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

BY

PRAISE.O. AZIEGBEMHIN

LSC1910210

FACULTY OF OPTOMETRY,

UNIVERSITY OF BENIN,

BENIN CITY.

NOVEMBER, 2025

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PRAISE.O. AZIEGBEMHIN

LSC1910210

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.

NOVEMBER, 2025

CERTIFICATION

This is to certify that this research project titled **A COMPARATIVE STUDY ON THE SINGULAR AND COMBINED EFFECT OF *SORGHUM BICOLOR* AND *ANDROGRAPHIS PANICULATA* LEAF EXTRACTS ON BLOOD PRESSURE, BLOOD SUGAR AND INTRAOCULAR PRESSURE LEVELS** was carried out by **PRAISE OKHOIYERENYE AZIEGBEMHIN** in the Faculty of Optometry, University of Benin in partial fulfilment of the requirement for the Doctor of Optometry degree in the 2024/2025 Academic Session.

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PROFESSOR.C. C. ASONYE	**DATE**
(PROJECT SUPERVISOR)	
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DR JUNO. O. OKUKPON	**DATE**
(PROJECT COORDINATOR)	
……………………………………	....
PROFESSOR. EKI OGHRE	**DATE**
(DEAN FACULTY OF OPTOMETRY)	
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EXTERNAL EXAMINER	**DATE**

DEDICATION

I dedicate this project to **GOD ALMIGHTY** and to my ever supportive parents, Mr. and Mrs. Aghedo – Aziegbemhin for their love and support throughout this journey.

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My deepest gratitude goes to God Almighty for His Grace and Mercy over my life all these years and for being forever faithful.

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ABSTRACT

Non-communicable diseases like high blood pressure, diabetes, and glaucoma cause serious health issues and hardships in sub-Saharan Africa, often made worse by a lack of access to regular medical services. This research examines how the leaf extracts from *Sorghum bicolor* and *Andrographis paniculata* affect blood pressure, blood sugar, and eye pressure in healthy adults, both separately and together. One hundred and seventy-four (174) participants (mean age 34.3 ± 7.1 years) received single administrations of hot aqueous extracts of *S. bicolor, A. paniculata*, or a 1:1 mixed extract. Systolic and diastolic blood pressure (mmHg), fasting blood glucose (mg/dL) and IOP (mmHg, right eye [RE] and left eye [LE]) were measured at baseline and four hours post-administration. The results revealed statistically significant reductions ($p < 0.05$) across all parameters in all treatment groups. For *Sorghum bicolor*, systolic pressure decreased from 126.15 ± 15.9 to 120.80 ± 15.0 mmHg, diastolic pressure from 85.60 ± 11.1 to 80.03 ± 10.4 mmHg, blood glucose from 82.86 ± 14.61 to 70.39 ± 11.99 mg/dL, and IOP from 16.88 ± 2.5 to 15.83 ± 1.6 mmHg (right eye) and from 17.14 ± 1.93 to 16.12 ± 1.8 mmHg (left eye). Similar reductions were observed with *Andrographis paniculata*, where systolic pressure fell from 129.44 ± 14.7 to 121.20 ± 16.9 mmHg, diastolic pressure from 84.60 ± 13.3 to 77.13 ± 11.4 mmHg, and blood glucose from 83.61 ± 13.2 to 75.26 ± 11.43 mg/dL, while IOP decreased to 14.49 ± 2.0 mmHg (right) and 15.98 ± 2.0 mmHg (left). The combined extract produced the greatest effect, with systolic pressure reducing from 134.63 ± 15.7 to 128.68 ± 15.9 mmHg, diastolic pressure from 87.10 ± 22.1 to 77.90 ± 12.2 mmHg, blood glucose from 80.42 ± 12.04 to 74.40 ± 10.20 mg/dL, and IOP from 15.94 ± 1.8 to 14.94 ± 2.0 mmHg (right) and 15.67 ± 1.5 to 15.13 ± 2.7 mmHg (left). These results demonstrate that both *Sorghum bicolor* and *Andrographis paniculata* extracts—singularly and in combination—can significantly lower blood pressure, blood glucose, and intraocular pressure within a short period following administration. The enhanced effects observed with the combined extract suggest possible synergistic interactions between their phytochemical constituents.

Keywords: *Sorghum bicolor*; *Andrographis paniculata*; blood pressure; blood glucose; intraocular pressure; aqueous extract; phytotherapy; optometry; traditional medicine integration.

CHAPTER ONE

1.0 INTRODUCTION

Hypertension, type 2 diabetes mellitus (T2DM), and glaucoma (ocular hypertension) are prevalent chronic conditions worldwide. An estimated 1.28 billion adults (ages 30–79) have hypertension, affecting roughly 30% of adults globally (World Health Organization, 2021). Diabetes mellitus, especially type 2, continues to rise at an alarming rate, with increasing prevalence observed even among young adults in sub-Saharan Africa, including Nigeria (Chinenye *et al*., 2012). Elevated IOP is the most significant modifiable risk factor for primary open-angle glaucoma, a leading cause of irreversible blindness worldwide (Tham *et al*., 2014).

The coexistence of these conditions poses a serious challenge to both systemic and ocular health. Hypertension and hyperglycemia have been linked to structural and functional damage to the retina and optic nerve, contributing to vision-threatening complications like hypertensive retinopathy, diabetic retinopathy, and glaucomatous optic neuropathy (Pascolini & Mariotti, 2012). In the context of optometric practice, early detection and management of these systemic risk factors are critical in preventing long-term visual impairment.

While pharmacologic treatments such as antihypertensives, antidiabetics, and ocular hypotensive agents are effective, they are often associated with adverse effects, cost constraints, and poor long-term compliance (Khatib *et al*., 2014; Inzucchi *et al*., 2015). These challenges have led to growing interest in plant-based interventions as safer and more accessible alternatives, especially in resource-limited settings. The World Health Organization acknowledges the role of traditional medicine in healthcare and encourages scientific validation of medicinal plants (WHO, 2013).

Sorghum bicolor, commonly known as guinea corn, is a cereal crop rich in bioactive phytochemicals such as polyphenols, flavonoids, and tannins, which exhibit antioxidant, antihypertensive, and antidiabetic effects (Awika & Rooney, 2004; Oboh *et al*., 2018). Several experimental studies have reported significant reductions in blood glucose and blood pressure following administration of sorghum leaf or grain extracts in animal models (Adebo *et al*., 2019; Adefegha & Oboh, 2012). Though widely consumed in various Nigerian diets, its therapeutic potential is still underutilized and under-investigated, particularly in ocular health.

Similarly, *Andrographis paniculata* is a medicinal plant known for its potent anti-inflammatory, antihyperglycemic, and hepatoprotective activities (Akbar, 2011). The plant contains a key phytoconstituent called andrographolide, which has demonstrated hypotensive and antidiabetic actions in both preclinical and limited clinical studies (Mishra *et al*., 2015; Sheeja & Kuttan, 2007). It is widely used in herbal medicine practices across Asia and Africa, yet its comparative efficacy with other medicinal plants like S. bicolor remains largely unexplored in clinical contexts.

Although these plants have been evaluated for systemic health benefits, few studies have focused on their comparative and combinatorial influence on blood pressure, blood sugar and Intraocular pressure levels, especially in human subjects. Given the interconnected nature of systemic vascular health and ocular function, it is important to investigate whether plant extracts known to affect blood pressure and glucose can also influence IOP. Since oxidative stress, vascular dysregulation, and inflammation play roles in glaucoma and diabetic eye disease, phytochemicals with antioxidant or vasoactive properties may offer dual systemic and ocular benefits (Abdulqadir *et al*., 2022; Ko *et al*., 2019).

This study, therefore, seeks to compare the effects of *Sorghum bicolor* and *Andrographis paniculata* leaf extracts, prepared using hot aqueous extraction, on blood pressure, blood sugar, and intraocular pressure in human participants. By evaluating these parameters in a controlled setting, the study aims to compare the efficacy of using singular extracts versus combined extract on body and ocular system. The outcomes could support the development of integrated plant-based therapies that address the underlying systemic drivers of visual impairment, thereby contributing to preventive and therapeutic approaches in optometry

1.1 Background Information

Due to inadequate health infrastructure and rising chronic disease prevalence, non-communicable diseases like hypertension, diabetes mellitus, and ocular hypertension (particularly glaucoma) are becoming major causes of morbidity globally, particularly in sub-Saharan Africa (Forouhi and Wareham, 2014; Weinreb *et al.,* 2014; Zhou *et al.,* 2021). These disorders, which include hyperglycemia, hypertension, and elevated intraocular pressure (IOP), are closely related due to their pathogenesis in metabolic dysregulation. Many patients have to rely on medication for the rest of their lives due to side effects and accessibility issues, which drives the search for safer and more economical treatments based on traditional medicine (Forouhi and Wareham, 2014*; Ali et al*., 2005; Suvarna *et al.,* 2024).

Medicinal plants such as *Sorghum bicolor* (sorghum) and *Andrographis paniculata* (king of bitters) have a long history in African and Asian traditional medicine and are widely utilized as both dietary staples and herbal remedies for various ailments including metabolic, cardiovascular, and inflammatory diseases (Nugroho *et al*., 2013; Nugroho *et al*., 2022; Suvarna *et al*., 2024). Sorghum, in particular, has seen increased attention for its rich content of polyphenols, tannins, and flavonoids, with experimental evidence supporting antidiabetic and vasoprotective effects (Suvarna *et al*., 2024). *Andrographis paniculata* is especially recognized for andrographolide, its key diterpenoid, which is shown in animal and cellular models to be highly antihyperglycaemic and anti-inflammatory (Nugroho *et al*., 2013; Nugroho *et al*., 2022).

Notably, polyherbal mixtures, combinations of plant extracts, are a mainstay in traditional medicine especially in Africa and Asia, but scientific validation and comparative studies between singular and combined plant uses remain limited (García-Muñoz *et al*., 2023).

1.1.1 Overview of Medicinal Plants in Disease Management

The wide range of bioactive substances found in medicinal plants, including polyphenols, flavonoids, saponins, and alkaloids, as well as their cultural acceptability, affordability, and often better safety profiles than synthetic pharmaceuticals, are what draw people to them (Nugroho *et al.,* 2013; Nugroho *et al.,* 2022; Suvarna *et al.,* 2024). Due to their rich phytochemical composition and proven advantages in laboratory and early clinical settings, *S. bicolour* and *A. paniculata* have both established ethnomedicinal and experimentally validated roles in addressing cardiovascular and metabolic conditions (Nugroho *et al.,* 2013; Suvarna *et al.,* 2024).

1.1.2 Botanical Profile of *Sorghum bicolor*

Sorghum bicolor is an ancient, highly drought-tolerant cereal from the Poaceae family, widely grown and consumed across Africa and Asia as food and remedy (Suvarna *et al*., 2024). Sorghum grain is especially notable for its content of resistant starch, polyphenols (including 3-deoxyanthocyanidins and condensed tannins), and flavonoids (luteolin, apigenin), which are believed to underpin its antioxidant, anti-inflammatory, and hypoglycaemic properties (Suvarna *et* *al*., 2024). Traditionally, sorghum is used for treating diabetes, gastrointestinal complaints, general tonic use, and as a cardiovascular protectant (Nwinyi and Kwanashie, 2013).

1.1.3 Botanical Profile of *Andrographis paniculata*

Andrographis paniculata is a widely distributed herb of the Acanthaceae family, native to South and Southeast Asia and distinguished by its intensely bitter taste and the presence of andrographolide, which demonstrates strong anti-hyperglycaemic actions in diverse models (Nugroho *et al*., 2013; Nugroho *et al*., 2022). The plant is utilized in folk medicine largely as a modulator of blood glucose, blood pressure, and inflammatory states, and is increasingly studied for its support in type 2 diabetes and cardiovascular risk reduction (Nugroho *et al*., 2013).

1.1.4 Pharmacological Effects

Sorghum bicolor

Modern studies consistently show that sorghum extract significantly lowers fasting and postprandial blood glucose, improves insulin sensitivity (through PPAR-γ activation), increases antioxidant capacity, and can positively influence lipid profiles (Suvarna *et al*., 2024). Sorghum also displays a favorable vascular safety profile in experimental animal models, with negligible negative effects on cardiac contractility or smooth muscle tone (Nwinyi and Kwanashie, 2013). Its antioxidant and anti-inflammatory actions are largely linked to high polyphenol concentrations, particularly in the bran fraction (Suvarna *et al*., 2024).

Andrographis paniculata

A. paniculata extracts and its major diterpenoid, andrographolide, significantly lower blood glucose in diabetic animal models, primarily by improving GLUT-4 expression, insulin sensitivity, and modulating inflammatory mediators (Nugroho *et al*., 2013; Nugroho *et al*., 2022). The plant demonstrates both insulin-mimetic and insulin-sensitizing effects and its antihyperglycemic activity is comparable to reference drugs like metformin in preclinical models (Nugroho *et al*., 2013).

Combined Extracts of *Sorghum bicolor* and *Andrographis paniculata*

Several animal studies have shown that combining *A. paniculata* with other antidiabetic plants, such as *Centella asiatica* or *Syzygium cumini*, results in additive or synergistic hypoglycaemic effects, greater improvement in HDL, and more pronounced effects on cholesterol and insulin sensitivity compared to single plant extracts alone (Nugroho *et al*., 2013; Nugroho *et al*., 2022).

The scientific rationale for studying the combined effect of *S. bicolor* and *A. paniculata* is based on polyherbal formulation experiences, where multiple bioactive pathways may be simultaneously targeted for superior outcomes in chronic metabolic disorders (Nugroho *et al*., 2013; García-Muñoz *et al*., 2023).

1.1.5 Pathophysiological Basis of Study Parameters

- **Blood pressure**: Regulated by hormonal signaling (most notably by the renin-angiotensin-aldosterone system, or RAAS), vascular tone, and renal sodium management. Extracts high in polyphenols improve endothelial function and adjust the equilibrium between vasodilators and constrictors (Odunaye-Badmus *et al.,* 2025).
- **Blood glucose**: Determined by pancreatic insulin release and peripheral insulin response, each a primary target of the phytochemicals found in these two plants (Nugroho *et al*., 2013; Suvarna *et al*., 2024).

- **Intraocular Pressure (IOP)**: Influenced by aqueous humor production and drainage in the eye, with elevation linked to increased risk of glaucoma and shown to be modifiable by antioxidants and metabolic regulators from plant sources such as sorghum (Pimentel *et al*., 2015; Odjimogho *et al*., 2024).

1.2 Statement of the Problem

The effects of *Sorghum bicolour* and *Andrographis paniculata* on blood pressure, blood glucose, and intraocular pressure are widely used in ethnomedicine, but there is little direct comparative scientific evidence for these effects, particularly in experimental or clinical models relevant to sub-Saharan Africa (Nwinyi and Kwanashie, 2013; García-Muñoz *et al.,* 2023). Despite polyherbal consumption being the traditional norm, the majority of existing research focus on these botanicals alone and very infrequently examines their combination use (García-Muñoz *et al.,* 2023). Given the overlap of hypertension, diabetes, and eye illness in co-morbid populations, especially in areas with limited access to conventional medical care, this is a gap of significant clinical and public health concern (García-Muñoz *et al.,* 2023; Odjimogho *et al.,* 2024).

1.3 Aim of the Study

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

1.4 Objectives of the Study

1. To evaluate the singular effects of *Sorghum bicolor* leaf extract on blood pressure, blood sugar, and intraocular pressure levels.

2. To evaluate the singular effects of *Andrographis paniculata* leaf extract on blood pressure, blood sugar, and intraocular pressure levels.

3. To evaluate the combined effect of *Sorghum bicolor* and *Andrographis paniculata* leaf extracts on blood pressure, blood sugar and intraocular pressure levels.

4. To compare the singular effect and combined effect of *Sorghum bicolor* and *Andrographis paniculata* leaf extracts on blood pressure, blood sugar and intraocular pressure levels..

1.5 Research Questions

1. What are the effects of *Sorghum bicolor* leaf extract on blood pressure, blood sugar, and intraocular pressure levels?

2. What are the effects of *Andrographis paniculata* leaf extract on blood pressure, blood sugar, and intraocular pressure levels?

3. What are the effects of a combined extract of *Sorghum bicolor* and *Andrographis paniculata* on blood pressure, blood sugar and intraocular pressure levels?

4. Is there a significant difference between the singular effect and combined effect of these extracts?

1.6 Research Hypotheses

Null Hypothesis (Ho_1): There is no significant effect of *Sorghum bicolo*r leaf extract on intraocular pressure, blood pressure or blood glucose in adults 25 years and above.

Null Hypothesis (Ho_2): There is no significant effect of *Andrographis paniculata* leaf extract on intraocular pressure, blood pressure or blood glucose in adults 25 years and above.

Null Hypothesis (Ho_3): There is no significant effect between the singular effect and combined effect of *Sorghum bicolor* and *Andrographis paniculata* on Blood pressure, glucose and Intraocular pressure in adults aged 25 and above.

1.7 Significance of the Study

This study is significant because it:

- **Addresses a critical health triad:** Hypertension, diabetes, and glaucoma are highly prevalent chronic conditions that frequently co-exist, imposing substantial health burdens on individuals and healthcare systems. This research directly addresses these interconnected conditions, aiming for a comprehensive approach to their management.
- **Explores novel therapeutic strategies:** The investigation of herbal extracts, particularly in combination, contributes to the ongoing search for natural, potentially safer, and multi-targeted therapeutic options. This approach is particularly relevant given the limitations and side effects associated with some conventional pharmacological treatments.
- **Scientific validation of traditional knowledge:** This research contributes to the scientific validation of traditional medicinal plant uses, translating empirical knowledge into evidence-based natural product development.
- **Foundation for future research:** The findings from this study will provide crucial preliminary data for future human clinical trials, particularly for developing standardized herbal formulations for integrated metabolic and ocular health management.

1.8 Definition of Terms

Andrographolide: Principal diterpenoid in *A. paniculata* responsible for hypoglycemic activity (Nugroho *et al*., 2013).

Ethnomedical: The study of how different cultures understand and treat illness using their own natural remedies, beliefs and practices.

Fasting Blood Glucose: Blood glucose after at least eight hours without food; a diagnostic marker for diabetes (WHO, 1999).

Intraocular Pressure (IOP): Fluid pressure within the eye; elevated levels are a risk factor for glaucoma (Pimentel *et al*., 2015).

Polyphenols: Bioactive plant compounds with antioxidant and anti-inflammatory effects found abundantly in *S. bicolor* (Suvarna *et al*., 2024).

Synergistic Effect: An interactive effect greater than the sum of individual effects, as observed in some plant extract combinations (Nugroho *et al*., 2013).

Blood pressure: the force that your blood exerts against the walls of your arteries as the heart pumps it around the body

CHAPTER TWO

LITERATURE REVIEW

Hossain *et al*. (2007) explored the antidiabetic activity of *Andrographis paniculata* using both hot water and ethanol extracts collected in Bangladesh. The primary aim was to evaluate the blood glucose-lowering effect of A. paniculata in both glucose-loaded and alloxan-induced diabetic rat models. Rats received either hot water or ethanol extracts, and the researchers measured blood sugar levels two hours after extract administration using the glucose oxidase-peroxidase method. Results showed that both extract types significantly ($p < 0.001$) lowered the elevated blood glucose, reductions were 41.51% (hot water) and 41.82% (ethanol) in glucose-loaded rats, and 46.21% (hot water) and 45.13% (ethanol) in alloxan-induced diabetic rats—comparable to the standard drugs used. The authors concluded that both aqueous and ethanolic extracts have substantial hypoglycemic properties, supporting their traditional use and recommending further isolation and mechanistic studies for drug development.

Widharna *et al*. (2010) explored the comparative antidiabetic properties of water and ethanol extracts of *Andrographis paniculata*, as well as ethanol extract of *Eugenia polyantha* (bay leaf), in healthy Wistar rats via oral glucose tolerance testing. Six groups, including controls and various extracts at 200 mg/kg, were assessed for blood glucose changes post-glucose loading. Water extract of *A. paniculata* and *E. polyantha* leaves both produced steady reductions in blood glucose that did not cause hypoglycemia, unlike glibenclamide, while ethanol extract acted more slowly. Thin-layer chromatography revealed distinct profiles for the extracts. The study recommends water extract of *A. paniculata* and *E. polyantha* for further development, noting their safety and lack of marked hypoglycemic episodes.

Syamsul *et al*. (2011) evaluated the antidiabetic potential of combining metformin with a purified extract of *Andrographis paniculata* in high-fructose-fat-fed, insulin-resistant rats. Test animals were split into four groups receiving metformin alone, extract alone, or either of two combinations of both. Over several weeks, pre- and postprandial glucose and GLUT-4 muscle expression were assessed. Results showed that both metformin and extract alone significantly lowered glucose and improved GLUT-4 expression, but combinations reduced the hypoglycemic effect compared to monotherapies. The researchers concluded that purified sambiloto extract combined with metformin does not enhance antihyperglycemic potency and may actually reduce bioavailability, cautioning against direct combined use.

Nugroho *et al*. (2012) assessed the antidiabetic and antihiperlipidemic effect of *Andrographis paniculata* and its active compound andrographolide in high-fructose-fat-fed rats—a model of type 2 diabetes. Rats were treated with a purified extract, isolated andrographolide, or metformin following hyperglycemia induction. Both the extract and andrographolide significantly reduced pre- and postprandial blood glucose as well as LDL and triglyceride levels, while cholesterol and body weight remained unchanged. These effects matched those of metformin. The authors recommended use of both the plant and its compound for managing diabetic hyperglycemia and hyperlipidemia, noting the need for further mechanistic studies.

Akter *et al*. (2013) aimed to evaluate and compare the antidiabetic potential and phytochemical profile of ethanolic leaf extracts of *Andrographis paniculata* and *Azadirachta indica* in rats. Using both glucose-loaded and alloxan-induced diabetic Wistar rats, the study administered the extracts (1 g/kg) and reference drug glimepiride, monitoring blood glucose at 2 hours post-treatment. Both plant extracts significantly reduced blood glucose in both models, with A. paniculata showing a 40.65% reduction in alloxan-induced and a 32.18% reduction in glucose-loaded rats, which was close to the effect of glimepiride. Acute toxicity studies found no adverse effects, and phytochemicals such as alkaloids, flavonoids, saponins, and terpenes were identified. They concluded that both plants, but especially *A. paniculata*, have strong anti-diabetic potential, recommending further research on active principles and mechanisms.

Nugroho *et al*. (2013) examined the anti-diabetic effect of a combination of andrographolide-enriched extract of *Andrographis paniculata* and asiaticoside-enriched extract of *Centella asiatica* in high fructose-fat-fed rats (Nugroho *et al*., 2013). Seven groups of Wistar rats received single extracts, combinations (three ratios), or metformin for seven days after hyperglycemia induction. The 70:30 (*A. paniculata* : *C. asiatica*) combination showed the strongest reduction on glucose, cholesterol, and HDL elevation, surpassing single treatments, and suggesting synergy. The study recommended developing the combination as a blood-glucose lowering formulation, especially for type 2 diabetes.

Nwinyi and Kwanashie (2013) performed a broad pharmacological screening of aqueous methanolic extract of *Sorghum bicolor* leaf base on various isolated animal tissues (rat atria, portal vein, rabbit jejunum, guinea pig ileum, rat stomach fundus, uterus, vas deferens) to assess effects on major organ systems. Their experimental approach involved organ-bath studies to compare tissue responses to the extract versus standard agonists. The extract showed no effect on cardiac tissues, induced relaxation in rabbit jejunum and guinea pig ileum, and caused non-dose-dependent contraction in rat stomach fundus; it neither altered uterine rhythmicity nor significantly impacted vas deferens. They concluded that the extract is likely safe for cardiovascular use, has antispasmodic potential for gastrointestinal issues, and is non-uterogenic, recommending follow-up mechanism studies on its smooth muscle effects.

Nugroho *et al*. (2014a) set out to evaluate the effect of andrographolide, a bioactive compound isolated from *Andrographis paniculata*, and an andrographolide-enriched extract (AEEAP) on the pancreas of neonatal streptozotocin (STZ)-induced diabetic rats. The researchers induced type 2 diabetes in neonatal rats using STZ and then administered andrographolide, AEEAP, or glibenclamide for eight days. They measured the effects through blood glucose levels, morphological assessment of pancreatic islets and beta-cell density, and immunohistochemical analysis of pancreatic insulin. The results revealed that andrographolide significantly decreased postprandial blood glucose and improved both pancreatic islet structure and beta-cell density compared to both AEEAP and control. The study concluded that andrographolide, more than crude extract, could restore pancreatic function. The authors recommended further research on andrographolide for diabetes therapy, especially focusing on isolating potent phytoconstituents for drug development.

Nugroho *et al*. (2014b) also investigated whether combining extracts of *Andrographis paniculata* and *Azadirachta indica* (Neem) enhanced antihyperglycemic effects over each single extract in alloxan-induced diabetic rats. After confirming diabetes induction by alloxan, rats received single or combined extracts for fifteen days, with regular monitoring of preprandial and postprandial blood glucose. The results indicated that both single extracts reduced glucose significantly, but the combination, especially at higher doses, showed superior hypoglycemic effects, although still less potent than glibenclamide. Phytochemical analysis showed that the extracts included major antidiabetic flavonoids. The authors suggested that combining herbal extracts can offer synergistic antidiabetic benefits and recommended further mechanistic and clinical studies to optimize combination dosing and formulations.

Komalasari and Harimurti (2015) performed a literature review on the anti-diabetic activity of *Andrographis paniculata* based on in-vivo studies. The aim was to summarize research findings regarding the use of *A. paniculata* extracts, isolated andrographolide and analogues, and plant combinations with synthetic drugs. Inclusion criteria were in-vivo studies published from 2000–2014 in English or Indonesian. Extracts, andrographolide, and its analogue AL-1 were all shown to improve glucose, insulin resistance, and GLUT-4 expression in animal models, and combinations with drugs or other herbs (e.g., metformin or Centella asiatica) produced varied effects. Notably, combinations with metformin reduced the drug's absorption, while herbal combinations could potentiate antidiabetic actions. Toxicity evaluations indicated safety at therapeutic doses. They recommended *A. paniculata* as a promising alternative or adjunct for diabetes but emphasized the need to study drug interactions and underlying mechanisms further.

Trilestari *et al*. (2015) aimed to scientifically evaluate the antihypertensive activity of ethanolic extract of *Andrographis paniculata* (EEAP) in Wistar rats using a non-invasive blood pressure recording method. The study induced hypertension in rats using the alpha-adrenergic agonist phenylephrine, then administered EEAP at doses of 45, 90, or 180 mg/kg body weight, with nifedipine as a positive control. Blood pressure was monitored at intervals post-induction. The extract was rich in andrographolide, flavonoids, and phenolics. All EEAP doses significantly reduced systolic and diastolic blood pressures, with comparable effect to standard drugs, in a dose-dependent manner. The results support the use of A. paniculata extracts as a promising natural antihypertensive agent, and the authors recommend further research to isolate active fractions and clarify mechanisms of action.

Widharna *et al*. (2015) examined the antidiabetic effects of an aqueous extract mixture of *Andrographis paniculata* and *Syzygium polyanthum* leaves in both oral glucose tolerance and alloxan-induced diabetic tests using Wistar rats. Seventy-two rats were divided into control groups, single extract groups, and mixture groups, with a dose of 200 mg/kg. The mixture lowered blood glucose significantly more than single extracts in both normal and diabetic rats after glucose loading and 14-day treatment. Histopathological examination showed that the extract mixture improved the morphology of pancreatic islets with no toxicity detected during acute toxicity testing. They recommended the extract mixture for future studies and potential development of type 2 diabetes therapy.

Akilandeswari *et al*. (2019) provided a comprehensive prospective review of the phytochemistry, pharmacology, and multifaceted medicinal actions of *Andrographis paniculata*. The review aimed to summarize global evidence and mechanistic insights into its anti-inflammatory, anti-bacterial, anti-diabetic, hepatoprotective, antioxidant, anticancer, and immunomodulatory properties. Their methodology involved extensive literature retrieval and synthesis, highlighting both animal and limited clinical trial findings. Results reinforced *Andrographis paniculata*'s efficacy, especially its active compound andrographolide, in reducing oxidative stress, regulating blood glucose, supporting liver detoxification, and modulating immune responses. The authors recommended further translational research, particularly focused on drug formulation and delivery systems for andrographolide, citing its pharmacological versatility and promise in managing chronic diseases.

Fatmawati *et al*. (2019) investigated the effects of a combination of *Moringa oleifera* leaf ethanol extract and *Andrographis paniculata* herb ethanol extract on blood glucose levels and pancreatic histopathology in streptozotocin-induced diabetic rats. Their study aimed to evaluate whether the combination possessed antihyperglycemic activity and could improve pancreatic beta cell recovery. Using 32 rats divided into eight groups, they compared various dosages and combinations alongside gliclazide as a control and measured fasting blood glucose pre-treatment, on days 0, 14, and 28. Pancreatic tissue was analyzed histologically after 4 weeks. The results showed that both single and combined extracts significantly reduced fasting blood glucose, restored weight loss, and improved pancreatic histopathology compared to hyperglycemic controls, with no significant difference between combination and single extract effects. The authors concluded that both interventions have important antihyperglycemic and regenerative effects, recommending further studies to optimize the combination and clarify mechanisms.

Dele-Olawumi *et al*. (2020) explored the effect of aqueous extracts of *Sorghum bicolor*, *Carica papaya*, and *Hibiscus sabdariffa* leaves on hematological parameters in cyclophosphamide-induced anaemia in male albino rats. Forty rats were sorted into eight groups, anaemia was induced, and the extracts (400/800 mg/kg) were administered orally for 21 days. *Sorghum bicolor* at 400mg/kg gave the highest percent decrease in neutrophils (28.2%) and the greatest lymphocyte increase (105.4%), while Hibiscus sabdariffa had the highest iron content. Both *Sorghum bicolor* and *Hibiscus sabdariffa* promoted weight gain and improved hematological indices. The authors recommend these leaf extracts as affordable, accessible means for anaemia management and call for clinical trials to translate these findings to humans.

Ischak and Botutihe (2020) conducted a preliminary clinical study to investigate the antidiabetic effects of Salam (*Eugenia polyantha*) and Sambiloto (*Andrographis paniculata*) leaves in patients with type 2 diabetes mellitus. The study used a pre- and post-treatment design involving 40 participants divided into two groups, each receiving either *E. polyantha* or *A. paniculata* capsules (300 mg, 1–2 capsules/day for one week). The main outcomes included fasting blood glucose, uric acid, total cholesterol, blood pressure, and subjective patient complaints. The results revealed that around 70–80% of participants in both groups experienced a reduction of fasting blood glucose below 140 mg/dL; notable decreases were also seen in uric acid and cholesterol for a majority of patients, alongside improvements in subjective well-being. They recommended further, larger-scale clinical studies to confirm the antidiabetic efficacy and safety of both plants in managing type 2 diabetes.

Prijesh *et al*. (2020) compared the blood-glucose-lowering effects of *Andrographis paniculata* (Serpentina) extract with metformin in alloxan-induced diabetic albino rabbits. Using a controlled experiment, three groups received either saline, metformin (150 mg/kg), or Serpentina extract (400 mg/kg) every 12 hours after alloxan induction, with glucose measured at multiple intervals. Results showed that Serpentina extract had glucose-lowering capability similar to metformin in the latter timepoints, though it initially caused a transient increase in glucose. Based on these differential effects, the authors concluded that Serpentina leaf extract is a viable alternative antihyperglycemic but recommend repetition and expansion of the study due to the lack of uniformity in responses and small sample size.

Wediasari *et al*. (2020) examined the hypoglycemic and metabolic effects of combined extracts of *Andrographis paniculata* and *Caesalpinia sappan* in streptozotocin-induced diabetic rats. The aim was to determine whether co-administration provided greater antidiabetic benefits compared to each extract alone. Rats received high-fat diets with repeated low-dose streptozotocin induction before seven-day treatment with single or combined extracts (100/200 mg/kg), with metformin as a reference control. The results revealed that the combined extract produced a moderate, but not superior, reduction in blood glucose compared to the single extracts; *C. sappan* alone significantly increased beta-cell number, while both single and combined treatments modified lipid profiles and adipocyte histology. The authors recommended further research into optimizing and fractionating the extract combinations, as their findings suggest that co-administration may not always yield additive effects.

Macadangdang Jr *et al*., (2021) performed a systematic review examining the biochemical impact of *Andrographis paniculata* extract on blood sugar levels in alloxan-induced albino Wistar rats. Their approach involved critical appraisal and inclusion of experimental studies published between 2000 and 2020 using relevant keywords and criteria such as alloxan induction and evaluation of blood glucose and body weight. All selected studies indicated that the extract significantly decreased blood glucose, with comparable efficacy to oral hypoglycemic drugs, and the effect was attributed chiefly to andrographolide. The authors recommend further exploration of the extract's utility in diabetes management, noting its affordability and low side-effect profile.

In their systematic review, Picones *et al*., (2021) aimed to synthesize evidence regarding the hypoglycemic effect of *Andrographis paniculata* (Serpentina) extract in alloxan- and STZ-induced diabetic rats. The methodology involved rigorous database searching and inclusion of ten eligible studies published between 2000–2020, all deploying randomized block designs using rats or rabbits. The reviewed studies universally confirmed significant reductions in blood glucose provided by Serpentina, with the effects arising from its active compound andrographolide. The review highlighted that the hypoglycemic effect was comparable with standard drugs, with minimal side effects reported. They concluded that *Andrographis paniculata* extract provides a potent, traditional, and affordable alternative for diabetes control and recommended additional comparative studies across different populations and induction agents.

Chandak *et al*., (2022) evaluated the antidiabetic activity of dried juice from the leaves of *Andrographis paniculata* in alloxan-induced diabetic rats, with the objective of scientifically validating its traditional use for diabetes. The researchers administered single oral doses (50, 100, or 200 mg/kg) to diabetic rats and compared the blood glucose response over five hours to that of a single dose of metformin. All doses produced significant and dose-dependent reductions in blood glucose, with the highest (200 mg/kg) achieving a 52.6% reduction after five hours, approaching the 61.6% seen with metformin. The authors concluded that *Andrographis paniculata* leaf juice is an effective hypoglycemic agent in acute studies and advocated further research to clarify the responsible active constituents and mechanisms of action.

Hidayat and Wulandari (2022) explored the effect of *Andrographis paniculata* extract on blood sugar regulation via intestinal alpha-glucosidase inhibition in alloxan-induced diabetic rats. In this experimental study, thirty rats were separated into five groups, receiving either no treatment, acarbose, or increasing doses of extract, all for seven days. Blood sugar levels and alpha-glucosidase activity were measured. Their results demonstrated that *Andrographis paniculata* extract reduced both blood glucose and intestinal alpha-glucosidase activity in a dose-dependent fashion, with high-dose extract matching or surpassing acarbose's effect. This antihyperglycemic effect was attributed to the extract's flavonoid content. The study recommended *Andrographis paniculata* as a promising natural alternative or adjunct to clinical alpha-glucosidase inhibitors in diabetes therapy.

Hazra *et al*. (2023) investigated the comparative antidiabetic efficacy of a combined herbal formulation (*Andrographis paniculata*, *Tribulus terrestris*, *Lagerstroemia speciosa*) versus glimepiride in alloxan-induced type 1 diabetic mice. The study randomly assigned mice to treatment and control groups, administering the herbal formulation (200 mg/kg), aqueous L. speciosa, or glimepiride for eight weeks. Outcomes included body weight, blood glucose, lipid profile, plasma creatinine, and histopathology of pancreas and kidney. Results showed that the herbal combination led to improved body weight, significantly reduced plasma glucose, and favorable changes in cholesterol, triglycerides, and creatinine, comparable to glimepiride. Histological analysis revealed partial pancreatic islet cell and renal tubular recovery. The study recommends further mechanistic studies to explore the synergy within the herbal combination and its translation to clinical use.

Permata *et al*. (2023) investigated the effects of ethanol extract of sorghum (*Sorghum bicolor* L.) in preventing hyperglycemia, inflammation, and oxidative stress in male Wistar rats with nicotinamide-streptozotocin-induced diabetes. The experimental design involved control, hyperglycemic, and two sorghum extract groups (600 and 800 mg/kg). Measured outcomes included blood glucose, interleukin-6 (IL-6), and malondialdehyde (MDA). Findings showed that the higher-dose (800 mg/kg) sorghum group had significantly lower glucose, IL-6, and MDA levels; both doses reduced oxidative and inflammatory markers versus hyperglycemic controls. The authors conclude that sorghum extract may help mitigate diabetic pathology by reducing glycemia, inflammation, and oxidative stress, advocating its dietary application in diabetes prevention strategies.

Eziefule *et al*. (2024) conducted a systematic review to analyze preclinical in vivo studies assessing the effects of *Andrographis paniculata* and its major compounds on cardiovascular diseases (CVDs). The review identified 16 eligible animal studies from 2013–2023, compiling evidence that A. paniculata and its compounds (especially andrographolide and related diterpenes) exhibit significant anti-inflammatory, antioxidant, antihypertensive, anti-apoptotic, anti-dyslipidemic, and cardioprotective effects in animal models of myocardial infarction, coronary artery disease, cardiac hypertrophy, aortic valve calcification, diabetes, and obesity. Notably, treatment improved various molecular and physiological markers of CVD, though the review highlights methodological limitations (bias risk) and a need for more animal and especially clinical trials. The authors recommend further research to determine effective doses, optimize bioavailability, and confirm human efficacy and safety.

Jeong *et al*. (2024) studied the antihypertensive effects of a combined ethanol extract of sorghum (*Sorghum bicolor*), adzuki bean (*Vigna angularis*), and finger millet (*Eleusine coracana*) in spontaneously hypertensive rats. The experiment divided rats into four groups (WKY control, hypertensive control, SAFE extract, captopril), administered the extract (500 mg/kg) or drug over six weeks, and compared blood pressure, body composition, liver function, cardiac mass, and histology. SAFE significantly lowered both systolic and diastolic blood pressures, matching the pharmaceutical comparator captopril. Treated rats showed reduced cardiac hypertrophy and fibrosis, with no hepatotoxicity observed. The authors conclude that the combined extract is effective and safe for hypertension control and could serve as a dietary supplement to prevent cardiovascular complications, recommending further mechanistic and human studies.

Saka *et al*. (2024) performed an experimental study to clarify how *Andrographis paniculata* improves glucose regulation in apparently healthy Wistar rats. In a 35-day intervention, rats were split into control and treatment groups (500 mg/kg/day A. paniculata). The study measured fasting blood glucose, insulin, insulin sensitivity indices (HOMA, QUICKI, TyG), glycated hemoglobin, serum lipids, glycolytic enzyme activity, GLUT4 expression, and redox state. Treatment with *A. paniculata* significantly improved insulin sensitivity, reduced blood glucose and HbA1c, enhanced activities of glycolytic enzymes, upregulated GLUT4 in muscle, and improved hepatic/muscular redox balance and inflammatory markers, without adversely affecting body weight. The findings indicate that A. *paniculata* promotes glucose metabolism and may prevent diabetes but warrant caution to avoid hypoglycemia in non-diabetic individuals and encourage clinical studies.

Suvarna *et al*. (2024) conducted a review to determine the antidiabetic potential of sorghum (*Sorghum bicolor* L. Moench) by examining its phytochemistry, nutritional value, mechanisms, and clinical evidence. Summarizing multiple preclinical and clinical studies, the authors describe that sorghum is high in dietary fiber, phenolic compounds, tannins, and resistant starch, nutrients linked to reduced glycemic response and improved insulin sensitivity. Mechanistic evidence indicates that sorghum's phenolic extracts inhibit hepatic gluconeogenesis and promote peroxisome proliferator-activated receptor gamma (PPARγ), contributing to lower blood glucose and enhanced lipid metabolism. Experimental data showed sorghum extracts lower blood glucose in animal models and exert effects comparable to standard drugs such as glibenclamide and acarbose. The review concludes that incorporating sorghum into diets as a staple or functional food is a holistic strategy for type 2 diabetes prevention and urges further human studies with tannin-rich genotypes.

Chen *et al*. (2025) conducted a narrative review to investigate the anti-diabetic and antioxidant properties of compounds from *Physalis angulata* (ciplukan) and *Andrographis paniculata*. Their aim was to synthesize published in vivo and in vitro evidence supporting the use of these plants for diabetes management. The review summarized data from animal studies showing that alkaloid- and ethanolic-extracts of A. paniculata led to dose-dependent improvements in blood glucose regulation, antioxidant status, and pancreatic tissue biomarkers in diabetic rats. Andrographolide and related diterpenoids were highlighted as key active components for glycemic improvement, with notable inhibition of α-glucosidase and moderate inhibition of α-amylase. Comparable findings were reported for Physalis fruit/leaf/seed extracts. They concluded that both plants, particularly their ethanol and aqueous extracts, are rich in natural antioxidants and show anti-diabetic effects without toxicity, but stress the need for clinical trials to confirm efficacy and safety in humans.

CHAPTER THREE

METHODOLOGY

3.1 Research Design

This study is a prospective cross-sectional experimental-based study where participants are observed over a short period after introducing a controlled intervention, with the aim of evaluating its effects.

3.2 Research Location

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

3.3 Study Population

The study population included participants aged 25 years and above, who are normotensive and have normal blood glucose and intraocular pressure levels selected within the University of Benin.

3.4 Sampling Technique and Sample Size

This study utilized 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

$n = (1.96 + 0.84)^2 \text{ x } 2 \text{ x } (18.6)^2 \div 6^2$

$n = (1.96 + 0.84)^2 \text{ x } 2\ (18.6)^2 \div 36$

$n = 7.84 \text{ x } 2 \text{ x } 345.96 \div 36$

$n = 150.68 \approx 151$

The calculated minimum required sample size was approximately 151 participants.

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

Adjusted Sample Size = 151 ÷ (1 - 0.20)

Adjusted Sample Size = 189

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

3.5 Research Materials

The following materials and instruments were used for data collection:

1. *Sorghum bicolor* leaf extracts
2. *Andrographis paniculata* leaf extracts
3. I-care Tonometer
4. Accu-check automated sphygmomanometer
5. Measuring beaker (250ml)
6. Sterile dry plastic containers
7. Stopwatch.
8. Consent forms
9. Accu touch glucometer
10. Glucometer strips
11. Alcohol swab
12. Sterile strip

3.6.1 Inclusion criteria

1. Adults aged 25–60 years
2. Have normal IOP; generally, 10-21mmHg.
3. No current antihypertensive, antidiabetic, or ocular medications.
4. Individuals available for all three intervention phases, including washout periods.
5. Individuals who provided written informed consent.

3.6.2 Exclusion Criteria

1. Subjects younger than 25 years

2. Subjects who have been diagnosed with hypertension, diabetes mellitus or glaucoma under active treatment.
3. Pregnant or lactating women.

4. Subjects who are unwilling to comply to informed consent.

5. Subjects with allergy to *Andrographis paniculata* or *Sorghum bicolor.*

6. Subject in participation in another study within 30 days.

7. Individuals who have eaten a meal within 2 hours prior to the study will be excluded to minimize variability in blood glucose measurements.

3.7 PROCEDURE

3.7.1 Preparation of *Sorghum bicolor* and *Andrographis paniculata* leaf extract

Dried Leaf samples were identified by the Plant Biology and Biotechnology Department of the University of Benin. 200g of these samples underwent hot aqueous extraction for ten minutes. 250ml of solution was then measured into plastic containers and ready for administration.

3.7.2 Informed consent was obtained from interested participants

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 were obtained from each participant using a standardized consent form.

3.7.3 Screening and Recruitment

The potential participants were screened for Intraocular pressure, blood pressure, and fasting blood glucose to confirm adequacy of eligibility based on the inclusion and exclusion criteria.

3.7.4 Time frame

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

Day 1 (*Sorghum bicolor* administration)

Baseline measurement of blood pressure, blood glucose and intraocular pressure were taken. 250ml of *Sorghum bicolor* 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 (*Andrographis paniculata* administration)

Baseline measurements of the parameters were taken. 250ml of *Andrographis paniculata* was administered orally and measurement was repeated four hours later to assess its singular effect.

Day 3 (Combined administration of *Sorghum bicolor* and *Andrographis paniculata*)

On the final day, participants were once again measured for baseline parameters of intraocular pressure, blood pressure, and blood glucose. Following this, a combined preparation containing both *Sorghum bicolor* and *Andrographis paniculata* was administered orally. Measurements were 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.

3.8 DATA ANALYSIS

Data was presented in tables and figures; analyzed using the Statistical Package for Social Sciences (SPSS version 22). T-test was used to compare the variables. Descriptive statistics such as mean, standard deviation, frequency, and percentages was used to summarize demographic characteristics and IOP measurements at baseline and following administration of therapy.

Inferential statistical tests were applied to determine whether there is a significant difference in the effects of *S. bicolor* and *A. paniculata* on IOP, blood pressure and blood glucose levels over time. Since each participant received both treatments, 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 presented in the form of tables and graphs for clarity and ease of interpretation.

3.9 ETHICAL CONSIDERATION

This study was conducted in strict adherence to ethical guidelines governing human research. Ethical clearance was obtained from the Research and Ethics Committee of the Department of Optometry, University of Benin, prior to the recruitment of participants. Continuous monitoring was maintained to ensure compliance with ethical requirements, and any adverse events or protocol deviations was promptly reported to the Ethics Committee.

CHAPTER FOUR

RESULTS AND DATA ANALYSIS

One hundred and seventy-four (174) patients were administered *Sorghum bicolor* and *Andrographis paniculata* singularly and as mixed extracts. The mean age of the patients was 34.3±7.1 years.

Using *Sorghum bicolor*, at baseline, the mean systolic value was 126.15±15.9, after 4 hours of applying the extract, the mean systolic value was 120.8±15.0. The diastolic value at baseline was 85.6±11.1, after 4 hours of applying the extract, it became 80.03±10.4. The baseline mean IOP for the right eye was 16.88±2.5, after 4 hours post-application of the extract, it reduced to 15.83±1.6. The baseline IOP for the left eye was 17.14±1.93, after 4 hours post-application, it reduced to 16.12±1.8. At baseline, the mean blood glucose was 82.86±14.61, after 4 hours post-application, it reduced to 70.39±11.99. *Sorghum bicolor* extract was effective on all the parameters (BP, IOP and BG) ($p<0.05$) (Table 4.1).

Table 4.1. Effect of *Sorghum bicolor* on BP, IOP and BG

	BP		**IOP**		**BG**
Time interval/parameter	**Systolic**	**Diastolic**	**RE**	**LE**	
Baseline	126.15±15.9	85.6±11.1	16.88±2.5	17.14±1.93	82.86±14.61
4 hours	120.8±15.0.	80.0±10.4	15.83±1.6	16.12±1.8	70.39±11.99
t-value	6.840	10.013	10.347	7.412	10.986

p-value	0.000*	0.000*	0.000*	0.000*	0.000*

* significant difference

Table 4.1 indicates the effectiveness of *Sorghum bicolor* on Blood pressure, although not statistically significant, but statistically significant on intraocular pressure and blood glucose level.

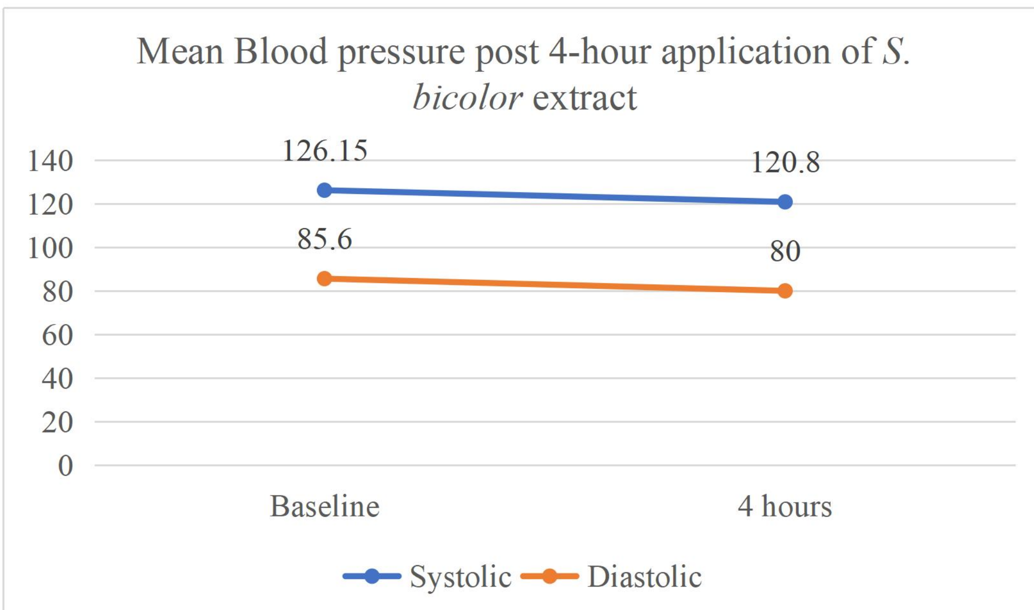

Fig. 4.1. Mean Blood pressure 4-hour post application of Sorghum bicolor extract

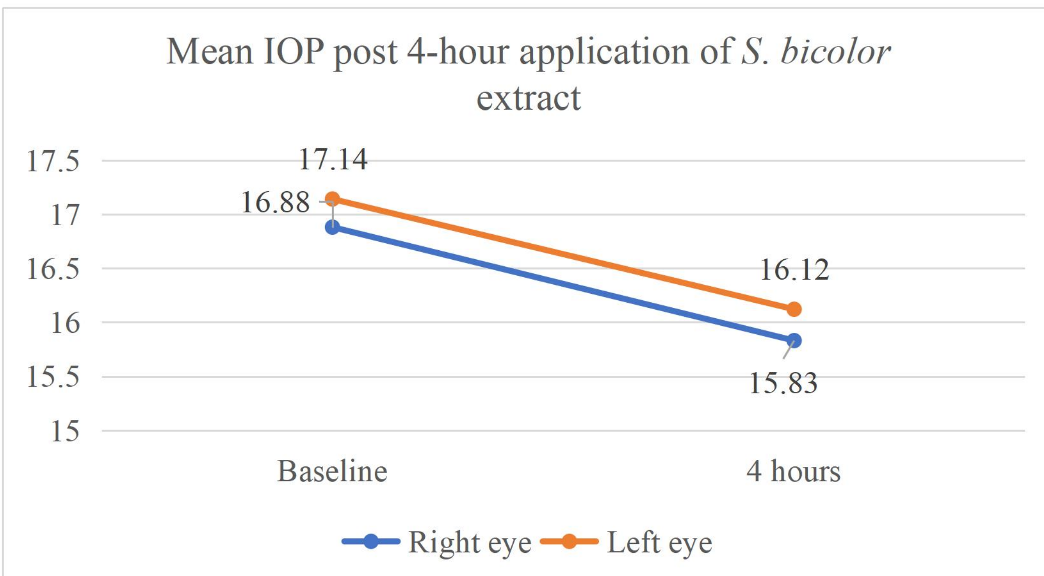

Fig. 4.2. Mean IOP 4-hour post application of *Sorghum bicolor* extract

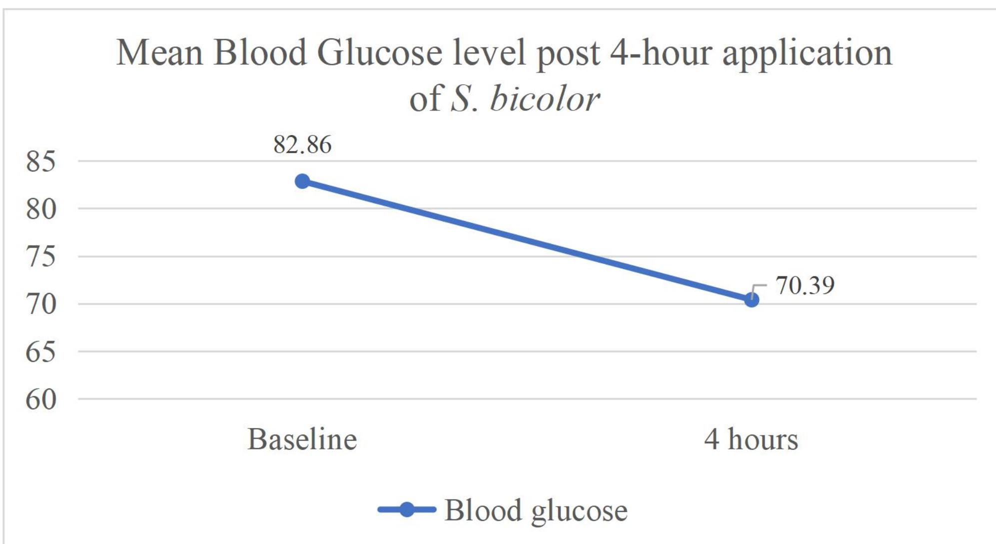

Fig. 4.3. Mean Blood glucose level 4-hour post application of *Sorghum bicolor* extract

Using *Andrographis paniculata*, at baseline, the mean systolic value was 129.44±14.7, after 4 hours of applying the extract, the mean systolic value became 121.2±16.9. The diastolic value at baseline was 84.6±13.3, after 4 hours of applying the extract, it became 77.13±11.4. The baseline mean IOP for the right eye was 15.76±2.5, after 4 hours post-application of the extract, it reduced to 14.49±2.0. The baseline IOP for the left eye was 16.64±2.5, after 4 hours post-application, it reduced to 15.98±2.0. At baseline, the mean blood glucose was 83.61±13.2, after 4 hours post-application, it reduced to 75.26±11.43. *Andrographis paniculata* extract was effective on all the parameters (BO, IOP and BG) ($p<0.05$) (Table 4.2).

Table 4.2. Effect of *Andrographis paniculata* on BP, IOP and BG

	BP		IOP		BG
Time interval/parameter	**Systolic**	**Diastolic**	**RE**	**LE**	
Baseline	129.44±14.7	84.6±13.3	15.76±2.5	16.64±2.5	83.61±13.2
4 hours	121.2±16.9	77.13±11.4	14.49±2.0	15.98±2.0	75.26±11.43
t-value	15.036	10.566	8.445	3.603	16.690
p-value	0.000*	0.000*	0.000*	0.000*	0.000*

* significant difference

Table 4.2 indicates the effectiveness of *Andrographis paniculata* on blood pressure, intraocular pressure and blood glucose level, which were all statistically significant ($p<0.05$).

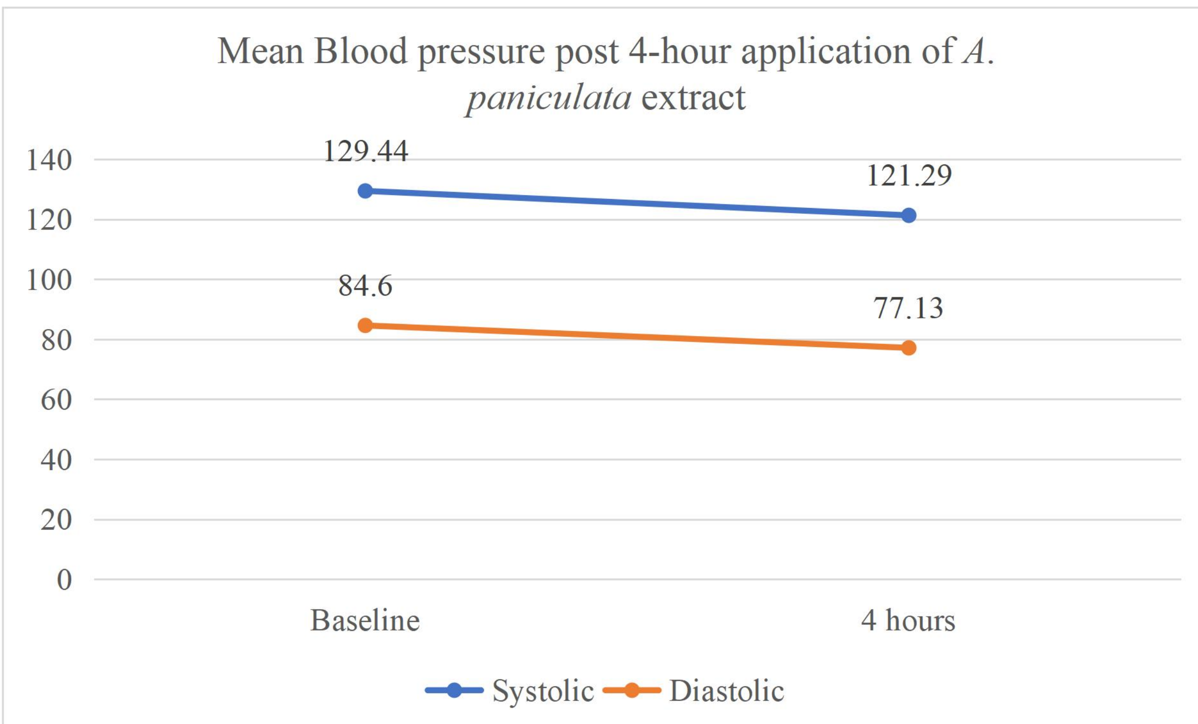

Fig. 4.4. Mean Blood pressure level 4-hour post application of *A. paniculata* extract

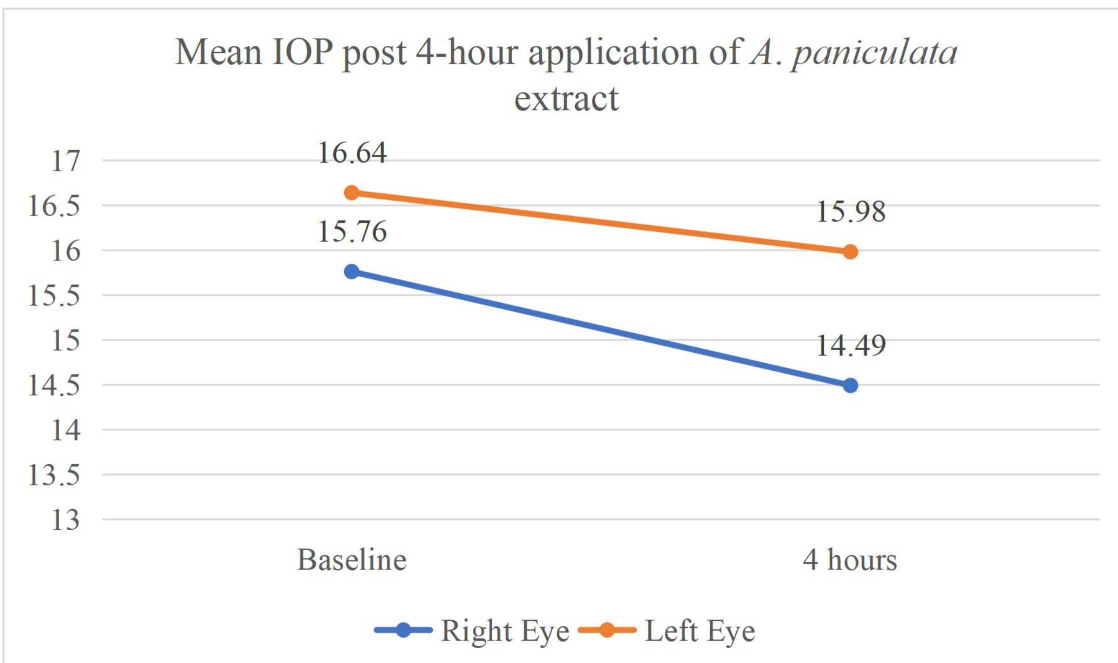

Fig. 4.5. Mean IOP 4-hour post application of *A. paniculata* extract

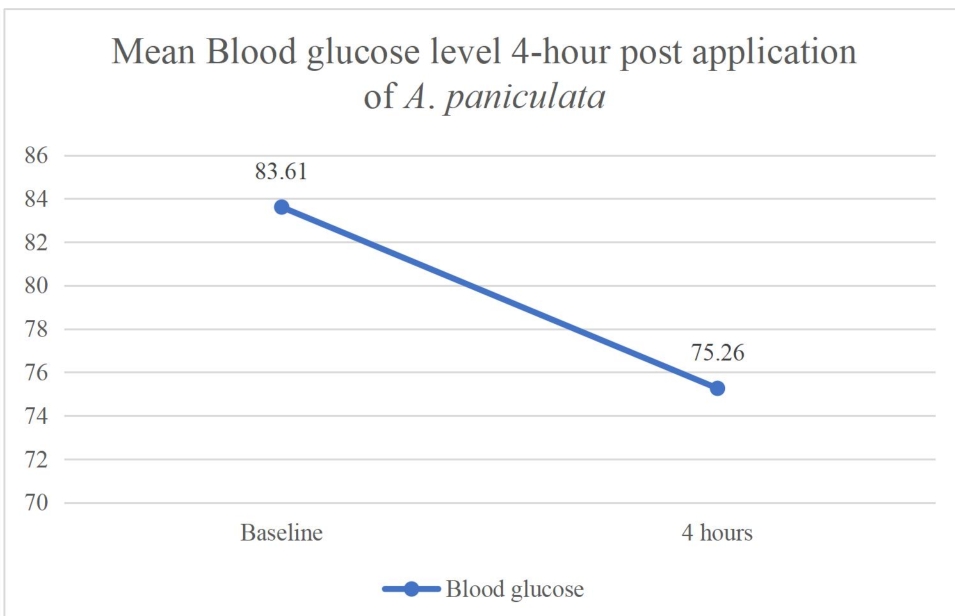

Fig. 4.6. Mean Blood glucose level 4-hour post application of *A. paniculata* extract

Using a mixture of *Sorghum bicolor* and *Andrographis paniculata*, at baseline, the mean systolic value was 134.63±15.7, after 4 hours of applying the extract, the mean systolic value became 128.68±15.9. The diastolic value at baseline was 87.1±22.1, after 4 hours of applying the extract, it became 77.9±12.2. The baseline mean IOP for the right eye was 15.94±1.8, after 4 hours post-application of the extract, it reduced to 14.94±2.0. The baseline IOP for the left eye was 15.67±1.5, after 4 hours post-application, it reduced to 15.13±2.7. At baseline, the mean blood glucose was 80.42±12.04, after 4 hours post-application, it reduced to 74.40±10.2. The mixed extract was effective on all parameters (BP, IOP and BG) ($p<0.05$) (Table 4.3).

Table 4.3 **Effect of mixed extracts of *Sorghum bicolor* and *Andrographis paniculata* on BP, IOP and BG**

	BP		**IOP**		**BG**
Time interval/parameter	**Systolic**	**Diastolic**	**RE**	**LE**	
Baseline	134.63±15.7	87.1±22.1	15.94±1.8	15.67±1.5	80.42±12.04
4 hours	128.68±15.9	77.9±12.2	14.94±2.0	15.13±2.7	74.40±10.2
t-value	13.397	5.921	8.037	3.078	17.189
p-value	0.000*	0.000*	0.000*	0.002*	0.000*

* significant difference

Table 4.3 indicates the effectiveness of the mixture of *Sorghum bicolor* and *Andrographis paniculata* extracts on blood pressure, intraocular pressure and blood glucose level, which were all statistically significant (p<).05).

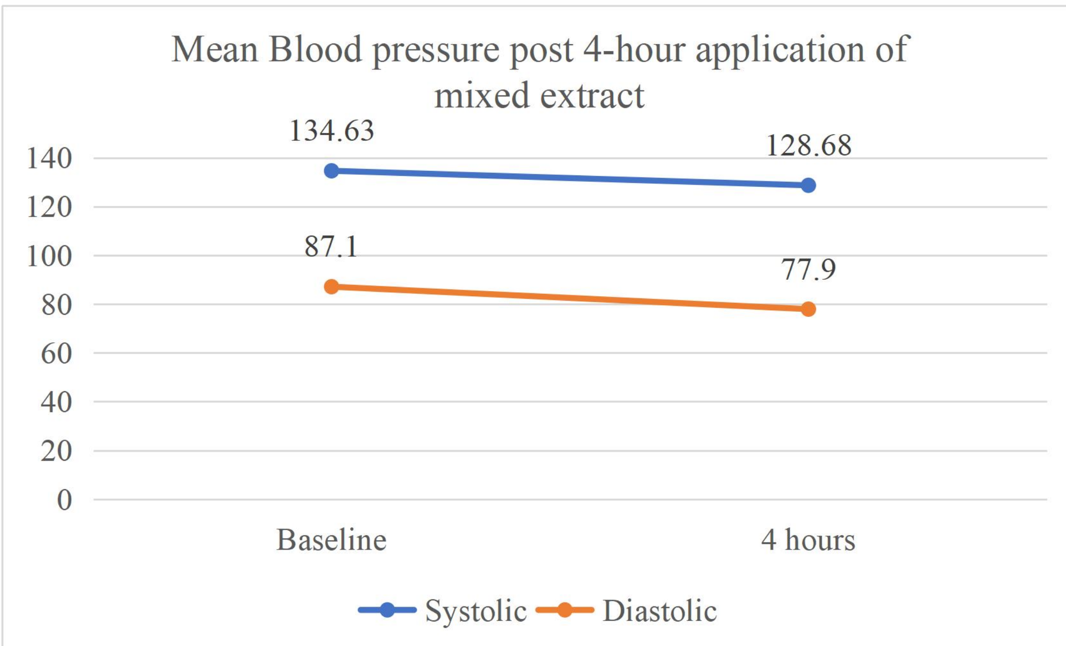

Fig. 4.7. Mean Blood Pressure 4-hour post application of mixed extracts

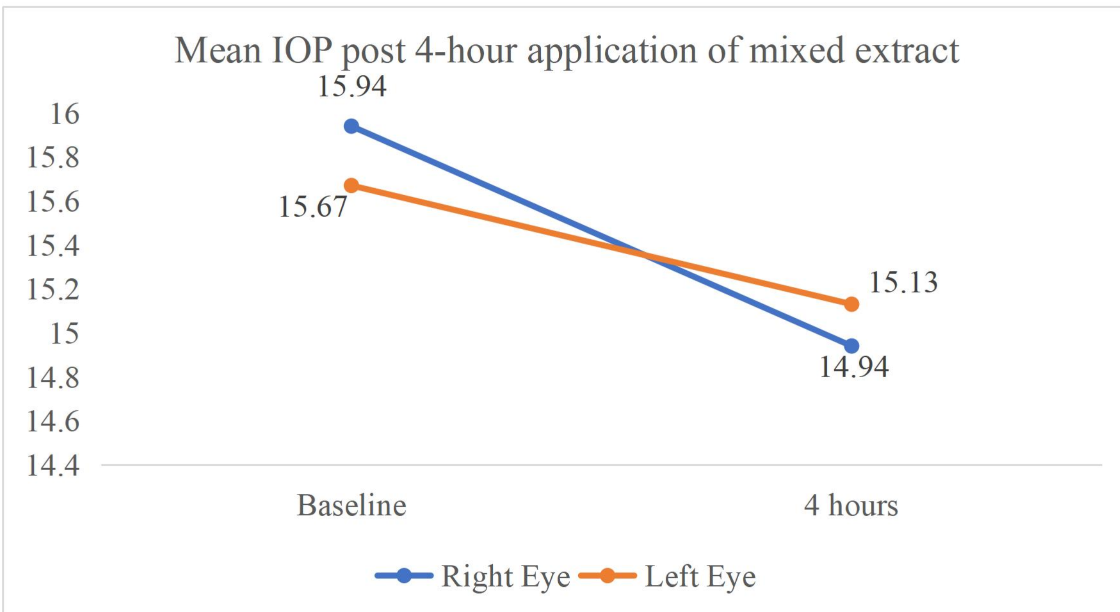

Fig. 4.8. Mean IOP 4-hour post application of mixed extracts

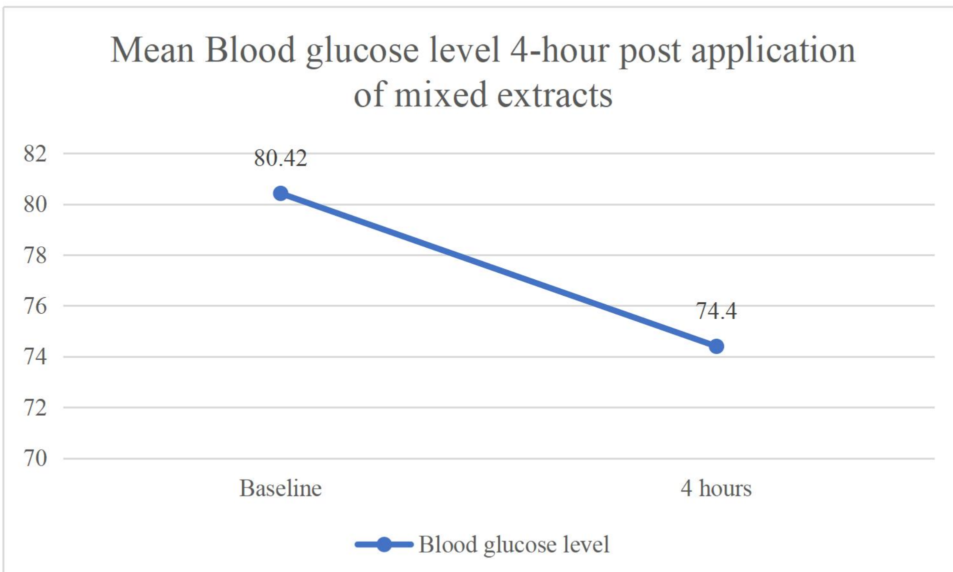

Fig. 4.9. Mean Blood glucose level 4-hour post application of mixed extracts

CHAPTER FIVE

CASE DISCUSSION

This study examined the effects of leaf extracts from *Sorghum bicolor* and *Andrographis paniculata*, both singularly and in combination, on intraocular pressure (IOP), blood pressure (BP), and blood glucose (BG) in 174 human subjects. After four hours of extract administration, each parameter exhibited statistically significant decrease ($p < 0.05$), indicating possible therapeutic and preventive value for metabolic and ocular health.

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

The mean systolic blood pressure dropped from 126.15 ± 15.9 mmHg to 120.8 ± 15.0 mmHg and the mean diastolic blood pressure dropped from 85.6 ± 11.1 mmHg to 80.0 ± 10.4 mmHg when the *Sorghum bicolor* extract was administered. This decrease is consistent with research by Jeong *et al.,* (2024), who found that *Sorghum bicolor* had notable antihypertensive effects in hypertensive rat models that were on par with captopril. The hypotensive tendency in this study is further supported by the vasodilatory and smooth muscle relaxation characteristics noted by Nwinyi and Kwanashie (2013), which are probably caused by polyphenolic antioxidant mechanisms that enhance endothelial function and nitric oxide availability.

Blood glucose levels significantly decreased from 82.86 ± 14.61 mg/dL to 70.39 ± 11.99 mg/dL, which is in line with research by Permata *et al.,* (2023) and Suvarna *et al.,* (2024), which emphasized sorghum's hypoglycemic activity and rich phenolic content, which modulates hepatic glucose output and improves insulin sensitivity.

Sorghum bicolor may have ocular hypotensive effects, as evidenced by the decrease in mean IOP (right eye: 16.88 ± 2.5 to 15.83 ± 1.6 mmHg; left eye: 17.14 ± 1.93 to 16.12 ± 1.8 mmHg). The reported result may be attributed to enhanced ocular perfusion and antioxidative actions that decrease the formation of aqueous humor or improve trabecular outflow, even though no direct prior investigation assessed its impact on IOP.

These findings support the clinical application of Sorghum in managing diabetes, reducing glaucoma risk, and addressing hypertension, highlighting its rich content of polyphenols, antioxidants, and flavonoids that work together to regulate glucose metabolism and decrease vascular resistance.

Research backs the idea that the polyphenols and anthocyanins in *Sorghum bicolor* enhance insulin sensitivity, promote vascular relaxation, and improve microcirculation. These mechanisms align with the conclusions drawn in the thesis (Rosen and Spiegelman, 2011; Augustine *et al.,* 2014).

5.2 Effect of *Andrographis paniculata* on Blood Pressure, Blood Sugar and Intraocular Pressure levels

Administration of *Andrographis paniculata* extract resulted in a significant reduction in systolic BP (129.44 ± 14.7 mmHg to 121.2 ± 16.9 mmHg) and diastolic BP (84.6 ± 13.3 mmHg to 77.13 ± 11.4 mmHg). These findings correspond with Trilestari *et al.,* (2015), who demonstrated comparable antihypertensive efficacy of ethanolic *A. paniculata* extract to nifedipine in animal models. The mechanism may involve inhibition of calcium channels or modulation of renin-angiotensin pathways, as supported by Eziefule *et al.,* (2024), who reviewed its vascular protective potential in cardiovascular disease models.

The extract also produced a significant hypoglycemic effect, reducing mean blood glucose from 83.61 ± 13.2 mg/dL to 75.26 ± 11.43 mg/dL. This supports the work of Hossain et al. (2007), Akter *et al.,* (2013), and Ischak and Botutihe (2020), who found that aqueous and ethanolic *A. paniculata* extracts lowered glucose levels in both animal and human models through mechanisms such as α-glucosidase inhibition and enhanced GLUT-4 expression (Saka *et al.,* 2024). The rapid response observed within 4 hours of administration in this study highlights the extract's potent bioactivity and supports its traditional use in glycemic control.

The significant reduction in IOP (right eye: 15.76 ± 2.5 to 14.49 ± 2.0 mmHg; left eye: 16.64 ± 2.5 to 15.98 ± 2.0 mmHg) suggests a novel ocular hypotensive potential. Although literature directly linking *A. paniculata* to IOP modulation is limited, the plant's antioxidant and anti-inflammatory effects (Akilandeswari *et al.,* 2019) may improve ocular vascular resistance and trabecular meshwork function, indirectly reducing IOP.

5.3 Effect of combined *Sorghum bicolor* and *Andrographis paniculata* on Blood Pressure, Blood Glucose and Intraocular Pressure levels

The combination of both extracts resulted in synergistic reductions across all parameters—systolic BP (134.63 ± 15.7 to 128.68 ± 15.9 mmHg), diastolic BP (87.1 ± 22.1 to 77.9 ± 12.2 mmHg), blood glucose (80.42 ± 12.04 to 74.40 ± 10.2 mg/dL), and IOP (right eye: 15.94 ± 1.8 to 14.94 ± 2.0 mmHg; left eye: 15.67 ± 1.5 to 15.13 ± 2.7 mmHg). These findings suggest additive or synergistic pharmacodynamic interactions. This aligns with previous animal studies (Nugroho et al., 2013; Widharna *et al.,* 2015), where combining *A. paniculata* with other herbal extracts (e.g., *Centella asiatica and Syzygium polyanthum*) enhanced antihyperglycemic activity. The presence of phenolic compounds, andrographolide, and flavonoids may collectively improve vascular and metabolic function.

5.4 Comparative summary on singular and combined effect

The extracts synergistically combined to provide beneficial effects, particularly for blood pressure and organ protection, but on occasion, the individual extracts were more successful at regulating blood glucose, demonstrating the complex interaction between plant phytochemicals (Wediasari *et al.,* 2020).

Both this study and external scientific evidence support the use of *Sorghum bicolor* and *Andrographis paniculata* as safe and effective treatments for high blood pressure, intraocular pressure, and blood glucose levels, all of which are caused by their high phenolic, flavonoid, and terpene content. These botanicals are valuable additions to functional foods, nutraceuticals, and integrated medical regimens due to their quick start and wide range of effects, especially in resource-constrained environments and as supplements to or replacements for traditional pharmaceutical treatment. The goal of future research should be to determine the best dosage, the long-term consequences, and the ideal methods for mixing extracts in order to maximize their advantages.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The results demonstrate that extracts from *Sorghum bicolor* and *Andrographis paniculata* are safe, efficient, and generally well-accepted options for reducing blood pressure, blood sugar levels, and eye pressure in adults. Both the standalone and combined extracts act quickly, which makes them appealing options for additional treatment of high blood pressure, diabetes, and glaucoma, as well as overall metabolic syndrome. Evidence of how they work indicates that their advantages come from better insulin sensitivity, reduced inflammation, antioxidant effects, and relaxation of blood vessels. Although the combination shows some added benefits, in certain instances, the individual extracts might provide better blood sugar reduction.

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. Some participants ate or drank possibly altering blood glucose results.

2. A few participants dropped out after the second day due to the bitter taste *of Andrographis paniculate extract* or discomfort from lancet use during blood sampling.
3. Some participants did 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 limits 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 *Andrographis paniculata* extracts.

6.3 General Recommendations

1. Extended studies with larger, more diverse patient populations and longer intervention periods are needed to assess chronic and dose-dependent effects, as well as long-term safety.

2. The standardization of extract preparation and dosage is essential for clinical reproducibility and efficacy.

3. Mechanistic research should further clarify pathways of action, including molecular and genetic targets.

4. Combination therapies should be further developed with optimal dosing ratios to maximize synergy and minimize antagonism.

5. Integration of validated medicinal herbs such as *Sorghum bicolor* and *Andrographis paniculata* into public health strategies and functional food development should be pursued, leveraging their affordability and cultural acceptance.

6. Community education on the use and benefits of these botanicals, alongside regular metabolic health screening, can enhance adoption and manage disease risk in resource-limited settings.

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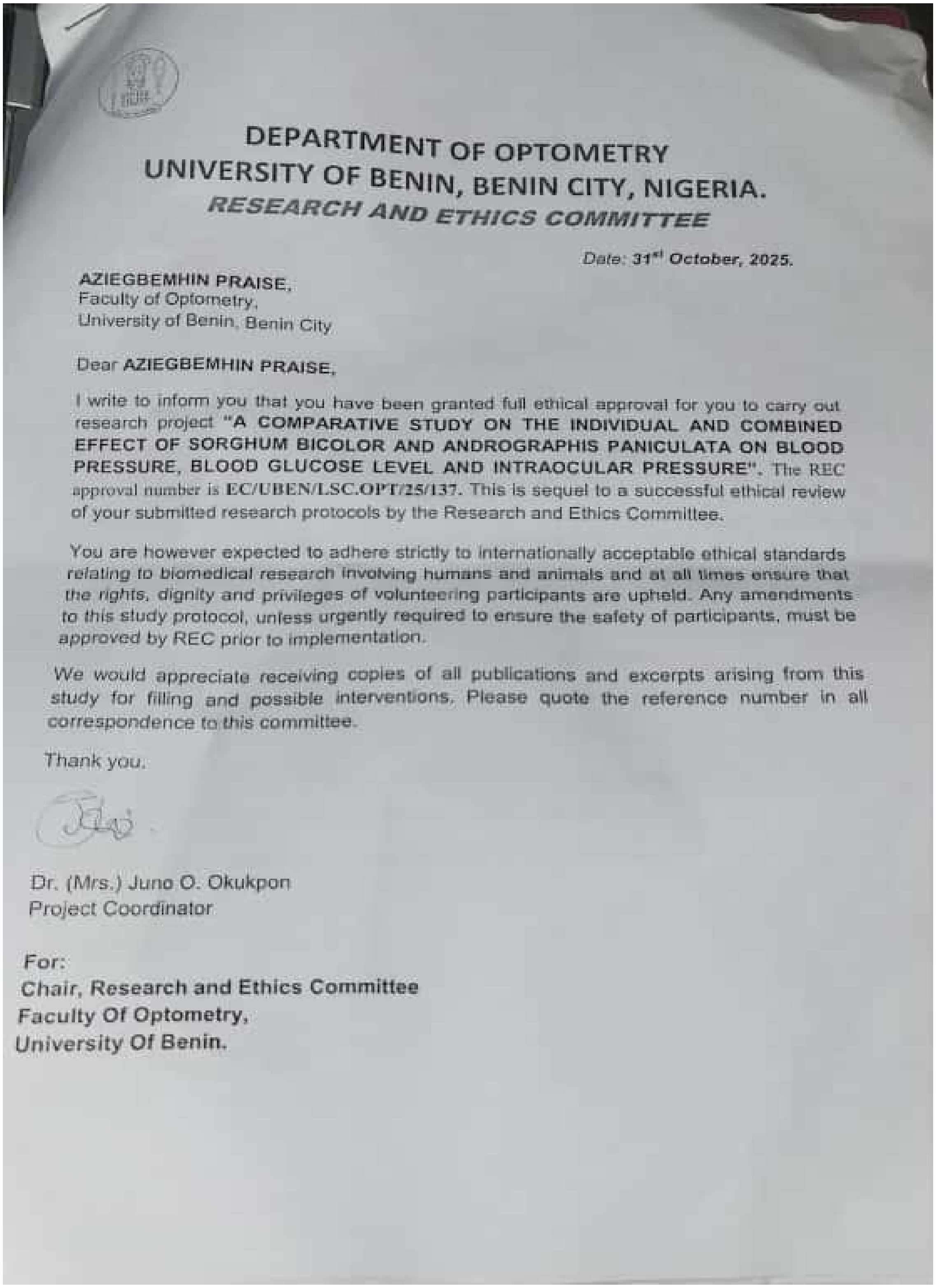
APPENDIX ONE

Fig 4.10 Ethical Approval letter.



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

Date: **31st October, 2025.**

AZIEGBEMHIN PRAISE,
Faculty of Optometry,
University of Benin, Benin City

Dear **AZIEGBEMHIN PRAISE,**

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 ANDROGRAPHIS PANICULATA ON BLOOD PRESSURE, BLOOD GLUCOSE LEVEL AND INTRAOCULAR PRESSURE".** The REC approval number is **EC/UBEN/LSC.OPT/25/137.** 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 *ANDROGRAPHIS PANICULATA* 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 *Andrographis paniculata* on Blood Pressure, Blood Glucose Level and Intraocular Pressure.

Principal investigator (PI):	**Investigator:**
PROF. CANICE .C. ASONYE	AZIEGBEMHIN PRAISE
	LSC1910210

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

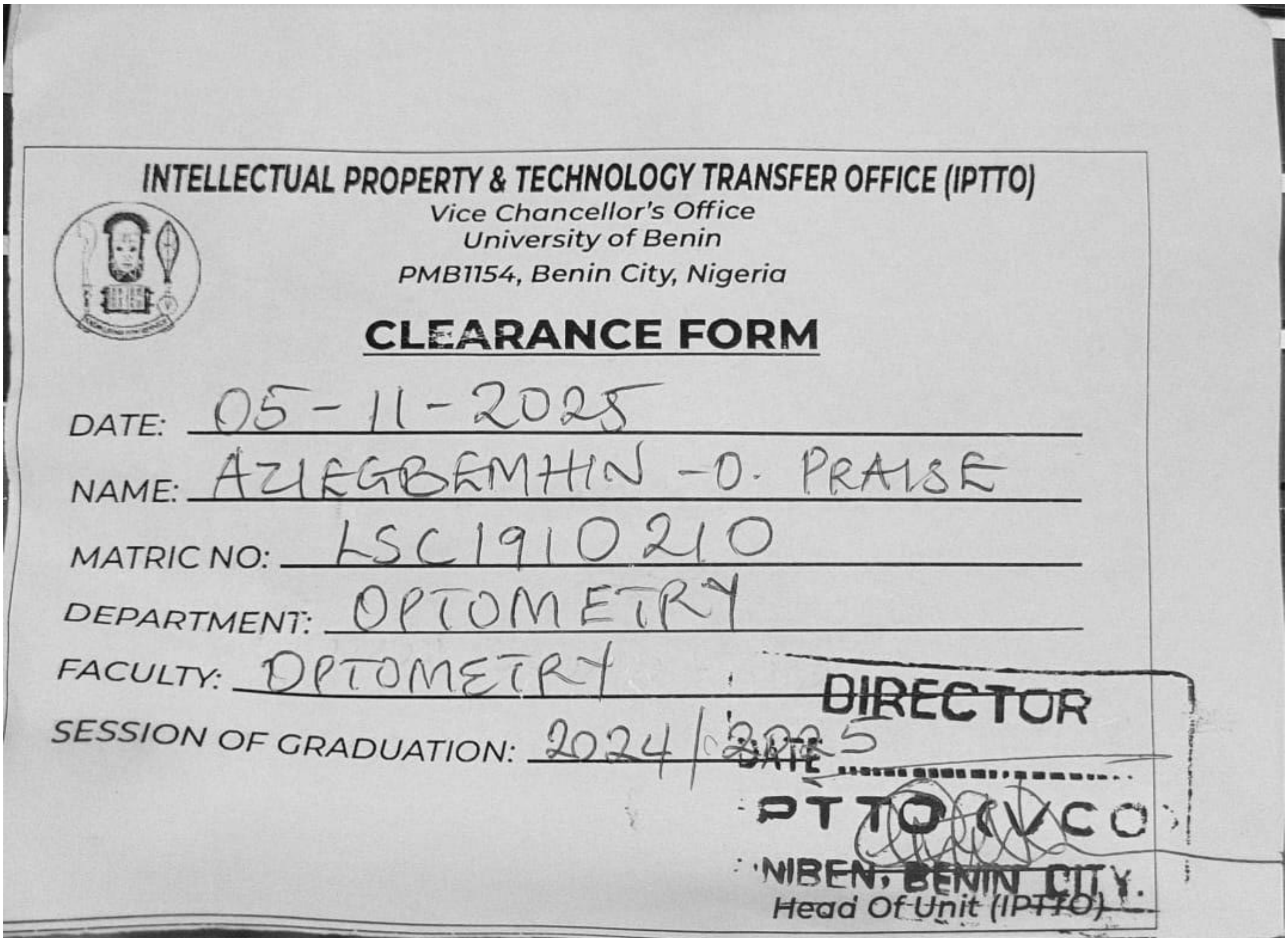
Thank you for your consideration. I look forward to your favorable response.

Yours faithfully,

AZIEGBEMHIN PRAISE
Investigator

APPENDIX TWO

Fig. 4.11 IPTTO Clearance form



INTELLECTUAL PROPERTY & TECHNOLOGY TRANSFER OFFICE (IPTTO)

Vice Chancellor's Office

University of Benin

PMB1154, Benin City, Nigeria

CLEARANCE FORM

DATE: 05-11-2025

NAME: AZIEGBEMHIN -O. PRAISE

MATRIC NO: LSC1910210

DEPARTMENT: OPTOMETRY

FACULTY: OPTOMETRY

SESSION OF GRADUATION: 2024/2025

DIRECTOR

DATE ....

PTTO (VCO)

NIBEN, BENIN CITY.

Head Of Unit (IPTTO)

APPENDIX THREE

Fig 4.12 200g of *Sorghum bicolor* dried leave

APPENDIX FOUR

Fig 4.13 *Andrographis paniculata* leave in powder form