FACULTY OF OPTOMETRY,

UNIVERSITY OF BENIN,

BENIN CITY.

A COMPARATIVE STUDY OF THE SINGULAR AND COMBINED EFFECTS OF SORGHUM BICOLOR AND HIBISCUS SABDARIFFA LEAF EXTRACTS ON BLOOD PRESSURE, BLOOD GLUCOSE AND INTRAOCULAR PRESSURE LEVELS

BY

EFEGHERIMONI VICTORY AKPOVIRI

LSC1907042

A PROJECT SUBMITTED TO THE FACULTY OF OPTOMETRY, UNIVERSITY OF BENIN, BENIN CITY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF DOCTOR OF OPTOMETRY (OD) DEGREE.

DEDICATION

This work is dedicated to **ALMIGHTY GOD**, whose grace, wisdom and strength have brought me this far.

It is also dedicated to my beloved parents, **Mr. And Mrs. Felix O. Efegherimoni**, for trusting and believing in me even on the days I doubted myself, for their endless love, prayers and encouragement.

ACKNOWLEDGMENT

I wish to express my profound gratitude to Almighty God for His grace, wisdom and strength throughout the course of this project.

I also wish to express my sincere appreciation to my project supervisor, Professor Canice C. Asonye, for his invaluable guidance, patience and constructive criticisms throughout the course of this research. His mentorship and dedication contributed greatly to the success of this work.

My heartfelt appreciation goes to my beloved parents, Mr. And Mrs. Felix O. Efegherimoni, for their unwavering love, support and encouragement which have been my greatest motivation.

I am equally grateful to my wonderful siblings for their constant care and understanding.

Special thanks to my extended family members, Chief Christiana Edafe and Pastor Wilson Okobia, for their prayers, guidance and kind support.

My deep gratitude goes to my senior colleagues, Dr. Ruth Aikhuemenlo and Dr. Chika Osuagwu, for their valuable advice, encouragement and support which contributed immensely to the success of this study.

I am also deeply grateful to my dear friends: Engr. Adedamola O. Sarumi, Miss Oluchi Uzokwe, Arch. Olajide Osolo, Mis Etinosa Owa, Miss Mercy Oladeji, Miss Ijeoma Ogbeni, Miss Favour Oveno, Miss Damilola Awobajo and Miss Gift Ozibe for their friendship, encouragement and assistance during the course of this study.

Finally, I extend my deepest appreciation to myself for the dedication, hard work and perseverance that made this project a reality. For every late night, every revision and every moment of doubt that turned into determination, I am proud of the effort, resilience and growth that brought this work to completion.

To everyone who in one way or another contributed to the success of this project, I say a heartfelt thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Non-communicable diseases such as glaucoma, hypertension, and diabetes mellitus present growing health and economic challenges, especially in sub-Saharan Africa. This study investigated the individual and combined effects of Sorghum bicolor and Hibiscus sabdariffa leaf extracts on intraocular pressure (IOP), blood pressure (BP), and blood glucose (BG) levels in adults. The increasing prevalence of these metabolic and ocular disorders highlights the need for safer, affordable, and accessible interventions, particularly in resource-limited settings.

A prospective cross-sectional experimental study was conducted among 182 normotensive adults aged 25–60 years at the University of Benin. Participants received standardized single oral doses of *Sorghum bicolor*, *Hibiscus sabdariffa*, and their combination on separate days. Baseline and four-hour post-administration measurements of IOP, BP, and BG were obtained and analyzed using paired t-tests and repeated-measures ANOVA at a significance level of $p < 0.05$.

Results showed that both *Sorghum bicolor* and *Hibiscus sabdariffa* significantly reduced IOP and BG levels ($p < 0.05$) but had no significant effect on systolic or diastolic BP after acute administration. The combined extract produced a modest additional reduction in diastolic BP and IOP, though no synergistic effect was observed for BG lowering compared to individual extracts. These findings provide scientific support for the ethnomedical use of these botanicals in promoting ocular and metabolic health. However, their antihypertensive benefits may require prolonged administration or may be more pronounced in hypertensive individuals.

The study concludes that *Sorghum bicolor* and *Hibiscus sabdariffa* are safe, culturally acceptable, and potentially beneficial adjuncts for improving glycemic control and reducing glaucoma risk in resource-limited populations. Further research should explore chronic effects, optimal dosing, mechanisms of action, and their possible integration into public health strategies.

Keywords: *Sorghum bicolor*, *Hibiscus sabdariffa*, intraocular pressure, blood pressure, blood glucose, phytotherapy, metabolic health.

CHAPTER ONE

INTRODUCTION

Medicinal plants have long played a vital role in the prevention and management of various diseases. In recent decades, there has been a renewed scientific interest in plant-based therapies due to their relative safety, affordability and availability compared to synthetic drugs. Among such plants are *Sorghum bicolor* and *Hibiscus sabdariffa*, both of which possess numerous bioactive compounds with potential health-promoting properties.

Hypertension, diabetes mellitus and ocular hypertension remain major public health concerns, often coexisting as metabolic disorders that affect millions globally. While conventional treatments exist, their siode effects and cost have encouraged the exploration of natural alternatives.

Although *Sorghum bicolor* and *Hibiscus sabdariffa* have individually been reported to influence blood pressuire, blood glucose and intraocular pressure, little is known about the effects of their combination on these parameters. This study is therefore designed to compare the singular and combined effects of *Sorghum bicolor* and *Hibiscus sabdariffa* leaf extracts on blood pressure, blood glucose and intraocular pressure levels.

1.1 Background information

The prevalence of non-communicable diseases including glaucoma, hypertension, and diabetes mellitus are becoming a major health and economic problem especially in sub-Saharan Africa (Forouhi and Wareham, 2014). These diseases are induced by metabolic dysregulation. Increased intraocular pressure (IOP) is a major risk factor of glaucoma. Hypertension is a cardiovascular disease-related silent killer, whereas high levels of glucose in the blood characterize diabetes mellitus (Weinreb *et al*., 2014; Zhou *et al*., 2021).

Traditional treatments, such as antihypertensive and hypoglycaemic medications, are linked to a number of side effects and accessibility and affordability problems. In that regard, the adoption of medicinal plants like *Sorghum bicolor* (also referred to as sorghum) and *Hibiscus sabdariffa* (also referred to as roselle or zobo) in complementary medicine is of increasing concern. The two plants are highly used in Africa as food and drinks and are known because of their tannins, phytochemicals, antioxidants, polyphenols, flavonoids, which are believed to be the underlying cause of their observed pharmacological effects (Ali *et al*., 2005; Suvarna *et al*., 2024).

It is shown that *Hibiscus sabdariffa* possesses lower intraocular pressure and blood pressure effects and hypoglycaemic properties (Nnanna *et al*., 2017; Okafor *et al*., 2022; Odjimogho *et al*., 2024). Similarly, *Sorghum bicolor* has also been identified with antidiabetic properties and possible cardiovascular positive effects (Nwinyi and Kwanashie, 2013; Suvarna *et al*., 2024). Although there are single reports, there is a dearth of information on the comparative and combined action of these extracts on important health measures.

Overview of Medicinal Plants in Disease Management

Traditional medicine and modern medicine, because of their abundance of phytochemicals, availability, and, in many cases, favourable safety profiles, have relied on medicinal plants (Suvarna *et al*., 2024). The need to discover low-cost and effective treatments of such chronic illnesses like high blood pressure, diabetes, and ocular diseases has led to the emergence of functional botanical extracts like *Sorghum bicolor* and *Hibiscus sabdariffa* to gain more scientific attention (Odunaye-Badmus *et al*., 2025; Suvarna *et al*., 2024).

Botanical Profile of *Sorghum bicolor*

Sorghum bicolor (L.) Moench is a prehistoric cereal grain found in the grass family Poaceae that is commonly grown as a source of food and industrial purposes, since it is not only drought-tolerant but also has a nutritional profile (Suvarna *et al*., 2024). Its grains are rich in starch, dietary fibre, proteins, vitamins, minerals, and a high concentration of polyphenols, flavonoids, and tannins, which is why they possess health-promoting properties (Suvarna *et al*., 2024). Conventionally, *S. bicolor* is employed to treat several diseases such as diabetes, gastrointestinal disorder, and as an overall tonic (Nwinyi and Kwanashie, 2013).

Botanical Profile of *Hibiscus sabdariffa*

Hibiscus sabdariffa L., also known as roselle or "zobo" in Nigeria, is a perennial species within the Malvaceae family, which is grown throughout the world because of its nutritive and medicinal properties (Odunaye-Badmus *et al*., 2025). The calyces and in certain instances the leaves have abundant anthocyanins, organic acids, flavonoid, and ascorbic acid (Odunaye-Badmus *et al*., 2025). Ethnomedicinal uses span blood pressure and glucose control, weight management, and management of liver and kidney disorders (Chukwu *et al*., 2017; Ani *et al*., 2022).

Pharmacological Effects of *Sorghum bicolor*

Antioxidant and Antidiabetic Effects

Sorghum is noted for its high antioxidant activity, attributable to phenolic acids, flavonoids (notably 3-deoxyanthocyanidins), and condensed tannins, which help scavenge free radicals and modulate oxidative stress (Suvarna *et al*., 2024). Several studies in rodent models demonstrate its capacity to significantly lower blood glucose, improve insulin sensitivity, and modulate lipid metabolism—

effects attributed to inhibition of hepatic gluconeogenesis, enhanced PPAR-γ expression, and increased adiponectin levels (Suvarna *et al*., 2024).

Effects on Intraocular Pressure and Cardiovascular System

Experimental pharmacology indicates that *Sorghum bicolor* leaf extracts do not negatively influence cardiac contractility or vascular smooth muscle tone, hinting at a favourable cardiovascular and ocular safety profile (Nwinyi & Kwanashie, 2013). Some studies suggest potential for anti-spasmodic and anti-motility action, supporting its traditional use for gastrointestinal issues without adverse effects on intraocular or blood pressure (Nwinyi & Kwanashie, 2013).

Pharmacological Effects of *Hibiscus sabdariffa*

Antioxidant, Antihypertensive, and Hypoglycemic Effects

Hibiscus sabdariffa calyces and leaves contain anthocyanins (cyanidin-3-sambubioside, delphinidin-3-sambubioside) and other polyphenols that exert potent antioxidant, antihypertensive, and antidiabetic effects (Odunaye-Badmus *et al*., 2025). Clinical and preclinical studies consistently show reductions in systolic and diastolic blood pressure in both hypertensive humans and animal models, comparable in some cases to conventional antihypertensive drugs like hydrochlorothiazide, captopril, or lisinopril (García-Muñoz *et al*., 2023; Odunaye-Badmus *et al*., 2025).

Ocular and Metabolic Effects

Recent human studies in Nigeria show that aqueous leaf extract of H. sabdariffa can significantly decrease intraocular pressure (IOP) in normotensive subjects, with peak effects at about 120 minutes post-ingestion, and no significant age or sex differences in response (Odjimogho *et al*., 2024).

Furthermore, both animal and human studies show hypoglycaemic effects, with significant reductions in fasting and postprandial glucose levels (Ani *et al*., 2022; Chukwu *et al*., 2017).

Combined Use of Plant Extracts in Therapy

Combining medicinal plant extracts can yield synergistic, additive, or antagonistic effects, depending on the interaction of active constituents (García-Muñoz *et al*., 2023). Systematic reviews and meta-analyses of combined H. sabdariffa with other plant extracts (e.g., lemon verbena, passion fruit) show enhanced reductions in blood pressure, blood glucose, body weight, and improvements in lipid profiles beyond placebo and sometimes beyond singular extracts (García-Muñoz *et al*., 2023; Ani *et al*., 2022). Notably, the combination of H. sabdariffa and dietary polyphenol-rich plants is associated with greater improvements in markers of metabolic syndrome (García-Muñoz *et al*., 2023).

Pathophysiological Basis of Study Parameters

Intraocular Pressure Regulation

Intraocular pressure is regulated by the balance of aqueous humor production and outflow. Several reports associate elevated IOP with systemic hypertension, diabetes, and fluctuations in blood glucose (Pimentel *et al*., 2015). Some plant extracts, notably H. sabdariffa, have been shown to moderately and acutely lower IOP, making them potential adjuncts in ocular hypertension risk management (Odjimogho *et al*., 2024).

Blood Pressure Regulation

Both *Sorghum bicolor* and *Hibiscus sabdariffa* extracts lower blood pressure via several mechanisms. H. sabdariffa is a competitive inhibitor of angiotensin-converting enzyme (ACE),

increases renal diuresis, and enhances nitric oxide synthase activity, leading to vasodilation and reduced vascular resistance (Odunaye-Badmus *et al*., 2025). S. bicolor exerts favourable vascular effects with no negative cardiac impact (Nwinyi & Kwanashie, 2013).

Blood Glucose Regulation

Dietary polyphenols from both plants act through inhibition of carbohydrate-digesting enzymes (α-amylase, α-glucosidase), improvement in insulin sensitivity, and modulation of hepatic glucose metabolism (Chukwu *et al*., 2017; Ani *et al*., 2022; Suvarna *et al*., 2024). Whole grain sorghum and *H. sabdariffa* consumption are associated with lower glycaemic index meals, better glucose tolerance, and protection against oxidative damage linked to hyperglycaemia (Suvarna *et al*., 2024).

1.2 Statement of the Problem

The prevalence of glaucoma, hypertension, and diabetes mellitus remains a significant public health challenge both globally and across sub-Saharan Africa, including Nigeria, where these disorders disproportionately contribute to morbidity and mortality rates (Odjimogho *et al*., 2024). Sub-Saharan Africa, in particular, bears a higher burden due to increasing incidence and generally poorer outcomes, a situation exacerbated by limited healthcare infrastructure, high out-of-pocket healthcare costs, and restricted access to specialist care. As a result, many in these populations are unable to obtain consistent, safe, and affordable conventional therapies for these largely chronic, lifelong conditions, therapies that are often associated with side effects, drug interaction potentials, and adherence difficulties (Odjimogho *et al*., 2024).

Within this context, traditional medicine and the use of locally available medicinal plants, such as *Sorghum bicolor* and *Hibiscus sabdariffa* (widely consumed as “zobo” drinks), persist as common healthcare alternatives. This is largely due to their cultural acceptability, accessibility, perceived

safety, and claims regarding efficacy (Nwinyi and Kwanashie, 2013). Despite this extensive ethnomedicinal use in Africa and other countries, there is a significant gap on scientific evidence to prove safety, efficacy, and mechanism of action of these plant-based remedies, in particular, their effects on clinical outcomes, including intraocular pressure (IOP), blood pressure (BP), and the level of blood glucose (BGL) (Nwinyi and Kwanashie, 2013).

Most available research investigates these botanicals individually, with scant attention given to potential synergistic or antagonistic effects that may emerge when combined. This oversight is critical because, in traditional African pharmacopoeia, polyherbal formulations, where multiple plant extracts are co-administered, are the norm, not the exception (García-Muñoz *et al*., 2023). As a result, there is a paucity of peer-reviewed studies rigorously comparing the singular versus combined effects of *Sorghum bicolor* and *Hibiscus sabdariffa* extracts on IOP, BP, and BGL, particularly in controlled experimental or clinical settings (Nwinyi & Kwanashie, 2013; García-Muñoz *et al*., 2023).

The pathophysiology of these chronic conditions intersects: elevated IOP is a major modifiable risk factor for glaucoma; hypertension and diabetes are metabolic-cardiovascular risk factors that frequently co-occur and are independently associated with microvascular and macrovascular damage, including progression to visual loss. Therefore, interventions capable of modulating any of these clinical parameters are of substantial therapeutic value, particularly if they can address comorbidity clusters common in high-risk groups prevalent in sub-Saharan Africa (García-Muñoz *et al*., 2023; Odjimogho *et al*., 2024).

There is thus a clear scientific and public health imperative to address the knowledge gap regarding:

- The singular effects of *Sorghum bicolor* and *Hibiscus sabdariffa* leaf extracts on IOP, BP, and BGL.
- The additive, synergistic, or antagonistic outcomes of their combined use, especially as pertains to chronic comorbidity management in resource-limited settings (García-Muñoz *et al*., 2023).

Without rigorously designed studies spanning these two key areas, the optimal application of these phytotherapeutics within evidence-based integrative medicine is constrained. This limits their rational inclusion in the development of standardized, safe, and effective plant-derived therapeutics for use in resource-constrained environments. Addressing this gap will either substantiate or refute traditional claims, support evidence-based herbal drug development, and potentially provide innovative, accessible solutions for managing high-impact chronic diseases in populations with the greatest unmet need (Odjimogho *et al*., 2024).

1.3 Aim of the Study

This study aims to compare the singular and combined effects of *Sorghum bicolor* and *Hibiscus sabdariffa* leaf extracts on intraocular pressure, blood pressure, and blood glucose levels.

1.4 Objectives of the Study

The specific objectives are:

- To determine the effect of *Sorghum bicolor* leaf extract on intraocular pressure, blood pressure, and blood glucose levels.
- To ascertain the effect of *Hibiscus sabdariffa* leaf extract on these same parameters.
- To evaluate the combined effect of both extracts on the same parameters.

- To compare the singular versus combined effects of the extracts on IOP, BP, and blood glucose.

1.5 Research Hypotheses

- **Null hypothesis (H_0):** *Sorghum bicolor* and *Hibiscus sabdariffa* leaf extracts have no significant singular or combined effect on intraocular pressure, blood pressure, or blood glucose levels.
- **Alternative hypothesis (H_1):** *Sorghum bicolor* and *Hibiscus sabdariffa* leaf extracts have significant singular or combined effects on these parameters.

1.6 Significance of the Study

This study will:

- Contribute to the growing body of knowledge in herbal pharmacology and integrative medicine by providing comparative evidence on two commonly used medicinal plants (Ali *et al*., 2005; Suvarna *et al*., 2024).
- Enhance scientific understanding necessary for the development of safe, plant-based therapeutic agents for the management of IOP, hypertension, and diabetes.
- Offer insights relevant for academic, clinical, and public health communities on the potential role of these extracts in chronic disease management, with possible policy implications, especially in low-resource settings.

1.7 Scope and Limitations of the Study

The study involves experimental evaluation of the effects of *Sorghum bicolor* and *Hibiscus sabdariffa* leaf extracts, individually and in combination, on intraocular pressure, blood pressure, and blood glucose levels, with assessment in animal models (and/or humans if applicable).

There may be variations in dose responses, challenges in extract standardization, short study duration, and potential lack of generalisability beyond controlled experimental settings (Odjimogho *et al*., 2024).

1.8 Definition of Terms

Alloxan: A chemical compound used to induce diabetes in animal studies by selectively destroying insulin-producing cells in the pancreas, resulting in hyperglycemia.

Anthocyanins: A class of flavonoid pigments responsible for red, purple, and blue hues in many fruits, vegetables, and flowers, notable in *Hibiscus sabdariffa* for their antioxidant properties.

Antihyperglycemic: Refers to substances or agents that help lower high blood glucose levels, often evaluated in diabetes research.

Antihypertensive: Describes a substance capable of reducing high blood pressure.

Antioxidant: Any compound that inhibits oxidation, protecting cells from the damage caused by free radicals.

Blood Pressure (BP): The force exerted by circulating blood on the walls of blood vessels. It is expressed as systolic (SBP) and diastolic (DBP) pressures (e.g., 120/80 mmHg). Hypertension refers to sustained elevated BP, a risk factor for cardiovascular diseases and organ complications.

Blood Glucose Level: The concentration of glucose in the bloodstream, measured in mg/dL or mmol/L. Normal fasting blood glucose ranges from 70 to 99 mg/dL.

Body Mass Index (BMI): A measure of body fat based on height and weight that applies to adult men and women; used as a health risk indicator.

Diabetes Mellitus: A chronic disease characterized by high blood glucose levels due to the body's inability to produce or effectively use insulin.

Flavonoids: A diverse group of phytonutrients found in many plants, including sorghum and hibiscus, known for their antioxidant activity and potential health benefits.

Glycemic Index (GI): A scoring system that ranks carbohydrates in foods in relation to the rate of increase in blood glucose level after consumption.

***Hibiscus sabdariffa*:** A species of hibiscus native to Africa and Asia, widely used as a beverage ("zobo drink"), food ingredient, and traditional medicine for its antioxidant, antihypertensive, and hypoglycemic effects.

Hyperglycemia: A state of elevated blood glucose levels, typical of diabetes mellitus and a risk factor for other metabolic disturbances.

Hypoglycemic: Describes a substance capable of lowering blood glucose levels.

Intraocular Pressure (IOP): The fluid pressure inside the eye, elevation of which is a major risk factor for glaucoma.

Leaf Extract: A solution made by processing and extracting the bioactive compounds from the leaves of plants such as *S. bicolor* or *H. sabdariffa*, often using solvents like water or alcohol. These extracts are used in experiments to assess medicinal properties.

Metabolic Syndrome: A cluster of conditions that occur together, increased blood pressure, high blood sugar, excess body fat around the waist, and abnormal cholesterol levels, increasing the risk of heart disease, stroke, and diabetes.

Phytochemicals: Bioactive chemical compounds that occur naturally in plants, such as flavonoids and anthocyanins, often with health-promoting properties.

Polyphenols: A category of chemicals naturally found in plants, noted for their antioxidant and anti-inflammatory effects.

***Sorghum bicolor*:** A cereal grain cultivated globally for food, feed, and biofuel, recognized for its rich content of fibers, phenols, flavonoids, and its low glycemic index, contributing to antidiabetic and antihyperglycemic effects.

Synergistic Effect: An effect where the actions of two or more agents are more than the sum of their respective actions e.g. can be seen with the combined action of herbal extracts.

Zobo Drink: The *Hibiscus sabdariffa* is a drink brewed using the calyces of this plant, which is commonly used in Nigeria and West Africa, and has the reputed effects of refreshing the drink and possibly having a health-promoting effect, such as antihypertensive and hypoglycemic proper

CHAPTER TWO

2.0 LITERATURE REVIEW

The study by Ojulari *et al*. (2014) aimed to determine the impact of one oral dose of *Hibiscus sabdariffa* (HS) aqueous extract on blood glucose, serum sodium and serum potassium in the albino rats. The experiment was split into two groups of twenty rats (control and 3 experimental groups that received the HS extract after 7, 14 and 21 days). Blood glucose and electrolyte concentrations were measured at weekly intervals using standard enzymatic and photometric methods, with data analyzed using t-tests. Results demonstrated a significant reduction in blood glucose after 21 days and significant decreases in serum sodium at 7 and 14 days; potassium changes were not significant. The authors concluded that HS reduces blood glucose and sodium concentrations and recommended further studies on the plant's effects on the relationship between serum glucose and electrolytes in different health conditions.

Pimentel *et al*. (2015) explored the relationship between blood glucose variation and intraocular pressure (IOP) in 37 adults (20 diabetic, 17 non-diabetic) by measuring fasting and postprandial capillary glucose and IOP in both eyes. Results showed significant increases in IOP after meals in both diabetics (mean +2.3 mmHg) and non-diabetics (+1.6 mmHg), with a strong linear association between glucose level changes and IOP increases (R^2=0.54 in diabetics, R^2=0.29 in non-diabetics, $p<0.05$). Baseline hyperglycemia was also associated with greater IOP shifts in diabetics. The authors rec ommend clinicians account for glycemic variability when interpreting IOP, especially in patients with diabetes.

Chukwu *et al*. (2017) conducted a comparative investigation to assess the effects of commonly consumed aqueous extracts of *Hibiscus sabdariffa* (zobo drinks) on body weight, glucose levels, and lipid profiles in Wistar Albino rats. Thirty rats were grouped and orally administered various

zobo drink formulations for 21 days, with biochemical parameters (body weight, glucose, total cholesterol, HDL, triglycerides, LDL, and VLDL) assessed using established analytical kits and compared to controls. Results indicated reduced weight gain, significant blood glucose lowering in certain groups, and decreased total cholesterol, and the drinks led to generally improved lipid profiles (increased HDL, reduced LDL, VLDL, and triglycerides, though not always statistically significant). The study concluded that zobo drinks possess anti-obesity, hypoglycemic, and hypolipidemic properties, recommending further study on their safety and toxicity before widespread therapeutic or nutritional use.

Dele-Olawumi *et al*. (2020) assessed the effects of *Sorghum bicolor*, *Carica papaya*, and *Hibiscus sabdariffa* leaf extracts on weight, neutrophil, and lymphocyte counts in cyclophosphamide-induced anemic adult male albino rats. The experimental design involved forty rats divided into eight groups, with anemia induced using cyclophosphamide. Groups were treated with aqueous extracts of the leaves at 400 or 800 mg/kg body weight for 21 days, while controls included untreated anemic and non-anemic rats. It was found that all extracts raised the weight and lymphocyte count, lowered neutrophil count, with *Sorghum bicolor* showing the strongest hematological effect. *Hibiscus sabdariffa* leaves contained the greatest amount of iron and all the three extracts were considered to be useful in the restoration of blood parameters and treatment of nutritional anemia. The authors recommend further clinical trials to confirm their efficacy for anemia management in humans.

Haidari *et al*. (2020) investigated the hypoglycemic effects of Afghan *Hibiscus sabdariffa* and *Carum carvi* hydro-alcoholic extracts, both alone and in combination, in streptozotocin-induced diabetic rats. Sixty-six male rats were randomized into 11 groups and administered varying doses of *H. sabdariffa* (75, 150, 300 mg/kg), *C. carvi* (150, 300, 500 mg/kg), or their combinations for 21 days. Fasting blood glucose and body weight measurements were taken at baseline, days 7, 14, and

21. Results showed that all doses of *H. sabdariffa* significantly reduced fasting blood glucose levels and that only the 75 mg/kg dose of *H. sabdariffa* improved body weight in diabetic rats. The combination of both extracts did not display synergistic effects, and the hypoglycemic effect of H. sabdariffa alone was strongest, sometimes normalizing glucose levels. The study recommends further studies on the optimized use of *H. sabdariffa* for diabetes management.

Ani *et al*. (2022) explored the antidiabetic properties of a combined methanol extract of *Hibiscus sabdariffa*, *Zingiber officinale*, and *Piper nigrum* on alloxan-induced diabetic Wistar rats, focusing on hematological parameters. Thirty rats were divided into five groups: a normal control, a negative control (diabetic untreated), two treatment groups (250 and 500 mg/kg extract), and a standard (metformin) group. Treatments were given for 21 days. Blood glucose, body weight, and hematological indices (WBC, RBC, Hb, PCV, and platelet count) were assessed. The combined extract reduced blood glucose, helped maintain body weight, increased PCV and hemoglobin, and lowered WBC counts in diabetic rats. The study recommends the combined extract for its potential in hyperglycemia management and hematological improvements in diabetes.

Montalvo-González *et al*. (2022) performed a systematic review of clinical trials analyzing the physiological effects and human health benefits of *Hibiscus sabdariffa* calyxes, synthesizing data from multiple human studies across diverse populations and clinical outcomes. The review summarized evidence from trials investigating antihypertensive, antidyslipidemic, hypoglycemic, nephroprotective, antioxidant, anti-inflammatory, and body-fat-reducing effects of various HS preparations (teas, extracts, capsules). Results found consistent antihypertensive and lipid-lowering benefits, some evidence of hypoglycemic effects, improvements in markers of oxidative stress and inflammation, and no reported adverse effects in clinical settings. The authors recommended larger,

well-designed trials with standardized dosing to better establish clinical efficacy for metabolic and cardiovascular disease management.

Okafor *et al*. (2022) evaluated the effects of aqueous *Hibiscus sabdariffa* calyx extract on selected biochemical parameters in alloxan-induced diabetic male Wistar rats. Twenty rats were assigned to four groups: negative control, diabetic control, and two diabetic groups treated with 250 mg/kg and 500 mg/kg of extract for four weeks. Blood glucose, lipid profiles, serum electrolytes, and oxidative stress markers were measured using standard assays. Results indicated a significant reduction in blood glucose with the higher extract dose, improved lipid profiles (lower total cholesterol and LDL-c, higher HDL-c), and an amelioration of oxidative stress markers in treated groups. The study concluded that the extract demonstrates antihyperglycemic, antioxidative, anticholesterolemic, and renal-protective properties, recommending its consideration as a complementary therapy for diabetes management.

Oyeniran *et al*. (2022) conducted a randomized, double-blind, placebo-controlled study to determine the acute effects of *Hibiscus sabdariffa* tea (HST) on blood pressure and pulse rate in healthy human volunteers. The study aimed to empirically establish whether a single oral dose of HST acutely reduces blood pressure and alters pulse rate in normotensive adults. Forty participants (20 males, 20 females; aged 18–25) were randomly assigned to receive either HST (200 mg/kg) or a color-matched placebo, and their systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and pulse rate (PR) were measured before and one hour after intervention. The results showed that acute ingestion of HST led to a great step in the decrease in SBP, but DBP, MAP, and PR were not statistically significant when compared to baseline, but all these changes were found to be significantly lower as compared to net changes in the placebo group. The authors concluded that there is a reduction of blood pressure in healthy individuals when acute HST is

administered and suggested that further studies are necessary in this field with more samples to support the findings and to respond to time dependency and chronic use observations.

García-Muñoz *et al*. (2023) conducted a systematic review and meta-analysis to assess the effects of the *Hibiscus sabdariffa* (HS) mixed with other plant extracts on the prevention of metabolic syndrome, including cardiovascular risk factors, such as obesity, hypertension, and dyslipidemia. The review covered randomized controlled trials (RCTs) published since January 2010, and a total of seven RCTs (332) were included. Combination The extracts that were usually used in interventions with HS include *Lippia citriodora*, *Passiflora edulis*, and others in formulations (capsules, teas, jelly drinks), in a duration of 6 to 12 weeks. The meta-analysis showed that significant decreases in BMI, body weight, body fat percentage, systolic and diastolic blood pressure, total cholesterol, and LDL cholesterol were significant but did not show any significant changes in triglycerides and HDL cholesterol. The study suggests that further studies are needed to maximize dosing and intake time and conclude that HS used in combination with other polyphenol-rich extracts can positively impact the cardiovascular risk markers when used in the management of metabolic syndrome.

Permata *et al*. (2023) investigated the impact of blood glucose, interleukin-6 (IL-6), and malondialdehyde (MDA) on male Wistar rats with diabetic conditions induced by nicotinamide-streptozotacin and treated with 100mmol/L ethanol extract of sorghum (*Sorghum bicolor* L.). The subjects (rats) were divided into four categories (placebo, negative control, two treatment groups (600mg/kg and 800mg/kg extract). Findings revealed that the increased dose of sorghum extract had significant anti-glycemic and anti-inflammatory effects in preventing the rise in blood glucose, IL-6, and MDA. The authors came to conclusion that the extract can prevent hyperglycemia and

oxidative stress in diabetes, and suggested that additional research is necessary to determine the therapeutic use of the extract in the management of diabetes in human beings.

In their study, Ben El Mahdi *et al*. (2024) evaluated the sorghum seed extracts potential in the management of hyperglycemia, oxidative stress, and glycation-related damage through the in vivo and in vitro models. The study results by phytochemical analysis (HPLC-HRMS), mineral analysis and antioxidant activity analysis as well as treatment of alloxan induced diabetic mice with these extracts indicated that sorghum seeds are rich in phenolics and minerals, greatly enhance antioxidant enzyme activities, decrease blood glucose, inhibit key carbohydrate-breaking enzymes (α-amylase and β-glucosidase) and prevent the formation of glycation products. Findings indicate that there are dose-dependent anti-diabetic and anti-oxidant properties with the recommendation that the sorghum seeds may be engineered into functional food/nutraceutical to prevent and manage diabetes.

Jeong *et al*. (2024) tested the antihypertensive effects of a free-flowing ethanol extract of sorghum (*Sorghum bicolor*), adzuki bean (*Vigna angularis*) and finger millet (*Eleusine coracana*) (hereby, called SAFE) on spontaneously hypertensive rats (SHR). The study aimed to evaluate not only blood pressure-lowering effects but also the impact of SAFE on cardiac hypertrophy, fibrosis, and markers of hepatic safety. Methodologically, male Wistar-Kyoto rats and SHRs were allocated into four groups (control, hypertensive control, SAFE-treated, and captopril-treated), and administered either saline, SAFE (500 mg/kg), or captopril (50 mg/kg) orally for six weeks, with various physiological, biochemical, and histological outcomes measured throughout and at the end of the experiment. The results demonstrated that SAFE significantly reduced both systolic and diastolic blood pressure in SHRs, comparable to captopril, and notably alleviated cardiac hypertrophy and fibrosis, while exerting no hepatotoxicity as indicated by normal serum AST and ALT levels. Further, SAFE decreased the fat-to-lean mass ratio without affecting overall body weight, food intake, or bone

mineral density. The authors recommend that SAFE may serve as a promising dietary supplement for managing hypertension and preventing cardiovascular complications, though more work is necessary to characterize its active compounds and underlying mechanisms of action.

Suvarna *et al*. (2024) reviewed the nutritional and antidiabetic potential of sorghum (*Sorghum bicolor*), focusing on its bioactive composition, glycemic properties, and evidence from animal and human studies. Utilizing *in vitro* analyses of phytochemicals and animal experiments (including alloxan- and streptozotocin-induced diabetic models), the review found that sorghum's fiber, phenolics (especially flavonoids and tannins), and resistant starches synergistically lower blood glucose, improve lipid metabolism, inhibit gluconeogenesis, and exert anti-inflammatory and anti-oxidant effects. Multiple experimental studies showed sorghum's effects comparable to pharmaceutical agents like acarbose and glibenclamide. The authors recommend routine inclusion of whole-grain sorghum in diets for diabetes prevention and call for further clinical research to validate its functional food potential.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Design

This study was a prospective cross-sectional experimental-based study involving participants who were administered Sorghum bicolor and *Hibiscus sabdariffa* leaf extracts, both singly and in combination. Data on blood pressure, blood glucose and intraocular pressure were collected after administration and compared among the different groups. This study was carried out within a period of 3 months.

3.2 Study Location

The study was conducted in the University of Benin, Benin City.

3.3 Study Population

The study population comprised adult volunteers recruited prospectively from the University of Benin. Eligible participants included men and women aged 25-60 years who provided written informed consent and were willing to comply with all study procedures. Participants were in generally good or had stable, well-controlled conditions and were not on medications or supplements known to affect blood pressure, blood glucose or intraocular pressure.

3.4 Sampling Technique and Sample Size

This study employed convenience sampling technique to identify study participants. The required sample size for this paired-sample design was calculated using the standard formula for a paired t-test:

$$n = [(Z\alpha/2 + Z_\beta)^2 \times 2\sigma^2 \div \delta^2$$

Where:

n = required sample size

$Z_{\alpha/2}$ = Z-score corresponding to the desired confidence level (1.96 for 95% confidence)

Z_{β} = Z-score corresponding to the desired power (0.84 for 80% power)

σ = standard deviation of the variable

δ = minimum detectable difference deemed clinically meaningful

$n = (1.96 + 0.84)^2 \times 2 \times (18.6)^2 \div 6^2$

$n = (1.96 + 0.84)^2 \times 2 \ (18.6)^2 \div 36$

$n = 7.84 \times 2 \times 345.96 \div 36$

$n = 150.68 \approx 151$

The calculated minimum required sample size is approximately 151 participants.

To account for potential participant dropout or incomplete data, an attrition rate of 20% is considered. The adjusted sample size is calculated as:

Adjusted Sample Size = 151 ÷ (1 - 0.20)

Adjusted Sample Size = 189

Thus, the required sample size is 189 participants to achieve adequate statistical power for this study.

3.5 Research Materials

The following materials and instruments was used for data collection:

1. *Sorghum bicolor* leaf extracts
2. *Hibiscus sabdariffa* leaf extracts
3. Icare tonometer
4. Acuu check automated Sphygmomanometer
5. Measuring beaker (250ml)
6. Sterile dry plastic containers
7. Stopwatch.
8. Consent forms
9. Acuu check Glucometer
10. Methylated spirit
11. Cotton wool
12. Disposable lancets
13. Disposable gloves
14. Trash bag

3.6 Inclusion criteria

1. Adults aged 25–60 years
2. Individuals who provided written informed consent to participate in the study.

3. Participants with no active ocular infection, inflammation, or history of ocular surgery within the previous six months.
4. Have normal IOP; generally, 10-21mmHg.
5. No current antihypertensive, antidiabetic, or ocular medications
6. Participants who were available all sessions and measurements over the three-day study period.

3.7. Exclusion Criteria

1. Pregnant or breastfeeding
2. Allergy to *Hibiscus sabdariffa* or *Sorghum bicolor.*
3. Current use of antihypertensive, antidiabetic, or steroid drugs
4. Participation in another study within 30 days
5. Individuals with cognitive impairments or unreliable follow-up history.
6. Individuals who have eaten a meal within 2 hours prior to the study will be excluded to minimize variability in blood glucose measurements.

3.8. Procedure

3.8.1 Obtain Informed consent

All participants were provided with a comprehensive explanation of the research objectives, procedures, potential risks, and benefits. The purpose of the study was clearly communicated in language understandable to the participants. Participants were informed of their right to voluntarily participate or withdraw from the study at any time without any consequences. Confidentiality and

anonymity of their data was ensured. After providing sufficient time for questions and clarifications, written informed consent was obtained from each participant using a standardized consent form.

3.8.2 Screening and Recruitment

Screening and recruitment of participants were conducted primarily through online referrals and digital communication channels. Information about the study was shared via social media platforms and departmental group chats within the university community.

3.8.3 Time frame

The experiment took three consecutive days of every subject to determine the individual and combined impact of *Sorghum bicolor* and *Hibiscus sabdariffa* on the intraocular, blood pressure, and blood glucose.

Day 1 (*Sorghum bicolor* administration)

The subjects was initially measured in terms of intraocular pressure, blood pressure, and blood glucose, which determined their course of physiological condition. Following baseline assessments, a standardized dose of *Sorghum bicolor* preparation was administered orally. Subsequent measurements of the same parameters were taken four hours post-administration to evaluate the acute effect of *Sorghum bicolor*.

Day 2 (*Hibiscus sabdariffa administration*)

Baseline measurements of intraocular pressure, blood pressure and blood glucose levels were taken.

Participants received the second administration of a standardized dose of *Hibiscus sabdariffa*, the measurements will be repeated four hours later to assess its singular effect.

Day 3 (Combined administration of *Sorghum bicolor* and *Hibiscus sabdariffa leaf* extracts)

On the final day, baseline measurements of intraocular pressure, blood pressure, and blood glucose were also taken. Following this, a combined preparation containing both *Sorghum bicolor* and *Hibiscus sabdariffa* leaf extracts were administered orally. Measurements was taken four hours post-administration to determine the combined effect of the two plant extracts.

Compliance and Monitoring

Daily compliance was monitored via follow-up calls. No adverse effects was reported.

3.9. Data Collection and Analysis

The data obtained from this study was analyzed using the Statistical Package for Social Sciences (SPSS) version 22.0. paired t-tests were used to analyse data. Inferential statistical tests were applied to determine whether there is a significant difference in the effects of *S. bicolor* and *H. sabdariffa* on IOP, blood pressure and blood glucose levels over time. Since each participant received both treatments (in opposite eyes), a paired sample t-test was used to compare pre- and post-instillation pupil diameters within subjects. Statistical significance was set at $p < 0.05$.

The results were systematically organized and presented in the form of tables and graphs to enhance clarity and facilitate a better understanding of findings. The tables provided a concise summary of the numerical data, allowing for easy comparison between variables, while graphs offered a visual representation that highlighted key patterns, trends relationship within the data. This combined approach ensured that the results could be interpreted accurately.

3.10 Ethical Consideration

Ethical clearance was obtained from the Research and Ethics Committee of the Department of Optometry, University of Benin, Benin City, under the tenets of the Declaration of Helsinki. This

study was conducted in strict adherence to ethical guidelines governing human research. Continuous monitoring was maintained to ensure compliance with ethical requirements.

CHAPTER FOUR

4.0 RESULTS AND DATA ANALYSIS

This chapter presents the findings of the study on the comparison of the singular and combined effects of *Sorghum bicolor* and *Hibiscus sabdariffa leaf* extracts on blood pressure, blood glucose and intraocular pressure levels in adults aged 25-60years in the University of Benin, Benin City. One hundred and eighty-two (182) patients were administered *Sorghum bicolor* and *Hibiscus sabdariffa individually* and as mixed extracts. The mean age of the patients was 39.64±10.2 years.

Using *Sorghum bicolor*, at baseline, the mean systolic value was 122.9±14.5, after 4 hours of applying the extract, the mean systolic value was 122.1±16.1. The diastolic value at baseline was 83.5±11.8, after 4 hours of applying the extract, it became 83.9±12.8. The baseline mean IOP for the right eye was 15.05±3.2, after 4 hours post-application of the extract, it reduced to 14.28±3.3. The baseline IOP for the left eye was 15.63±3.39, after 4 hours post-application, it reduced to 14.38±3.5. At baseline, the mean blood glucose was 87.27±15.35, after 4 hours post-application, it reduced to 82.06±18.16. *Sorghum bicolor* extract was effective on IOP and BG ($p<0.05$), but did not significantly affect blood pressure ($p>).05$) (Table 4.1).

Table 1. **Effect of *Sorghum bicolor* on BP, IOP and BG**

	BP		**IOP**		**BG**
Time interval/parameter	**Systolic**	**Diastolic**	**RE**	**LE**	
Baseline	122.9±14.5	83.5±11.8	15.03±3.3	15.62±3.39	87.27±15.35
4 hours	122.1±16.1	83.9±12.8	14.27±3.3	14.38±3.5	82.06±18.16
t-value	0.977	-0.599	2.643	4.153	3.918
p-value	0.330	0.550	0.009*	0.000*	0.000*

* significant difference

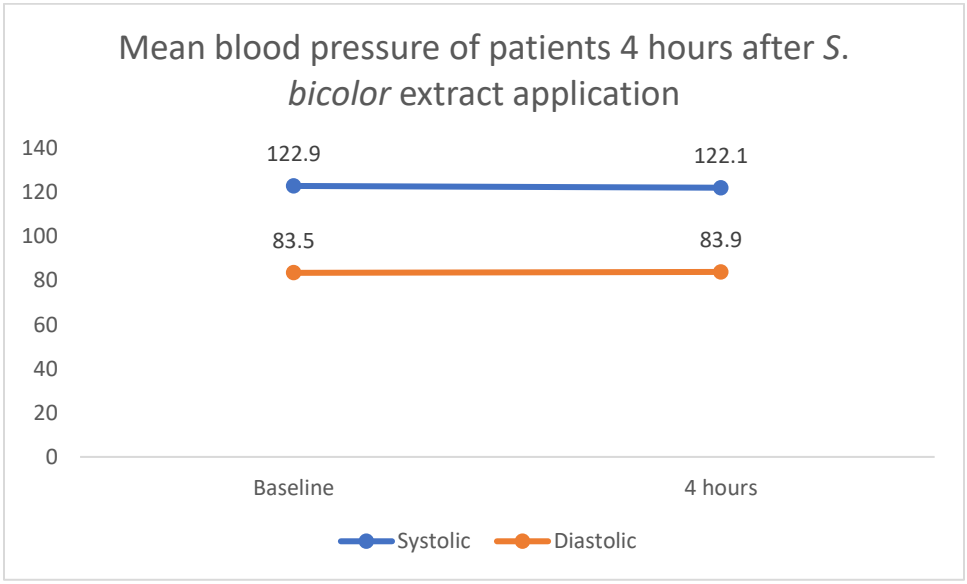


Figure 1. Mean blood pressure of patients 4 hours post Sorghum bicolor extract application

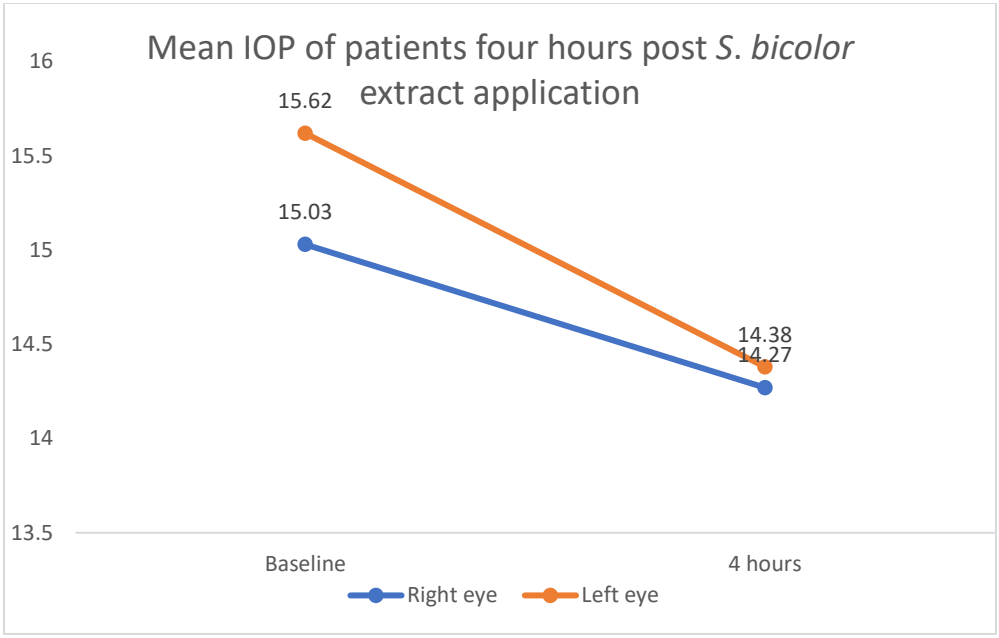


Figure 2. Mean IOP of patients 4 hours post *Sorghum bicolor* extract application

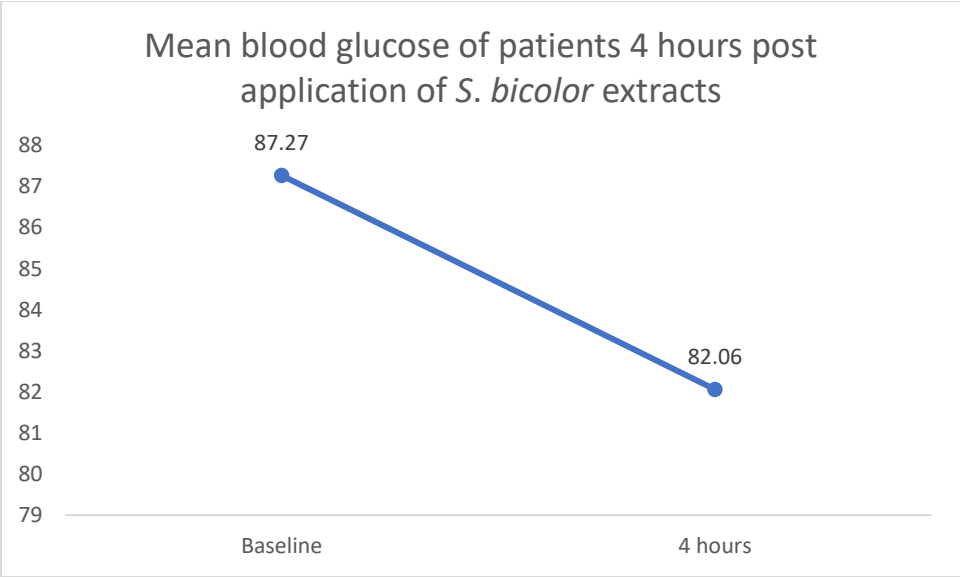


Figure 3. Mean Blood glucose of patients 4 hours post *Sorghum bicolor* extract application

Using *Hibiscus sabdariffa*, at baseline, the mean systolic value was 118.3±13.8, after 4 hours of applying the extract, the mean systolic value became 118.2±13.7. The diastolic value at baseline was 82.8±10.2, after 4 hours of applying the extract, it became 82.2±10.5. The baseline mean IOP for the right eye was 15.02±1.7, after 4 hours post-application of the extract, it reduced to 13.82±1.8. The baseline IOP for the left eye was 14.91±1.9, after 4 hours post-application, it reduced to 13.86±2.1. At baseline, the mean blood glucose was 87.82±10.54, after 4 hours post-application, it reduced to 84.53±11.0. *Hibiscus sabdariffa* extract was effective on IOP and BG ($p<0.05$), but did not significantly affect blood pressure ($p>).05$) (Table 4.2).

Table 2. Effect of *Hibiscus sabdariffa* on BP, IOP and BG

	BP		**IOP**		**BG**
Time interval/parameter	**Systolic**	**Diastolic**	**RE**	**LE**	
Baseline	118.3±13.8	82.8±10.2	15.02±1.7	14.91±1.9	87.82±10.54
4 hours	118.2±13.7	82.2±10.5	13.82±1.8	13.86±2.1	84.53±11.00
t-value	0.060	1.269	21.645	11.274	2.918
p-value	0.953	0.206	0.000*	0.000*	0.004*

* significant difference

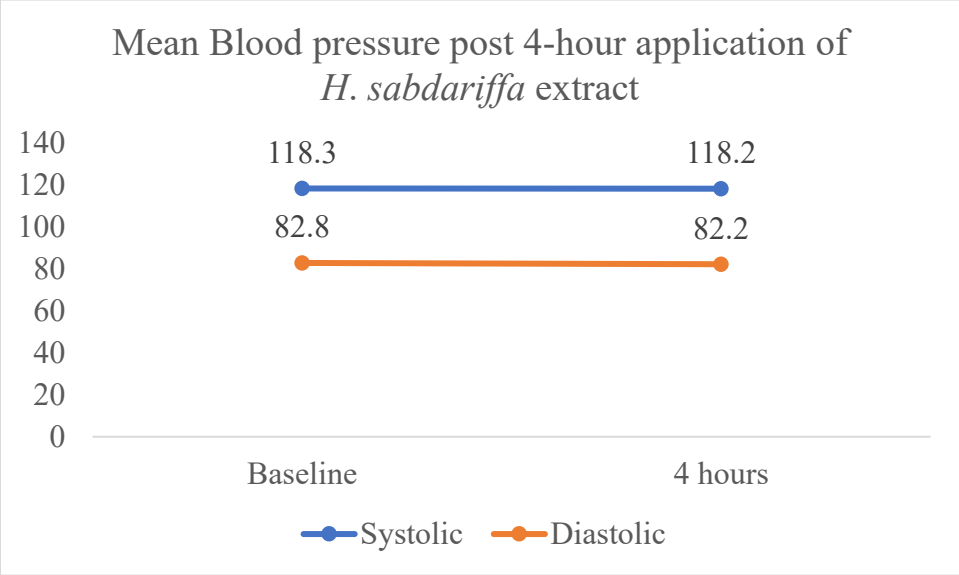


Figure 4. Mean Blood pressure of patients 4 hours post *Hibiscus sabdariffa* extract application

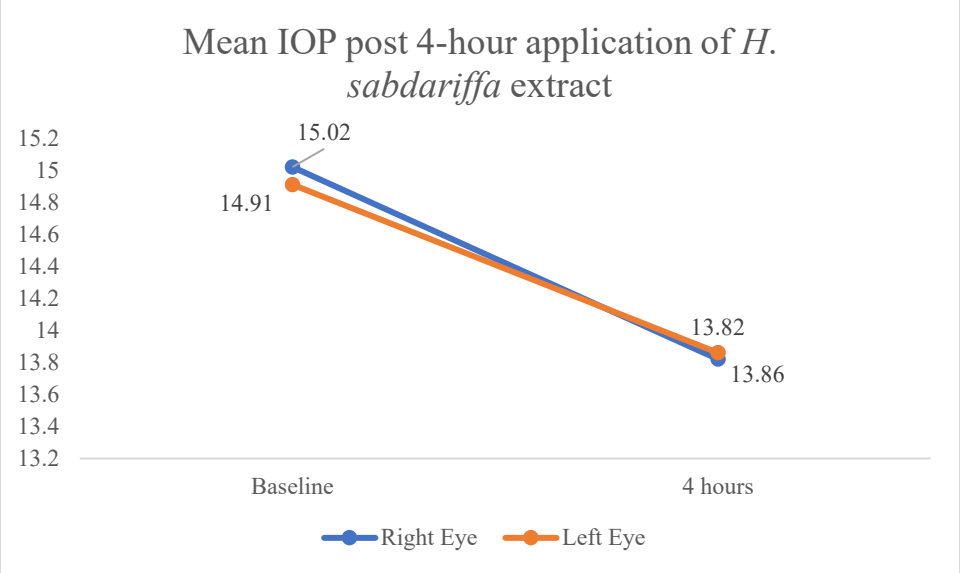


Figure 5. Mean IOP of patients 4 hours post *Hibiscus sabdariffa* extract application

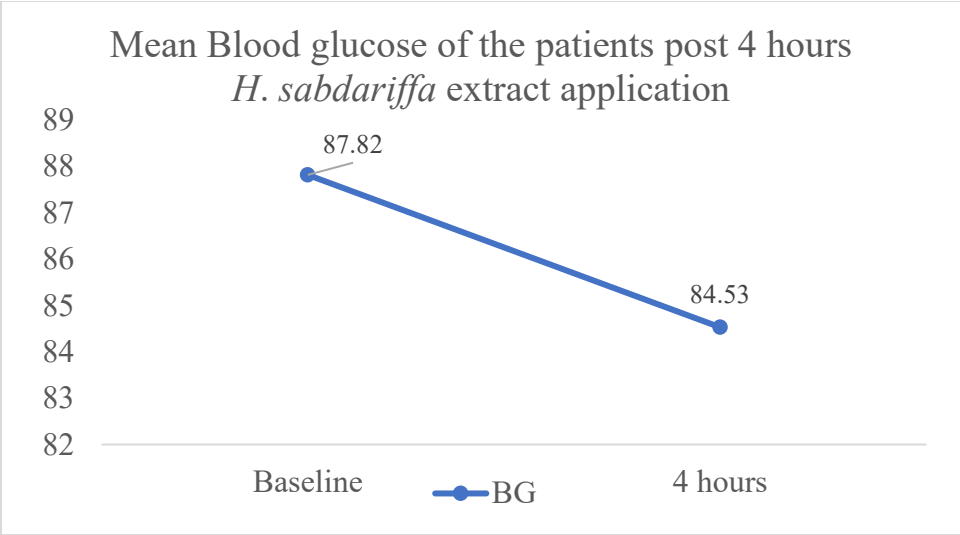


Figure 6. Mean Blood glucose of patients 4 hours post *sabdariffa extract* application

Using a mixture of *Sorghum bicolor* and *Hibiscus sabdariffa*, at baseline, the mean systolic value was 117.3±15.7, after 4 hours of applying the extract, the mean systolic value became 116.8±14.2. The diastolic value at baseline was 78.6±10.7, after 4 hours of applying the extract, it became 80.9±8.8. The baseline mean IOP for the right eye was 14.38±1.6, after 4 hours post-application of the extract, it reduced to 13.99±1.6. The baseline IOP for the left eye was 14.66±1.8, after 4 hours post-application, it reduced to 14.12±1.8. At baseline, the mean blood glucose was 88.81±16.16, after 4 hours post-application, it reduced to 87.74±11.5. The mixed extract was effective on, Diastolic blood pressure and IOP ($p<0.05$), but did not significantly affect systolic blood pressure and Blood glucose ($p>).05$) (Table 4.3).

Table 3. Effect of *Hibiscus sabdariffa* on BP, IOP and BG

	BP		**IOP**		**BG**
Time interval/parameter	**Systolic**	**Diastolic**	**RE**	**LE**	
Baseline	117.3±15.7	78.6±10.7	14.38±1.6	14.66±1.8	87.82±10.54
4 hours	116.8±14.2	80.9±8.8	13.99±2.1	14.12±1.8	87.74±11.46
t-value	1.097	-3.975	7.753	10.464	1.079
p-value	0.274	0.000*	0.000*	0.000*	0.282

* significant difference

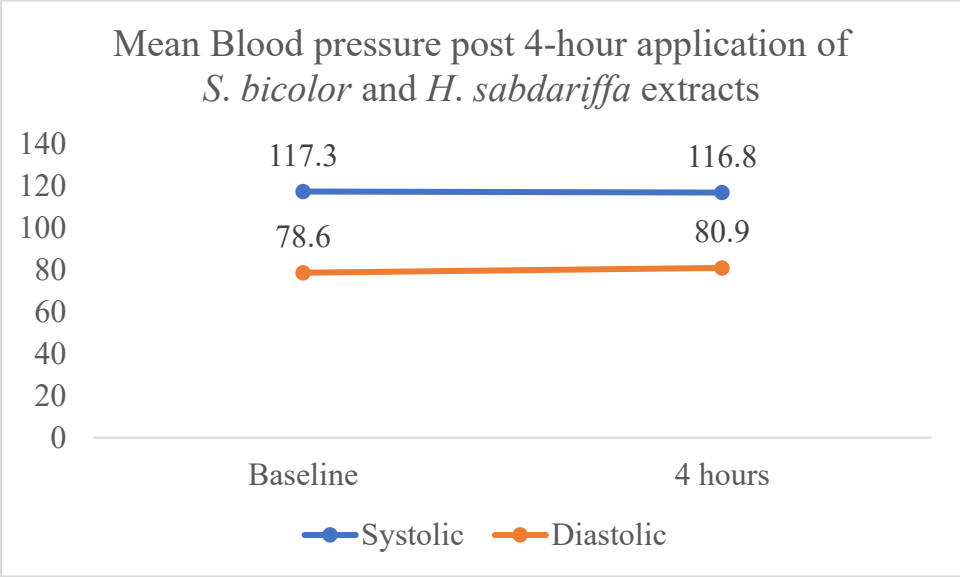


Figure 7. Mean Blood pressure of patients 4 hours post mixed extracts application

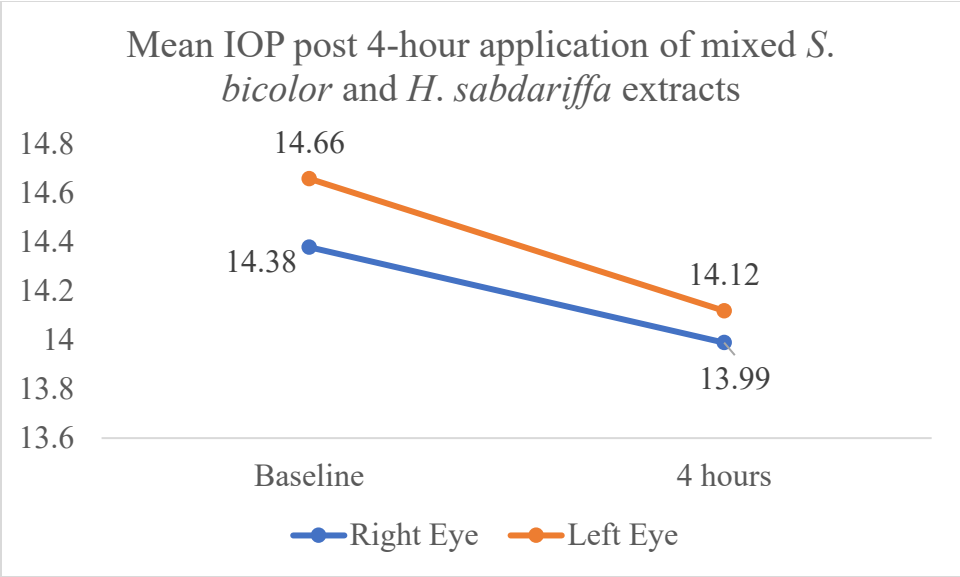


Figure 8. Mean IOP of patients 4 hours post mixed extracts application

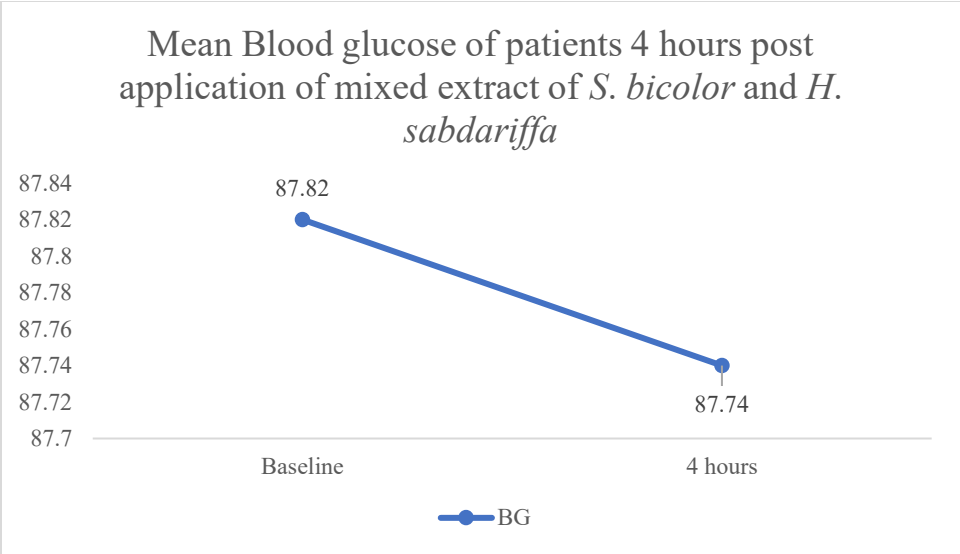


Figure 9. Mean Blood glucose of patients 4 hours post mixed extracts application

CHAPTER FIVE

5.0 CASE DISCUSSION

This chapter interprets the acute effects of *Sorghum bicolor* (SB) and *Hibiscus sabdariffa* (HS) leaf extracts, administered singly and in combination, on intraocular pressure (IOP), blood pressure (BP), and blood glucose (BG). Each objective is discussed with direct reference to the tables and figures presented in Chapter Four. The interpretation considers possible physiological mechanisms underlying the findings and situates them within the context of existing literature.

5.1 Effect of Sorghum bicolor on Intraocular Pressure, Blood Pressure, and Blood Glucose

Table 4.1 and Figures 4.1–4.3 show that administration of Sorghum bicolor (SB) extract produced selective acute effects. Systolic and diastolic blood pressures demonstrated negligible variation within the four-hour observation period (SBP: 122.9 ± 14.5 → 122.1 ± 16.1 mmHg; DBP: 83.5 ± 11.8 → 83.9 ± 12.8 mmHg), reflecting an absence of significant systemic BP change. In contrast, a marked reduction was observed in IOP for both eyes (RE: 15.03 ± 3.3 → 14.27 ± 3.3 mmHg; LE: 15.62 ± 3.39 → 14.38 ± 3.5 mmHg), alongside a significant decrease in blood glucose (87.27 ± 15.35 → 82.06 ± 18.16 mg/dL).

The observed reduction in IOP and BG may be attributed to SB's phytochemical composition, which includes polyphenols, flavonoids, especially 3-deoxyanthocyanidins, and condensed tannins. These compounds are known for their antioxidant and metabolic regulatory properties. Improved glucose handling through inhibition of carbohydrate-digesting enzymes, enhancement of insulin sensitivity, and modulation of hepatic glucose output have been described in previous reports. At the ocular level, antioxidant activity may improve aqueous humour dynamics and reduce oxidative stress, thereby facilitating IOP reduction.

The present findings corroborate experimental reports of sorghum's hypoglycaemic action (Permata *et al*., 2023; Ben El Mahdi *et al*., 2024). The lack of significant acute BP reduction is consistent with findings that S. bicolor's cardiovascular influence, while favourable, is not strongly hypotensive in normotensive subjects (Nwinyi and Kwanashie, 2013). These outcomes suggest that SB's immediate benefits are likely ocular and metabolic rather than cardiovascular in normotensive adults.

5.2 Effect of *Hibiscus sabdariffa* on Intraocular Pressure, Blood Pressure, and Blood Glucose

Table 4.2 and Figures 4.4–4.6 demonstrate that acute administration of *Hibiscus sabdariffa* (HS) extract produced no significant change in systemic blood pressure (SBP: 118.3 ± 13.8 → 118.2 ± 13.7 mmHg; DBP: 82.8 ± 10.2 → 82.2 ± 10.5 mmHg). However, a notable reduction occurred in IOP for both eyes (RE: 15.02 ± 1.7 → 13.82 ± 1.8 mmHg; LE: 14.91 ± 1.9 → 13.86 ± 2.1 mmHg) and in blood glucose (87.82 ± 10.54 → 84.53 ± 11.00 mg/dL).

The results suggest that HS exerts significant short-term ocular and metabolic actions without an acute systemic BP effect. This pattern aligns with the phytochemical profile of HS, which is rich in anthocyanins and polyphenols with antioxidant, vasodilatory, and angiotensin-converting enzyme (ACE) inhibitory properties. These constituents have been associated with improved insulin sensitivity, enhanced glucose metabolism, and oxidative stress reduction. Such mechanisms may explain the observed decline in IOP and BG.

The findings are in agreement with earlier studies demonstrating HS's hypoglycaemic and IOP-lowering potential (Odjimogho *et al*., 2024; Okafor *et al*., 2022). The absence of a significant BP reduction is also consistent with reports showing that HS-induced antihypertensive effects generally emerge after repeated dosing or in hypertensive subjects (Oyeniran et al., 2022; García-Muñoz et

al., 2023). Thus, while acute administration produced metabolic and ocular improvements, longer exposure may be necessary to elicit sustained BP changes.

5.3 Effect of Combined *Sorghum bicolor* and *Hibiscus sabdariffa* Extracts

As shown in Table 4.3 and Figures 4.7–4.9, combined administration of SB and HS extracts led to a significant reduction in IOP in both eyes and a small but statistically significant change in diastolic BP, while systolic BP and blood glucose remained largely unchanged after four hours. Specifically, RE IOP decreased from 14.38 ± 1.6 to 13.99 ± 2.1 mmHg and LE IOP from 14.66 ± 1.8 to 14.12 ± 1.8 mmHg, while DBP showed a modest yet significant alteration.

The IOP response mirrored the effects observed with single extracts, suggesting additive or complementary activity. However, the absence of a notable additional hypoglycaemic effect compared to single extracts indicates a possible pharmacodynamic interaction or saturation of effect in normoglycaemic participants. Competition for absorption, metabolic enzyme interference, or differing bioavailability could explain this attenuated response. Alternatively, ceiling effects in normoglycaemic subjects may have limited further BG reduction within the short observational period.

These findings reflect reports from previous combination studies, which revealed mixed outcomes, some showing enhanced cardiovascular or glycaemic effects, while others reported neutral or antagonistic interactions depending on dose, duration, and extract ratio (García-Muñoz et al., 2023; Haidari *et al*., 2020; Ani *et al*., 2022). The current pattern suggests that while combining SB and HS may sustain ocular benefits, it does not necessarily intensify glycaemic modulation under acute conditions.

5.4 Comparative Summary of Singular and Combined Effects

Across the three interventions, both SB and HS individually produced significant acute reductions in IOP and BG but minimal influence on systolic BP. The combined extract, while maintaining IOP reduction, exhibited a mild diastolic BP effect and no additive glycaemic improvement. Collectively, these findings indicate that the ocular and metabolic actions of each extract were reproducible in the acute phase, whereas their cardiovascular effects were modest and possibly time-dependent.

The pattern also highlights the complexity of phytochemical interactions in combined botanical preparations. Some compounds may exert additive or synergistic effects, while others interact competitively, reducing overall efficacy. The absence of enhanced BG reduction with the combination may therefore reflect pharmacodynamic neutrality or a ceiling effect within the normoglycaemic range. Comparable outcomes have been described in previous reviews assessing combined plant-based interventions for metabolic control.

CHAPTER SIX

6.1 CONCLUSION

This study examined the individual and combined effects of Sorghum bicolor and *Hibiscus sabdariffa* leaf extracts on intraocular pressure (IOP), blood pressure (BP), and blood glucose (BG) among normotensive adults. The investigation has provided credible scientific support for the pharmacological potentials of these two commonly consumed plants, especially in relation to ocular and metabolic health.

Both Sorghum bicolor and *Hibiscus sabdariffa* significantly reduced intraocular pressure and blood glucose levels within four hours of administration. These outcomes reaffirm earlier reports that associate their phytochemical richness, particularly in polyphenols, flavonoids, and antioxidants, with enhanced insulin sensitivity, reduced oxidative stress, and improved aqueous humour dynamics. Collectively, these mechanisms may explain the acute ocular and glycaemic benefits observed.

However, neither extract produced a significant immediate reduction in systemic blood pressure, implying that their antihypertensive actions are likely time-dependent and may manifest more clearly in hypertensive rather than normotensive individuals. The combined extract produced a statistically significant fall in diastolic blood pressure and IOP, but without a corresponding synergistic improvement in blood glucose control. This observation suggests that the phytochemical interaction between both plants may not enhance every parameter equally; some effects may remain neutral or even competitive at certain metabolic levels.

Overall, the study concludes that both Sorghum bicolor and *Hibiscus sabdariffa* possess short-term ocular hypotensive and hypoglycaemic properties, confirming their traditional use as beneficial natural agents. Their influence on systemic blood pressure, however, appears limited under acute

conditions. Thus, long-term and dose-dependent studies are needed to establish the extent of their cardiovascular efficacy and to clarify the dynamics of their combined use.

These findings, in essence, lend scientific weight to the traditional claims surrounding these botanicals. When standardized and used appropriately, they may hold valuable promise as safe, complementary agents in the preventive management of ocular hypertension, diabetes risk, and related metabolic conditions.

6.2 Limitations of the Study

The study was limited by the following factors:

1. It was not possible to monitor all participants continuously during the four-hour observation period, allowing some to eat or drink and possibly altering blood glucose results.
2. A few participants dropped out after the second day due to the sour taste of Hibiscus *sabdariffa* extract or discomfort from lancet use during blood sampling.
3. Some participants could not comply with the instruction to avoid eating before coming for the study, which may have affected their baseline blood glucose readings.
4. The study assessed only acute (four-hour) effects, which limit its the ability to generalize the findings to long-term use or different populations.

Despite these limitations, the findings remain credible and provide useful insights into the short term ocular and metabolic effects of Sorghum bicolor and Hibiscus *sabdariffa* extracts.

6.3 Recommendations

Based on the findings and identified limitations, the following recommendations are proposed for research, policy, practice, and individual application.

A. For Future Research and Academic Institutions

1. Longitudinal studies should be designed to assess the chronic, dose-dependent, and cumulative effects of Sorghum bicolor and *Hibiscus sabdariffa* on blood pressure, blood glucose, and intraocular pressure over extended periods.

2. Subsequent research should include hypertensive, diabetic, and ocular-hypertensive participants to determine therapeutic relevance under clinical conditions.

3. Standardization of extract preparation, quantification of active constituents, and comprehensive toxicological evaluations are essential to ensure safety and reproducibility.

4. Collaborative studies involving phytochemists, pharmacologists, and optometrists should be encouraged to elucidate biochemical pathways and potential herb–drug interactions.

5. Academic institutions should promote interdisciplinary research within integrative medicine, highlighting locally available plants with substantiated pharmacological benefits.

B. For Government and Policy Makers

1. The Federal Ministry of Health and allied agencies should fund and support research on medicinal plants such as Sorghum bicolor and *Hibiscus sabdariffa* to advance evidence-based integration of traditional medicine into formal healthcare systems.

2. Regulatory frameworks are needed to govern the production, standardization, and distribution of herbal formulations to safeguard public health.

3. Public health initiatives should encourage the validated use of medicinal plants in preventive programs targeting diabetes, hypertension, and glaucoma—especially in resource-constrained communities.

4. Agricultural agencies should promote the local cultivation of these plants to boost indigenous production and reduce reliance on imported herbal supplements.

C. For Communities and Health Practitioners

1. Community-based health programs should create awareness on the scientifically validated benefits—and limitations—of Sorghum bicolor and Hibiscus sabdariffa, encouraging informed and safe usage.

2. Healthcare professionals should offer guidance to patients using herbal remedies, emphasizing the avoidance of untested mixtures and possible drug–herb interactions.

3. Traditional healers and herbal vendors should be encouraged to collaborate with researchers and clinicians to ensure product safety, documentation, and quality control in herbal practices.

D. For Families and Individuals

1. Individuals are encouraged to maintain health-conscious lifestyles through balanced nutrition, regular physical activity, and moderate consumption of safe herbal drinks such as zobo made from *Hibiscus sabdariffa*.

2. Persons with a family history of diabetes, hypertension, or glaucoma should routinely monitor blood glucose, blood pressure, and eye health while seeking professional advice before using any herbal formulation.

3. Families should foster nutrition education and promote diets rich in locally available, plant-based foods that support metabolic and ocular health.

4. Self-prescription of multiple herbal combinations should be discouraged, as not all plant mixtures yield synergistic benefits; professional or scientific guidance should always be sought.

REFERENCES

Ali, B.H., Al Wabel, N. and Blunden, G. (2005). Phytochemical, pharmacological and toxicological aspects of *Hibiscus sabdariffa* L.: a review. *Phytotherapy Research*, 19(5), 369-375.

Ani, I.F., Atangwho, I.J., Agwupuye, E.I. and Oghenefejiro, O.A. (2022). Effect of *Hibiscus sabdariffa* L., Zingiber officinale Roscoe and Piper nigrum L. on the Hematological Parameters of Alloxan Induced Diabetic Wistar Rats. *Global Journal of Pure and Applied Sciences*, 28(1), 13-21.

Ben El Mahdi, N., Lemée, L., Remaury, Q.B., Eloy, L., Nhiri, N., Lakhssassi, N., Cacciola, F. and Nhiri, M. (2024). Potential of Sorghum Seeds in Alleviating Hyperglycemia, Oxidative Stress, and Glycation Damage. Molecules, 29, 3445.

Chukwu, C.N., Akaninwor, J.O. and Ikewuchi, C.C. (2017). Comparative investigation of the effects of the commonly-consumed aqueous extracts of *Hibiscus sabdariffa* (zobo drinks) on body weight, glucose level and lipid profile using normal Wistar albino rats. *International Journal of Biochemistry Research & Review*, 16(4), 1-8.

Chukwu, C.N., Akaninwor, J.O. and Ikewuchi, C.C. (2017). Comparative Investigation of the Effects of the Commonly-consumed Aqueous Extracts of *Hibiscus sabdariffa* (Zobo Drinks) on Body Weight, Glucose Level and Lipid Profile Using Normal Wistar Albino Rats. *International Journal of Biochemistry Research & Review*, 16(4), 1-8.

Dele-Olawumi, B., Olanrewaju, O.I., Ayodeji, P.A. and Adedayo, E.O. (2020). Effect of some Plant Leaves Extracts on Weight, Neutrophil and Lymphocyte Constituents of Cyclophosphamide-Induced Anaemia in Adult Male Albino Rats. *International Journal of Innovative Science and Research Technology*, 5(6), 663-669.

Forouhi, N.G. and Wareham, N.J. (2014). Epidemiology of diabetes. *Medicine*, 42(12), 698-702.

García-Muñoz, A.M., García-Guillén, A.I., Victoria-Montesinos, D., Abellán-Ruiz, M.S., Alburquerque-González, B. and Cánovas, F. (2023). Effect of the combination of *Hibiscus sabdariffa* in combination with other plant extracts in the prevention of metabolic syndrome: A systematic review and meta-analysis. *Foods*, 12, 2269.

Haidari, M., Alami, K., Hossaini, A. and Mousavi, S.Y. (2020). Effect of Afghan *Hibiscus sabdariffa* L. and *Carum carvi* L. hydro-alcoholic extracts either alone or in combination on blood glucose level in diabetic rats. *International Journal of Ayurvedic Medicine*, 11(4), 759-764.

Jeong, E., Yun, D., Baek, Y., Kim, H.J. and Lee, H.G. (2024). Antihypertensive effects of the combined extract of Sorghum bicolor, Vigna angularis, and Eleusine coracana in spontaneously hypertensive rats. *Scientific Reports*, 14, 803. https://doi.org/10.1038/s41598-024-51364-5.

Montalvo-González, E., Villagrán, Z., González-Torres, S., Iñiguez-Muñoz, L.E., Isiordia-Espinoza, M.A., Ruvalcaba-Gómez, J.M., Arteaga-Garibay, R.I., Acosta, J.L., González-Silva, N. and Anaya-Esparza, L.M. (2022). Physiological effects and human health benefits of *Hibiscus sabdariffa*: A review of clinical trials. *Pharmaceuticals*, 15, 464.

Nnanna, C.C., Akaninwor, J.O. and Ikewuchi, C.C. (2017). Comparative investigation of the effects of the commonly-consumed aqueous extracts of *Hibiscus sabdariffa* (zobo drinks) on body weight, glucose level and lipid profile using normal Wistar albino rats. *International Journal of Biochemistry Research & Review*, 16(4), 1-8.

Nwinyi, F.C. and Kwanashie, H.O. (2013). Comparative effects of *Sorghum bicolor* leaf base extract on tissues isolated from some body systems of experimental animals. *Journal of Medicinal Plants Research*, 7(41), 3041-3051.

Odjimogho, E.S., Odjimogho, S.E., Asemota, T.A. and Gabriel, B.O. (2024). Intraocular pressure reducing effect of *Hibiscus sabdariffa* leaf aqueous extract in normotensive subjects. *Journal of Scientific Research and Development*, 23(1), 109-119.

Ojulari, L.S., Oyeniyi, R.O. and Owoyele, B.V. (2014). Effect of *Hibiscus sabdariffa on* blood glucose and serum electrolytes in rats. *IOSR Journal of Dental and Medical Sciences*, 13(11), 60-62.

Okafor, C.C., Obiandu, C., Owhorji, B.I., Oriji, E.I. and Laz-Okenwa, J. (2022). Beneficial effects of *Hibiscus sabdariffa* in diabetic Wistar rats. *Asian Journal of Research in Biochemistry*, 11(3-4), 22-29.

Oyeniran, O.I., Mojiminiyi, F.B.O., Abubakar, I.A., Isezuo, S.A., Igbokwe, G.O., Igbokwe, E.E. and Oyeniyi, Y.J. (2022). Effects of Acute Oral Administration of *Hibiscus sabdariffa* Tea on Blood Pressure and Pulse Rate in Apparently Healthy Humans: A Randomized Double-blind Placebo-controlled Study. *Journal of African Association of Physiological Sciences*, 10(1), 24-31.

Permata, R.T., Darwinata, A.E., Saraswati, M.R., Pinatih, G.N.I., Weta, I.W. and Yasa, I.W.P.S. (2023). Effect of Sorghum (*Sorghum bicolor* L.) ethanol extract in preventing significant increased blood glucose levels, Interleukin-6 (IL-6) and Malondialdehyde (MDA) in White Rats (*Rattus norvegicus*) Wistar male strain with Nicotinamid-Streptozotocin induced Diabetes Mellitus. *International Journal of Scientific Advances*, 4(4), 571-575.

Pimentel, L.G.M., Gracitelli, C.P.B., da Silva, L.S.C., Souza, A.K.S. and Prata, T.S. (2015). Association between glucose levels and intraocular pressure: pre- and postprandial analysis in diabetic and nondiabetic patients. *Journal of Ophthalmology*, 2015, Article ID 832058.

Suvarna, Y.R., Ashwini, K., Shivaleela, S., Macha, S.I. and Lakshmikanth, M. (2024). Ascertaining Sorghum (*Sorghum bicolor* (L.) Moench) as an antidiabetic plant. *European Journal of Nutrition & Food Safety*, 16(1), 79-94.

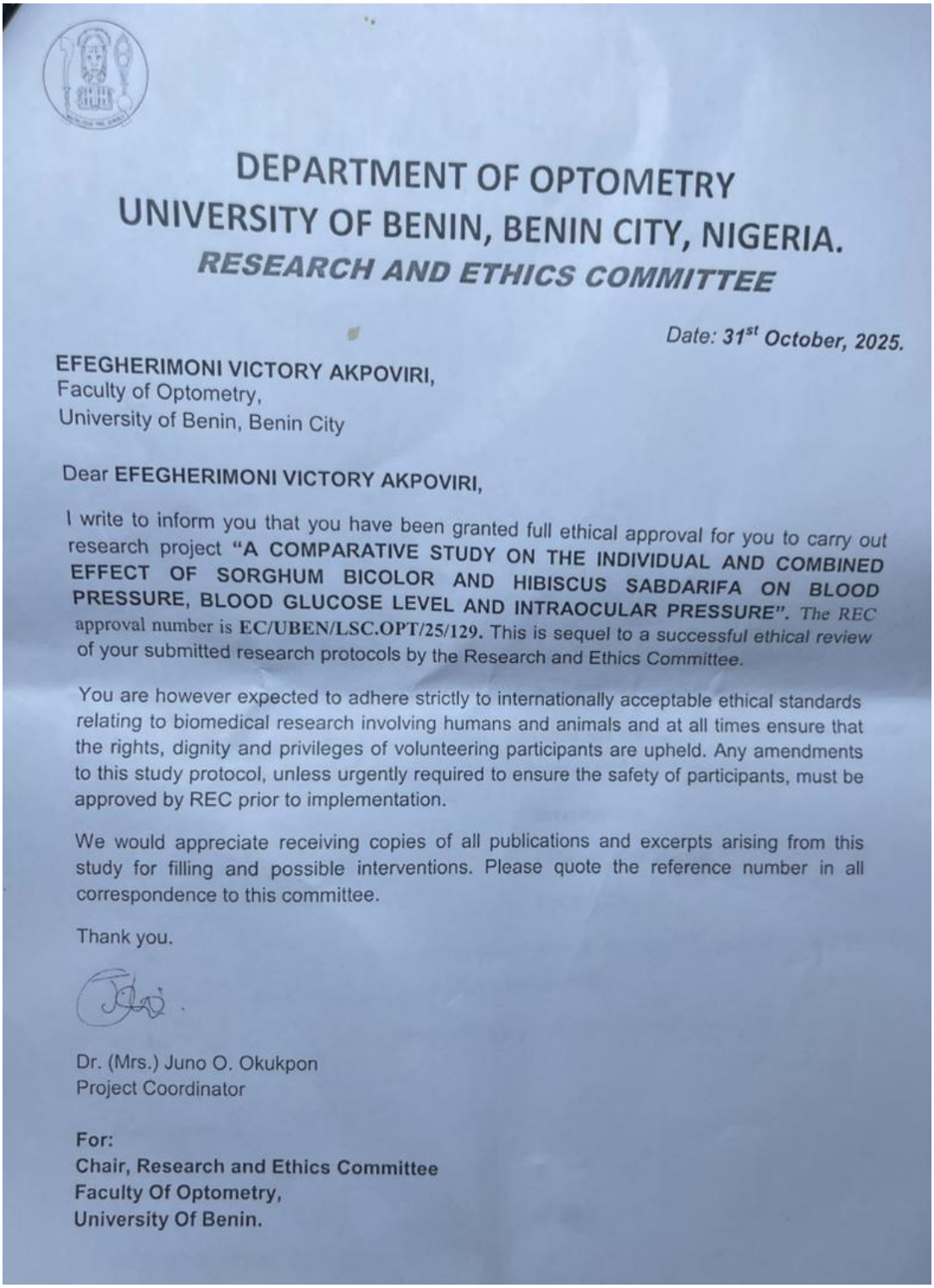
Suvarna, Yashaswini R., Ashwini K., Shivaleela, Sangeeta I. Macha, D. and Lakshmikanth, M. (2024). Ascertaining Sorghum [*Sorghum bicolor* (L.) Moench] as an antidiabetic plant. *European Journal of Nutrition & Food Safety*, 16(1), 79-94.

Weinreb, R.N., Aung, T. and Medeiros, F.A. (2014). The pathophysiology and treatment of glaucoma: a review. *JAMA*, 311(18), 1901-1911.

Zhou, B., Perel, P., Mensah, G.A., & Ezzati, M. (2021). Global epidemiology, health burden and effective interventions for elevated blood pressure and hypertension. *Nature Reviews Cardiology*, 18, 785–802.

APPENDIX I

Figure 10. Ethical Approval



DEPARTMENT OF OPTOMETRY
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.
RESEARCH AND ETHICS COMMITTEE

Date: 31st October, 2025.

EFEGHERIMONI VICTORY AKPOVIRI,
Faculty of Optometry,
University of Benin, Benin City

Dear **EFEGHERIMONI VICTORY AKPOVIRI,**

I write to inform you that you have been granted full ethical approval for you to carry out research project **"A COMPARATIVE STUDY ON THE INDIVIDUAL AND COMBINED EFFECT OF SORGHUM BICOLOR AND HIBISCUS SABDARIFA ON BLOOD PRESSURE, BLOOD GLUCOSE LEVEL AND INTRAOCULAR PRESSURE".** *The REC* approval number is **EC/UBEN/LSC.OPT/25/129.** This is sequel to a *successful ethical review* of your submitted research protocols by the Research and Ethics Committee.

You are however expected to adhere strictly to internationally acceptable ethical standards relating to biomedical research involving humans and animals and at all times ensure that the rights, dignity and privileges of volunteering participants are upheld. Any amendments to this study protocol, unless urgently required to ensure the safety of participants, must be approved by REC prior to implementation.

We would appreciate receiving copies of all publications and excerpts arising from this study for filling and possible interventions. Please quote the reference number in all correspondence to this committee.

Thank you.

Dr. (Mrs.) Juno O. Okukpon
Project Coordinator

For:
Chair, Research and Ethics Committee
Faculty Of Optometry,
University Of Benin.

Faculty of Optometry,
University of Benin,
28th October, 2025

The Chairperson
Research Ethics Committee (REC)
Faculty of Optometry,
University of Benin.

Through;
The Project Coordinator,
Faculty of Optometry.
University of Benin,
P.M.B 1154
Ugbowo, Benin City.

Dear Sir/Ma,

RE: APPLICATION FOR ETHICAL REVIEW AND CLEARANCE

I hereby apply for ethical clearance to conduct a research study titled:

"A COMPARATIVE STUDY ON THE INDIVIDUAL AND COMBINED EFFECT OF *SORGHUM BICOLOR* AND *HIBISCUS SABDARIFFA* ON BLOOD PRESSURE, BLOOD GLUCOSE LEVEL AND INTRAOCULAR PRESSURE".

This study aims to investigate and compare the individual and combined effect of *Sorghum bicolor* and *Hibiscus sabdariffa* on Blood Pressure, Blood Glucose Level and Intraocular Pressure.

Principal investigator (PI):

PROF. CANICE .C. ASONYE

Investigator:

EFEGHERIMONI VICTORY AKPOVIRI

LSC1907042

I kindly request the Research Ethics Committee to provide the required application documents for completion and submission as part of the ethical review process.

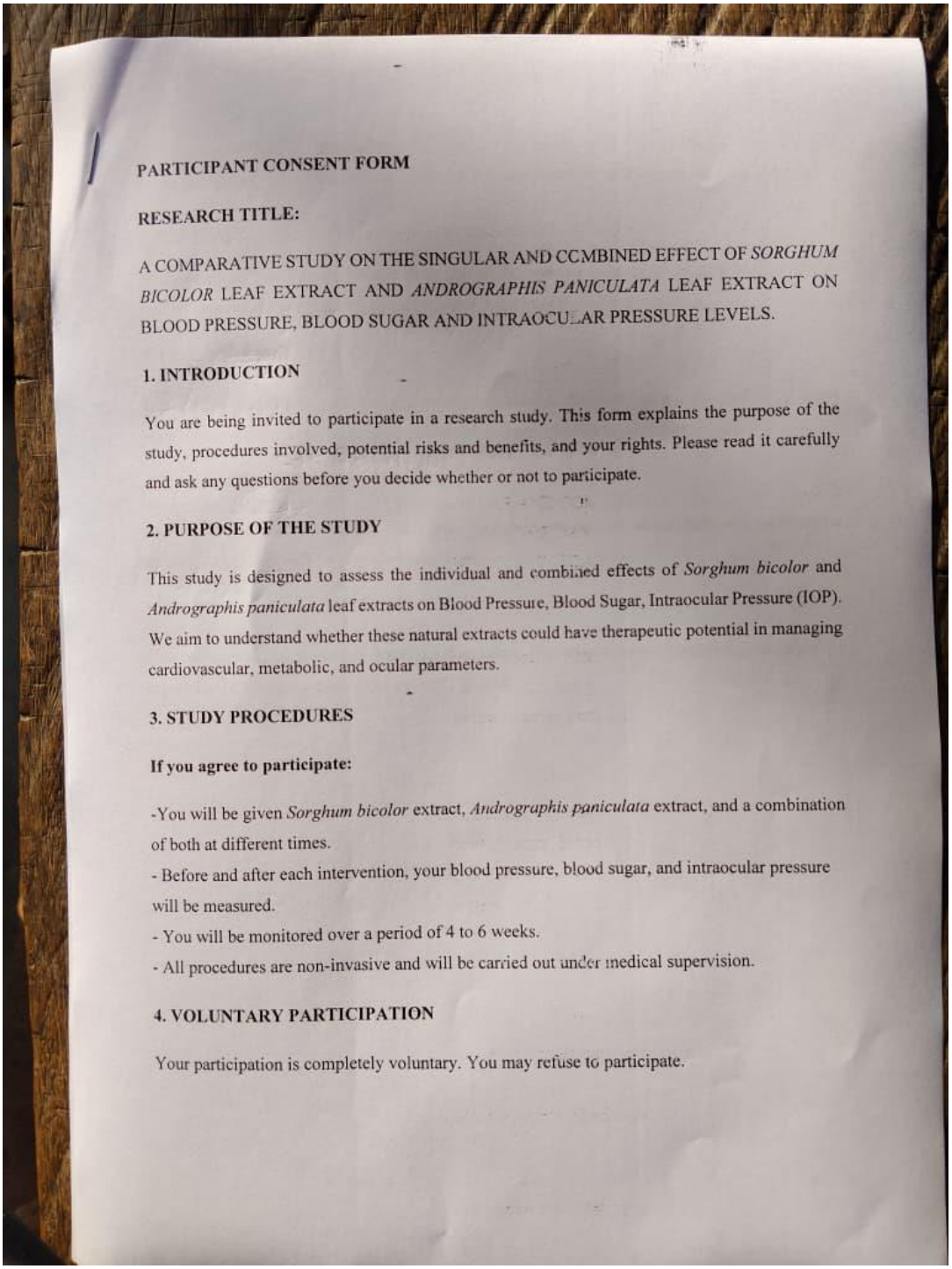
Thank you for your consideration. I look forward to your favorable response.

Yours faithfully,

EFEGHERIMONI VICTORY AKPOVIRI
Investigator

APPENDIX II

Figure 11. Questionnaire used for study



PARTICIPANT CONSENT FORM

RESEARCH TITLE:

A COMPARATIVE STUDY ON THE SINGULAR AND COMBINED EFFECT OF *SORGHUM BICOLOR* LEAF EXTRACT AND *ANDROGRAPHIS PANICULATA* LEAF EXTRACT ON BLOOD PRESSURE, BLOOD SUGAR AND INTRAOCULAR PRESSURE LEVELS.

1. INTRODUCTION

You are being invited to participate in a research study. This form explains the purpose of the study, procedures involved, potential risks and benefits, and your rights. Please read it carefully and ask any questions before you decide whether or not to participate.

2. PURPOSE OF THE STUDY

This study is designed to assess the individual and combined effects of *Sorghum bicolor* and *Andrographis paniculata* leaf extracts on Blood Pressure, Blood Sugar, Intraocular Pressure (IOP). We aim to understand whether these natural extracts could have therapeutic potential in managing cardiovascular, metabolic, and ocular parameters.

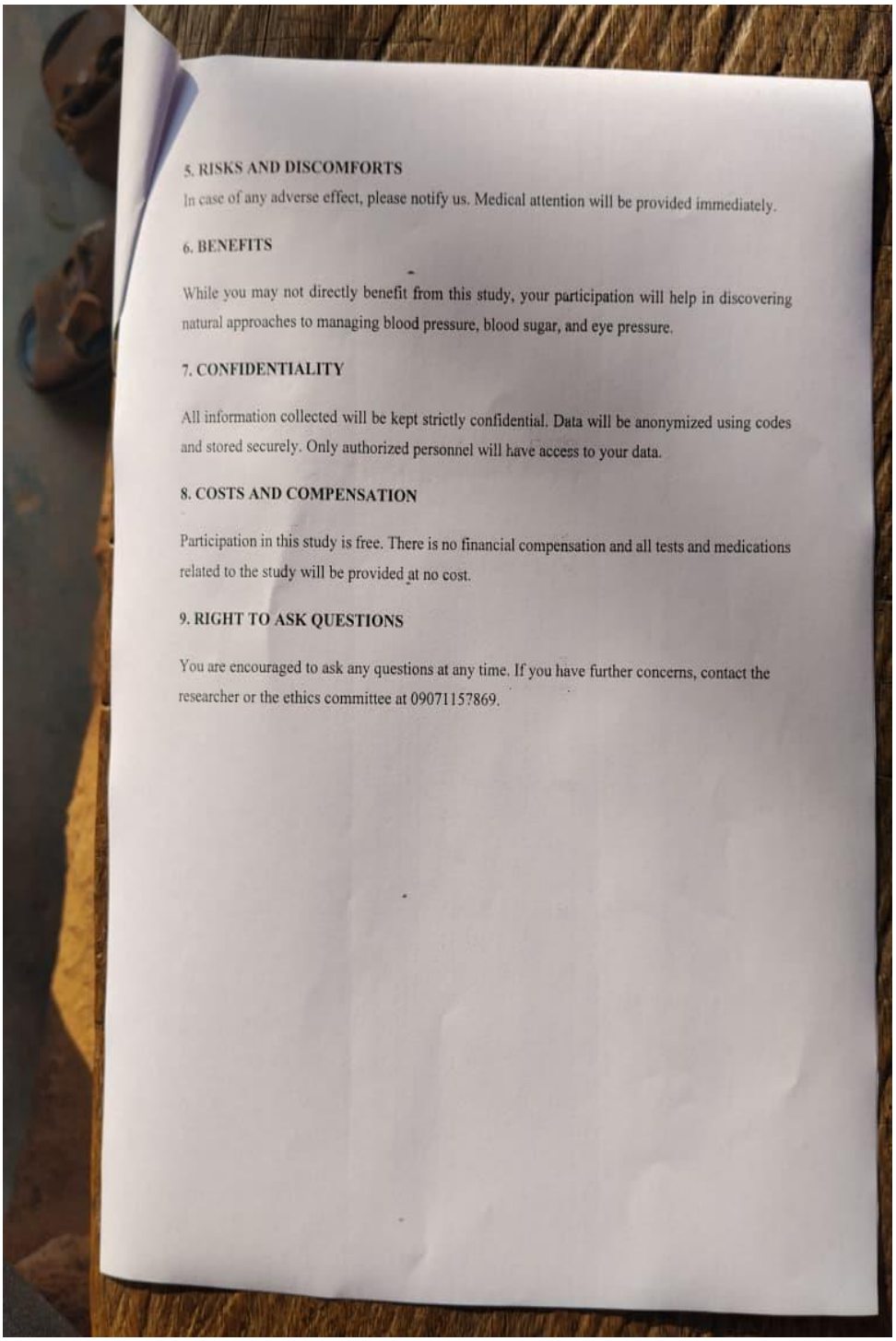
3. STUDY PROCEDURES

If you agree to participate:

-You will be given *Sorghum bicolor* extract, *Andrographis paniculata* extract, and a combination of both at different times.
- Before and after each intervention, your blood pressure, blood sugar, and intraocular pressure will be measured.
- You will be monitored over a period of 4 to 6 weeks.
- All procedures are non-invasive and will be carried out under medical supervision.

4. VOLUNTARY PARTICIPATION

Your participation is completely voluntary. You may refuse to participate.



5. RISKS AND DISCOMFORTS

In case of any adverse effect, please notify us. Medical attention will be provided immediately.

6. BENEFITS

While you may not directly benefit from this study, your participation will help in discovering natural approaches to managing blood pressure, blood sugar, and eye pressure.

7. CONFIDENTIALITY

All information collected will be kept strictly confidential. Data will be anonymized using codes and stored securely. Only authorized personnel will have access to your data.

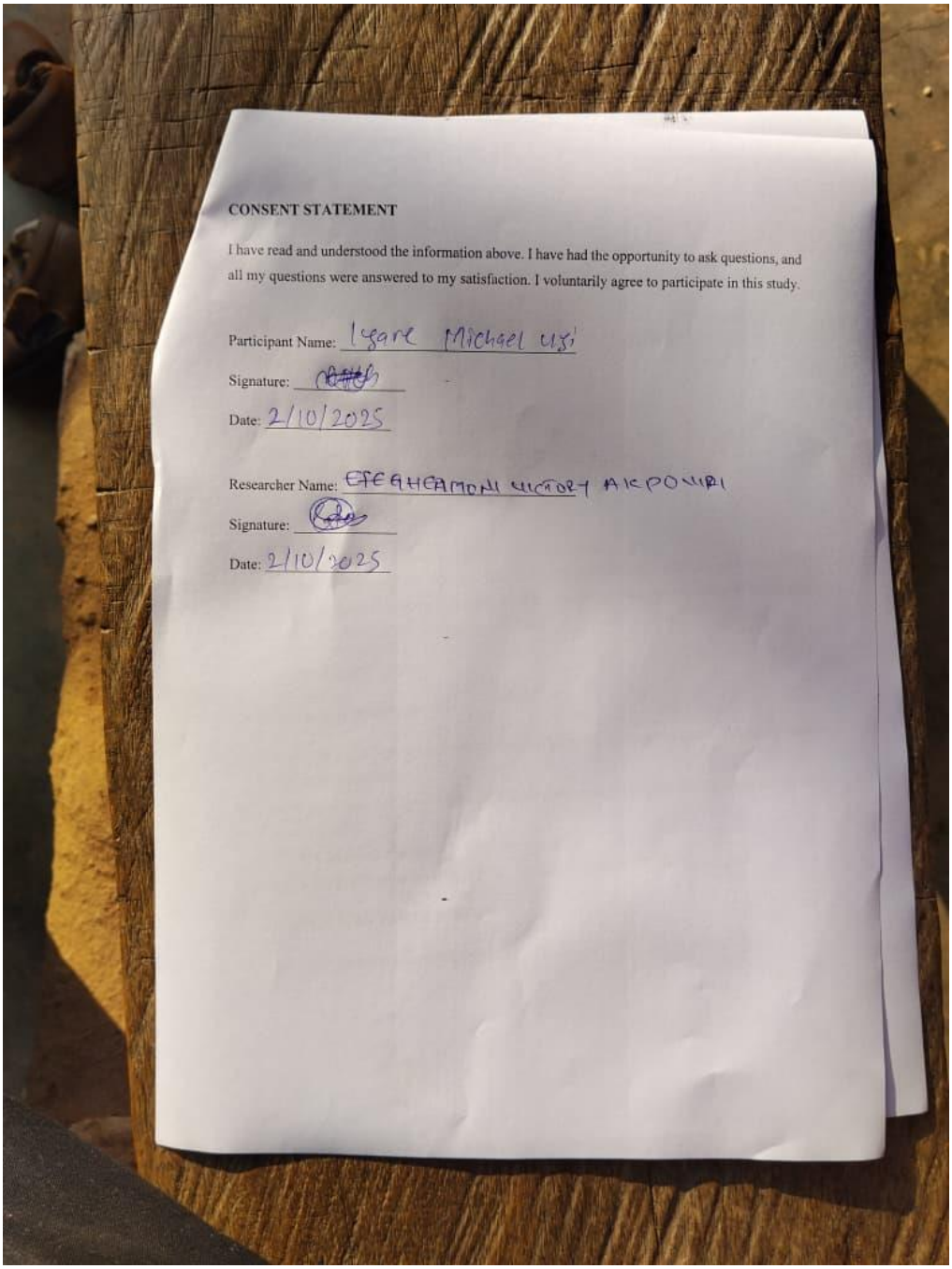
8. COSTS AND COMPENSATION

Participation in this study is free. There is no financial compensation and all tests and medications related to the study will be provided at no cost.

9. RIGHT TO ASK QUESTIONS

You are encouraged to ask any questions at any time. If you have further concerns, contact the researcher or the ethics committee at 09071157869.

Figure 12. Consent form



CONSENT STATEMENT

I have read and understood the information above. I have had the opportunity to ask questions, and all my questions were answered to my satisfaction. I voluntarily agree to participate in this study.

Participant Name: Iyare Michael Usi

Signature:

Date: 2/10/2025

Researcher Name: EFEGHEAMONI VICTORY AIGPONMI

Signature:

Date: 2/10/2025

Figure 13. 200g of Sorghum bicolor dried leaves

Figure 14. 200g of dried hibiscus sabdariffa leaves

Figure 15. Participant taking 250ml of hibiscus sabdariffa leaf extract

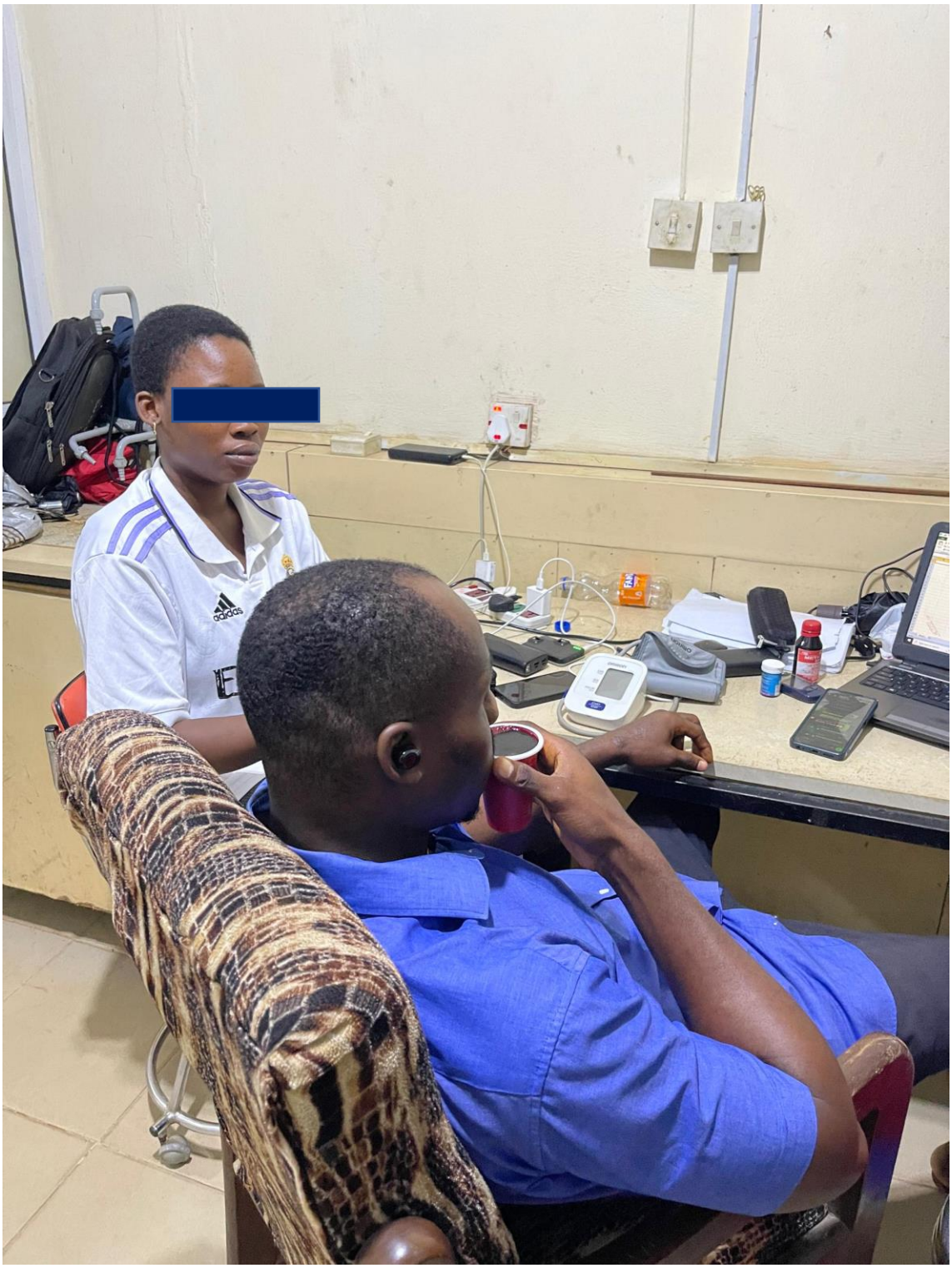


Figure 16. Measurement of 250ml of hibiscus sabdariffa and sorghum bicolor leaf extract combined.

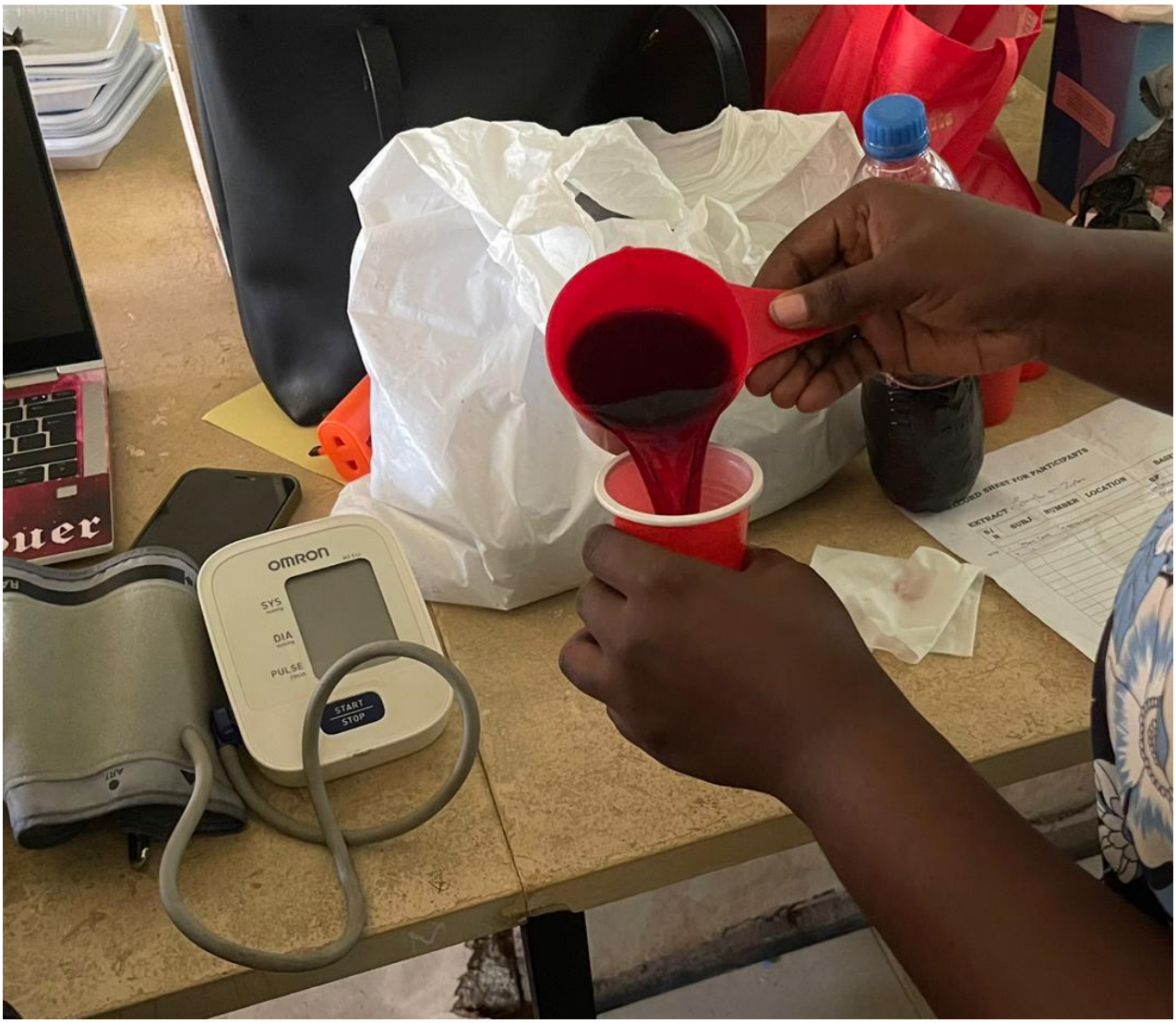


Figure 17. Participant drinking 250 ml of sorghum bicolor leaf extract