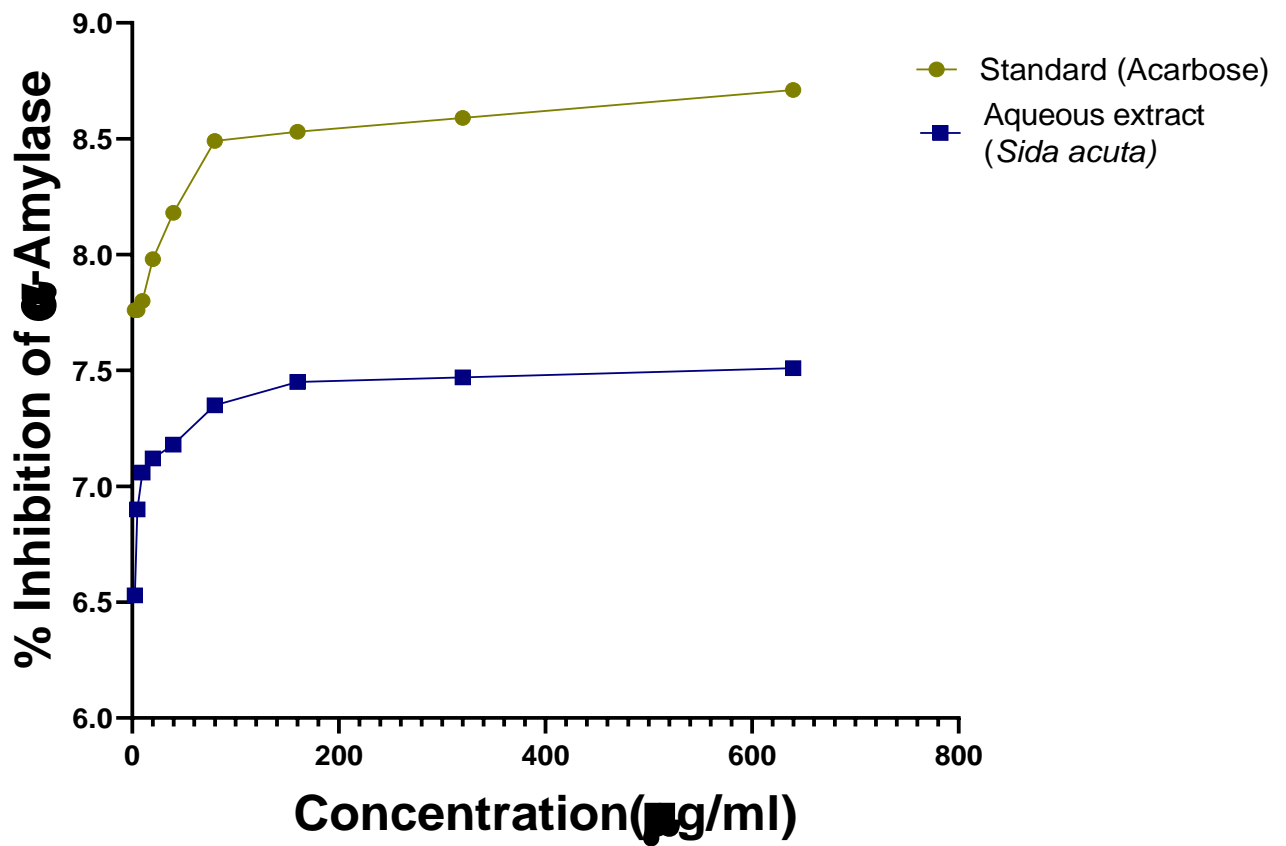


Figure 4.1: α -amylase inhibitory activities of the aqueous of *Sida acuta* leaf. Data are mean \pm SEM of triplicate determinations.

Figure 4.2 shows antidiabetic α -Glucosidase Inhibitory activity of the aqueous extract of *Sida acuta* leaf and the standard acarbose. The study (figure 4.2) below shows that the standard (acarbose) had higher inhibitory activity on α -Glucosidase enzyme when compared to the extract. The IC₅₀ values as seen from table 4.2 also reveals that the standard (10120.52 μ g/ml) inhibited α -Glucosidase better in comparison to the extract (14333.29 μ g/ml).

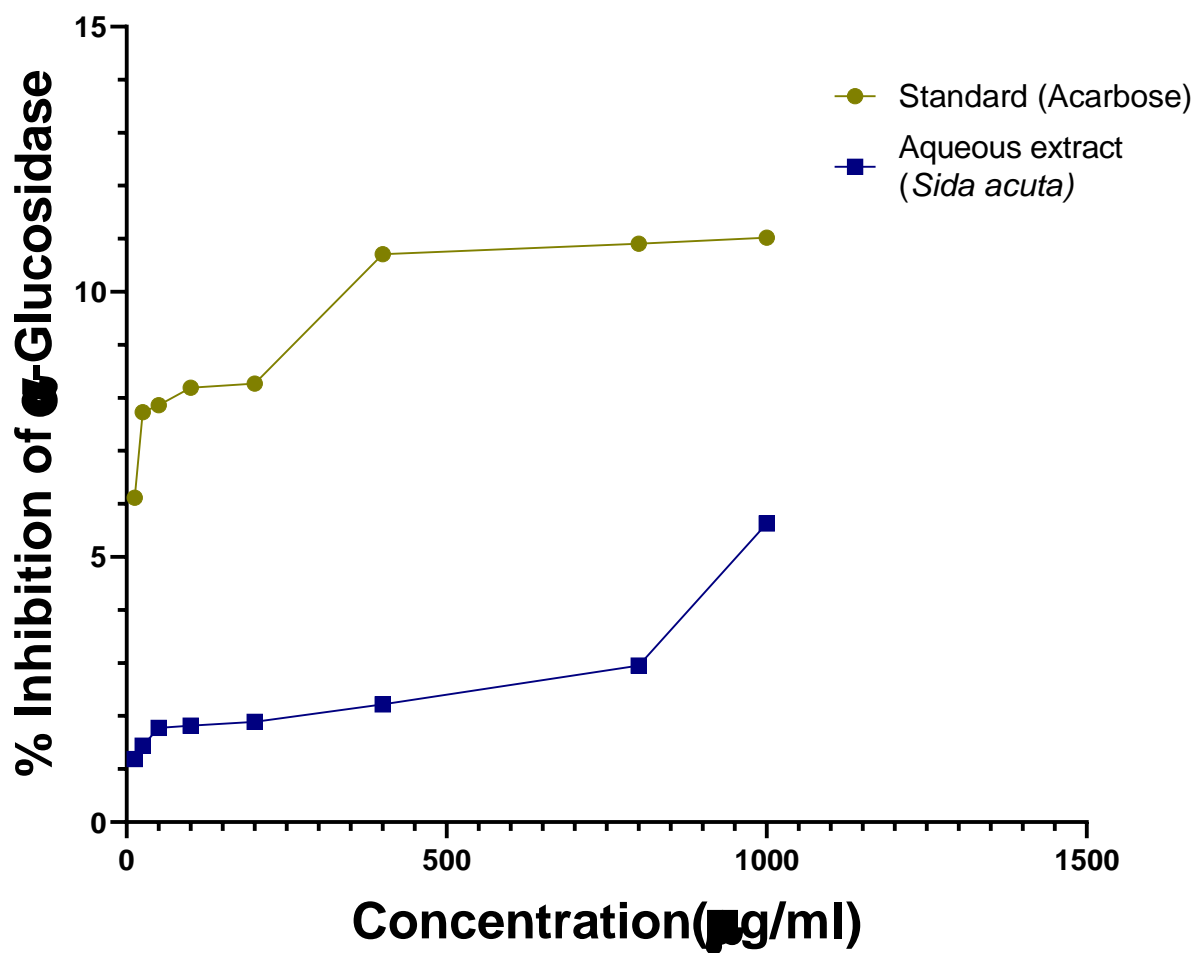


Figure 4.2: α -glucosidase inhibitory activities of the aqueous of *Sida acuta* leaf. Data are mean \pm SEM of triplicate determinations.

Table 4.1: The IC₅₀ values of standards and aqueous extracts of *Sida acuta* leaf

Inhibitory Assay	Standard	Standard IC ₅₀ (µg/ml)	Aqueous Extract IC ₅₀ (µg/ml)
α-amylase	Acarbose	29997 ^a	42966.9 ^b
α-Glucosidase	Acarbose	10120.52 ^a	14333.29 ^b

Data were calculated from a linear or non-linear graph of percentage inhibition versus concentration of standard or samples as appropriate. Values carrying different superscript letters within a row are statistically different at $p < 0.05$.

CHAPTER FIVE

5.0 DISCUSSION

Diabetes Mellitus (DM), represents a universal metabolic issue that arises from hyperglycemia that stimulates oxidative stress to occur which cause a generation of free radicals (El *et al.*, 2016).

Diabetes is a metabolic derangement that arises as a result of absolute or relative deficiency of insulin. It is the most predominant disease in the world in which the number of diabetic patients will reach 592 million by 2035 (Guariguata *et al.* 2014; Shewei *et al.*, 2016). As diabetes progresses, there is a distinct pathogenic process that varies from autoimmune destruction of the Beta cell of the pancreas to abnormalities that result in insulin resistance. The abnormalities in the metabolism of carbohydrate, protein and lipid are as a result of the deficient action of insulin (Riaz *et al.*, 2015),

Medicinal plants play a significant role in the treatment of diabetes mellitus which is a serious metabolic disorder. Traditional plants are reported to have significant anti-diabetic properties with no harmful side effects (Modak *et al.*, 2007). They are found to be highly rich sources of antioxidants and phytochemical agents such as flavonoids, alkaloids, phenols and tannins that improve the efficiency of pancreatic tissues by increasing insulin secretion or decreasing the intestinal absorption of glucose (Kooti *et al.*, 2016).

Half maximal inhibitory concentration (IC₅₀) is a measure of the potency of a substance in inhibiting a specific biological or biochemical function. IC is a quantitative measure that indicates how much of a particular inhibitory substance (e.g. drug) is needed to inhibit, *in vitro*, a given biological process or biological component by 50% (Stewart *et al.*, 2013).

α -Amylase is a crucial enzyme in the human digestive system that catalyzes the hydrolysis of starch into sugars, such as maltose and glucose. It is predominantly produced in the salivary glands

and the pancreas. Inhibiting α -amylase activity is a therapeutic strategy for managing postprandial hyperglycemia in diabetic patients, as it slows down carbohydrate digestion and glucose absorption. Natural α -amylase inhibitors have gained significant attention for their potential to control blood sugar levels with minimal side effects compared to synthetic drugs (Kazeem *et al.*, 2013).

While for the α -Glucosidase inhibitory studies in figure 4.2 demonstrates that the *Sida acuta* extracts also had significant antidiabetic potentials. It was observed in this study that when compared with the standard, the IC_{50} of the extract (14333.29 $\mu\text{g/ml}$) was observed to be higher than that of standard (acarbose) (10120.52 $\mu\text{g/ml}$) a widely used and marketed antidiabetic drug. IC_{50} is an important indicator.

This correlates with the study by Kazeem *et al.*, 2013, that the methanol extract of *Picralima nitida* leaves showed significant inhibitory activity against α -amylase and α -glucosidase enzymes, with IC_{50} values of 2.10 mg/mL and 3.90 mg/mL, respectively. These results suggest the potential of *Picralima nitida* as a source of natural antidiabetic agents (Kazeem *et al.*, 2013).

CONCLUSION

This study was carried out to ascertain the invitro anti diabetic potential of the aqueous extract of *Sida acuta* and acarbose (standard). The result from the study shows the *in vitro* antidiabetic properties of both extract and standard by inhibiting α -Amylase and α -Glucosidase enzyme. These properties suggest that the aqueous extract of *Sida acuta* can be considered as potential anti diabetic agent for the management of diabetes mellitus.

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