

**DEVELOPMENT, HYDROGEN PEROXIDE ACTIVITY, TOTAL ANTIOXIDANT
CAPACITY AND NITRIC OXIDE ANALYSES OF BISCUITS MADE FROM
CARDABA BANANA, BEETROOT, TIGERNUTS AND JUSTICIA CARNEA
LEAVES AS A PORTABLE ANTI-HYPERTENSIVE SNACK.**

BY

AKWUEH ISRAEL CHUKWUKA

BMS2101378

**DEPARTMENT OF MEDICAL BIOCHEMISTRY
SCHOOL OF BASIC MEDICAL SCIENCES
COLLEGE OF MEDICAL SCIENCES
UNIVERSITY OF BENIN**

NOVEMBER, 2025

**DEVELOPMENT, HYDROGEN PEROXIDE ACTIVITY, TOTAL ANTIOXIDANT
CAPACITY AND NITRIC OXIDE ANALYSES OF BISCUITS MADE FROM
CARDABA BANANA, BEETROOT, TIGERNUTS AND JUSTICIA CARNEA
LEAVES AS A PORTABLE ANTI-HYPERTENSIVE SNACK.**

BY

AKWUEH ISRAEL CHUKWUKA

BMS2101378

**DEPARTMENT OF MEDICAL BIOCHEMISTRY
SCHOOL OF BASIC MEDICAL SCIENCES
COLLEGE OF MEDICAL SCIENCES
UNIVERSITY OF BENIN**

NOVEMBER, 2025

CERTIFICATION

This is to certify that **AKWUEH ISRAEL CHUKWUKA** with matriculation number – **BMS2101378**, performed this research at the department of Medical Biochemistry, School of Basic Medical Sciences, University of Benin and thereby approve in scope and quality, for the award of Bachelor of Science degree (B.Sc.) in Medical Biochemistry.

Prof. (Mrs.) H.A. Oboh

(Project Supervisor)

Date

Dr. N.B. Aguebor-Ogie
(A.g.Head of Department)

Date

External Examiner

Date

DEDICATION

Firstly, this research work is dedicated to God Almighty, for His unwavering faithfulness and mercy towards me. I also want to extend my heartfelt gratitude to my lovely parents- Mr. and Mrs. Akwueh for their unclenching support especially in the area of finance. God bless you all.

ACKNOWLEDGEMENT

With all sense of joy and gladness in my heart, I wish to express my profound gratitude to my wonderful project supervisor in the person of Professor (Mrs.) H.A. Oboh, for her selfless supervision and mentoring to ensure my research work came to fruition. Indeed, words will fail me to demonstrate how I deeply appreciate you ma. May the good lord richly bless you in Jesus name. Sincere thanks also go to Sir Precious Adu for his relentless efforts in making sure I complete this project work. I also want to acknowledge my various lecturers who have impacted me with knowledge namely: Dr. B.N. Aguebor-Ogie, Dr. Mrs. Eweka, Dr. Mrs. Eluehike, Dr. S. Oghagbon, Dr. Omorowa, Dr. Agbontaen, Dr. J.C. Anionye, Dr. Mrs. Eseosa-Oronsaye Oseghale, Mr. Aisosa, Mrs. Ukwonu-Ediale Ada.

Lastly, I express my sincere appreciation to all my project colleagues who took this same journey with me. You all have been a source of motivation and encouragement to me and I pray that may God bless you all, Amen.

TABLE OF CONTENT

TITLE PAGE.....	ii
CERTIFICATION.....	iii
DEDICATION.....	iv
ACKNOWLEDGEMENT.....	v
OUTLINE.....	vi
LIST OF FIGURES.....	ix
LIST OF TABLES.....	x
ABSTRACT.....	xi
CHAPTER ONE.....	i
1.0. INTRODUCTION.....	i
1.1. Background of the study.....	i
1.2. Aim of the study.....	ii
1.3. Objectives of the study.....	ii
1.4. Justification of study.....	iii
CHAPTER TWO.....	iv
2.0. LITERATURE REVIEW.....	iv
2.1. Functional foods with bioactive properties.....	iv
2.1.1. Cardaba banana and its pharmacological benefits.....	iv
2.1.2. Beetroot, its nutritional components and bioactive composition.....	vi
2.1.3. The role of beetroot in nitric oxide production.....	viii
2.1.4. Tigernuts, its local names and proximate composition.....	ix
2.1.5. Tigernuts and its impact on Cardiovascular health	xi
2.1.6. Justicia carnea, traditional uses and its common names.....	xii
2.1.7. Phytochemical properties and health benefits of Justicia carnea.....	xiv

2.1.8. Soya beans and its effect on blood pressure.....	xiv
2.2. Overview and Biochemistry of Hypertension.....	xvi
2.2.1. Bariatric surgery (surgical interventions for hypertension).....	xvii
2.2.2. Current anti-hypertensive treatments.....	xviii
2.2.3. Formulation of a snack bar with diet as a management strategy.....	xix
2.3. Hydrogen Peroxide activity in Oxidative stress and Cell damage.....	xx
2.4. Health benefits of Antioxidants.....	xxi
2.5. The role of Nitric Oxide in Cardiovascular health.....	xxii
CHAPTER THREE.....	xxiii
3.0. MATERIALS AND METHODS.....	xxiii
3.1. MATERIALS.....	xxiii
3.1.1. APPARATUS AND EQUIPMENTS.....	xxiii
3.1.2. Chemicals and Reagents.....	xxiv
3.2. METHODS.....	xxv
3.2.2. Preparation of Cardaba banana flour.....	xxvii
3.2.3. Preparation of Soyabean flour.....	xxviii
3.2.4. Preparation of Justicia carnea flour.....	xxx
3.2.5. Preparation of Tigernut flour.....	xxxi
3.3. Functional anti-hypertensive snack bar preparation(baking Process).....	xxxii
3.4.1. Nitric oxide scavenging assay.....	xxxiii
3.4.2. Total Antioxidant Capacity (TAC).....	xxxiii
3.4.3. Hydrogen Peroxide Scavenging Activity.....	xxxiv
3.5. Statistical Analysis.....	xxxv
CHAPTER 4.....	xxxvi
4.0. RESULTS.....	xxxvi

CHAPTER 5.....	xl
5.0. DISCUSSION AND CONCLUSION.....	xl
5.1. Discussion.....	xl
5.2 Conclusion.....	xlii
REFERENCES.....	xliii

LIST OF FIGURES

Figure 2.1: Uses and Biological activities of <i>Musa balbisiana</i>	vi
Figure 2.4: Brazilian plume (<i>Justicia carnea</i>) leaf (Jabar <i>et al.</i> , 2025).....	xiii
Figure 2.5: Different natural sources of Isoflavones.....	xv
Figure 3.1: Flowchart for the preparation of Beetroot flour.....	xxvi
Figure 3.2.: Flowchart for the preparation of Cardaba banana flour.....	xxviii
Figure 3.5: Flowchart for the preparation of Tigernut flour.....	xxxi
Figure 4.3: Nitric Oxide Radical Scavenging activity.....	xxxvii

LIST OF TABLES

Table 2.1: Proximate composition of Tigernuts.....	x
Table 3.1: Different formulations for Control, Sample A, Sample B and Sample C.....	xxxii
Table 4.1: Nitric Oxide (NO) Scavenging Activity (IC50) of Sample.....	38

ABSTRACT

Hypertension is a major global health burden, often termed the "silent killer." The increasing prevalence, especially in low and middle-income countries, necessitates the development of accessible, non-pharmacological management strategies. Functional foods rich in bioactive compounds offer a promising approach for blood pressure control. This study seeks to develop an anti-hypertensive snack bar from Cardaba banana, beetroot, tigernuts, soyabeans, and *Justicia carnea* leaves and to evaluate its *in vitro* antioxidant and vasoprotective potential. Flours were individually prepared from the raw materials. Four snack bar formulations were developed: a control (with all-purpose flour) and three variations (Samples A, B, C) with increasing proportions of Cardaba banana flour. The samples were analyzed for their Hydrogen Peroxide (H₂O₂) scavenging activity, Total Antioxidant Capacity (TAC), and Nitric Oxide (NO) radical scavenging activity. All experimental samples (A, B, and C) demonstrated significantly higher antioxidant and NO-scavenging activities compared to the control. Sample A exhibited the most potent bioactivity, showing the strongest H₂O₂ and NO scavenging abilities, as well as the highest TAC. It also had the lowest IC₅₀ value for NO scavenging (12.5 µg/ml), indicating superior efficacy. The activities were dose-dependent, with Sample A > Sample B > Sample C >. The formulated snack bars, particularly Sample C, possess significant antioxidant and nitric oxide-related vasoprotective properties *in vitro*. These results suggest that the combination of Cardaba banana, beetroot, tigernut, soyabean, and *Justicia carnea* flours can yield a functional food with strong potential to mitigate oxidative stress and promote cardiovascular health, validating its development as a portable anti-hypertensive snack.

CHAPTER ONE

1.0. INTRODUCTION

1.1. Background of the study

An estimated 1.28 billion adults aged 30-79 years worldwide have hypertension, most living in low and middle income countries. Also, 46% of adults with hypertension are unaware that they have the disease and this is a major cause of premature death worldwide (WHO, 2023).

Hypertension also called the “silent killer”, occurs when the blood pressure of an individual is too high (140/90mmHg or higher) and can become fatal if not attended to on time (WHO, 2023). The first (systolic) number indicates the pressure in blood vessels when the heart beats or contracts while the second (diastolic) number represents the pressure in the vessels when the heart rests between the beats.

Hypertension has become a major global health concern with deaths expected to increase to 1.57 million by 2034, particularly affecting low and middle-income countries such as those within the sub-Saharan Africa (Samakosky and Norris, 2024). With the increase in development of the social economy of various nations, the daily dietary structure of different households has changed in a significant manner. This, as well as the acceleration in the pace of life and work activities, has made the age category of hypertensive patients to lean towards the younger generation (Rison *et al.*, 2022). Functional foods are industrially processed natural foods which when consumed regularly in effective levels, may have a positive impact on health combined with other essential nutrients (Granato *et al.*, 2020). The traditional treatment of hypertension includes the use of angiotensin II receptor inhibitors and beta receptor blockers but these drugs have some side effects attached to it. It has been reported that certain functional foods can modify the intestinal flora composition, thereby helping to

manage the symptoms brought about by hypertension (Chen *et al.*, 2023). Functional foods such as Cardaba banana, soybeans, tigernuts, beetroot and Justicia carnea contain bioactive ingredients which are helpful in managing high blood pressure in hypertensive patients. Cardaba banana (*Musa balbisiana*), contains high amount of potassium which is an essential mineral that helps in lowering blood pressure and reduce the risk of heart diseases. Beetroot (*Beta vulgaris*), which is a Middle Eastern species that has spread around the world (Mirmiran *et al.*, 2020), contains several active phytochemicals such as flavonoids, betalains and polyphenols. The cardiovascular health benefits of beetroot have been linked to its high inorganic nitrate concentration where the body converts nitrate into nitrite and nitric oxide, thereby acting as a vasodilator (Bahrami *et al.*, 2021). In addition to this, studies have shown that fermented soy protein which can be gotten from soybeans (*Glycine max*), effectively reduces blood pressure by reducing serum ACE (angiotensin converting enzyme) activity and promoting gut bacteria (Daliri *et al.*, 2020). The leaves of Justicia carnea contains a rich source of micronutrients and natural antioxidants which assist in eliminating radicals (Udedi *et al.*, 2020) combined with that of tigernuts (*Cyperus esculentus*) which is an almond-like sweet tuber, rich in fatty acids, vitamins, energy and can help to moderate the occurrence of colon cancer, coronary heart diseases, obesity and diabetes (Asare *et al.*, 2020). With these rich phytochemicals all present in the functional foods mentioned above, the need to seeing the treatment capability of its combination cannot be overemphasized.

1.2. Aim of the study

The aim of this study was to develop and evaluate the potential of the anti-hypertensive biscuit formulated from Cardaba banana, beetroot, tigernuts and Justicia carnea.

1.3. Objectives of the study

The specific objectives of this study were to:

- i. Evaluate the hydrogen peroxide activity and nitric oxide analyses of the biscuits using varying proportions of Cardaba banana, beetroot, tigernuts and Justicia carnea.
- ii. Determine the total antioxidant capacity (TAC) of the anti-hypertensive biscuit.

1.4. Justification of study

Hypertension is a major public health challenge, especially in low- and middle-income countries where access to antihypertensive drugs is limited. This highlights the need for safe, affordable, food-based interventions. The formulated snack bar, made from Cardaba banana (*Musa balbisiana*), beetroot (*Beta vulgaris*), tigernuts (*Cyperus esculentus*), soybean (*Glycine max*), and *Justicia carnea*, provides potassium, dietary nitrates, healthy lipids, ACE-inhibitory peptides, and antioxidants that collectively support vascular function and reduce oxidative stress. The study is further justified by its promotion of indigenous crops, reduced reliance on imported wheat products, and contribution to functional food development for cardiovascular health.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Functional foods with bioactive properties

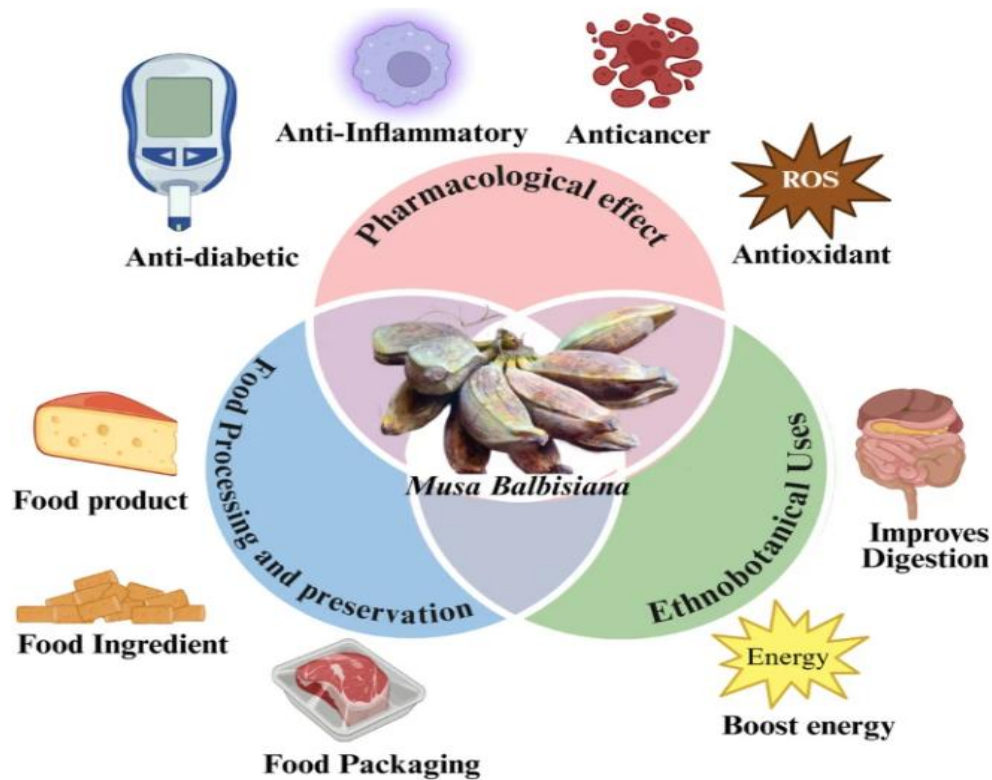
With the occurrence of a decrease in the quality of life coupled with the prevalence of diseases, diet is expected to play a key role in sustaining human health. Various nutritional and medical practitioners are working to formulate and provide foods that are associated with therapeutic benefits, popularly known as functional foods, which help in improving the general wellbeing of individuals, thereby minimizing the risk of diseases (*Lobine et al., 2021*). Functional foods exhibit a wide range of physiological benefits, also assisting in reducing the risk of health hazards to the consumers.

Bioactive compounds often called functional ingredients, are biomolecules found within the edible and non-edible parts of food substances that also possess unique physiological contributions (*Mondal et al., 2021*). These bioactive compounds form the key components in the development of functional foods which offer health benefits which go beyond the basic nutrition. Compounds such as polyphenols, carotenoids, flavonoids, fatty acids, etc, all contribute to the regulation of metabolic activities, immune system support and the reduced risk of having diseases such as hypertension (*Martirosyan, 2025*).

2.1.1. Cardaba banana and its pharmacological benefits

Cardaba banana (*Musa balbisiana*) belongs to the species of banana that is cultivated in Africa especially South-Western Nigeria and it is usually susceptible to post-harvest spoilage due to its high moisture content (*Olawoye and Gbadamosi, 2020*). Cardaba banana (*Musa balbisiana*) is an underutilized food crop that is seen throughout the year in Southern Nigeria.

It contains starch which serves as the primary source of glucose for the body, mainly functioning as a cooking banana due to its medicinal properties (Ayo-Omogie *et al.*, 2022) and has found its use in the tropics (Olawoye *et al.*, 2020a; Olawoye *et al.*, 2020b). It has been accepted that Cardaba banana, also known as cooking banana, has a lot of techno-functional and nutritional properties in many food formulations (Ayo-Omogie *et al.*, 2021; China *et al.*, 2022 ; Reginio *et al.*, 2020). The overall potential of Cardaba banana has not fully been discovered and this food crop is still thought to be underutilized in South and Western countries of Africa of which Nigeria is included. Studies have shown that Cardaba banana has some inbuilt nutritional qualities that rival that of traditional plantains. Essential micronutrients were seen in unripe Cardaba banana flour when it was substituted in the place of wheat in the formulation of cookies (Ayo-Omogie, 2023). Cardaba banana has shown to contain a low glycemic index with high presence of fiber making it suitable to lower the risk of obesity, colon cancer, high blood pressure and heart attack (Ayo-Omogie *et al.*,2021). Cardaba banana contains rich phytochemical components and also produces polyphenols, flavonoids, tannins, saponins, found in different parts of its flesh (Swargiary *et al.*, 2021). The flavonoids contained in Cardaba banana are rich antioxidants which assist in fighting against oxidative stress, cardiovascular diseases and reducing inflammation.



(Saikia *et al.*, 2025)

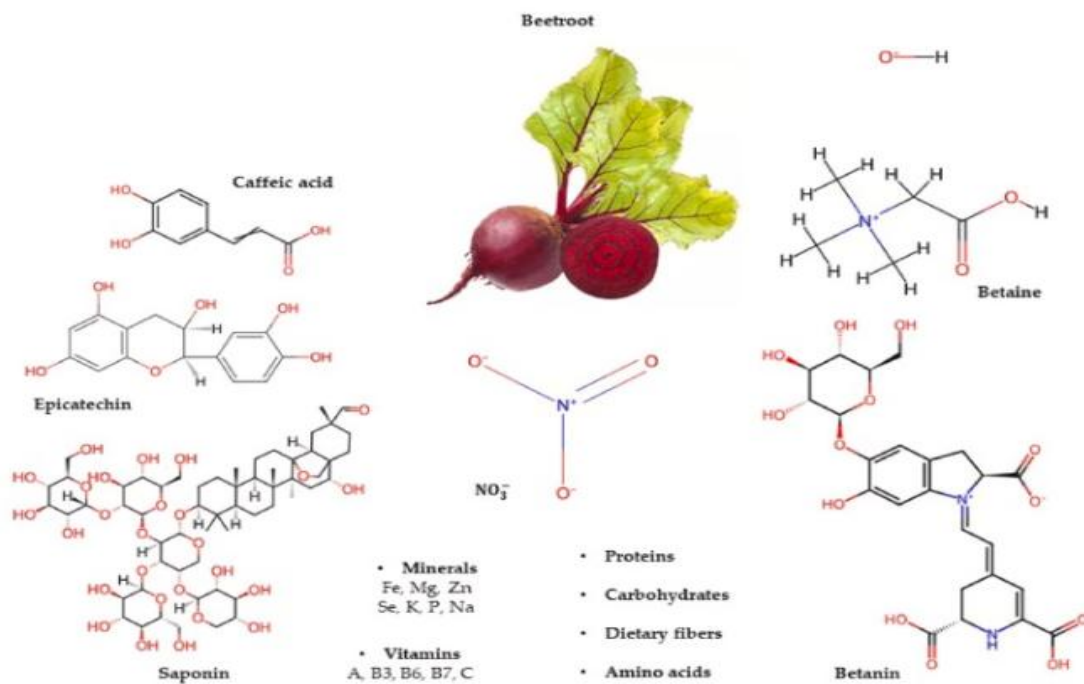
Figure 2.1: Uses and Biological activities of Musa balbisiana.

2.1.2. Beetroot, its nutritional components and bioactive composition

Beetroot (*Beta vulgaris*) is a food crop that grows throughout the year and majorly thrives under lower temperatures, which helps to enhance its deep red colour (Carreon-Hidalgo *et al.*, 2022). Beetroot's vibrant colour and numerous nutritional benefits has made it to be termed a 'superfood'(Sentkowska and Pyrzynska, 2023). It contains B vitamins which assist in increasing the flow of blood to the brain, thereby reducing the occurrence of dementia and memory loss. Beetroot has also been found to possess natural minerals sodium, iron,

potassium, calcium, zinc, phosphorus, magnesium, which supports the health of tissues and bones (Olumese and Oboh, 2020). The peels obtained from beetroots have the following chemical composition: Moisture (86.3%), Protein(1.02%), Ash(1.48%), Crude fiber(2.6%), total sugars (8.4%) and total lipids (0.2%) (Shuaibu and Aremu, 2021). These beetroot peels exhibit a wide range of actions which are antibacterial, anti-inflammatory, anti-cancer, anti-diabetic and anti-hypertensive in nature (Shakir and Simone, 2024).

Beetroots are rich in bioactive compounds such as betalains, flavonoids(quercetin), terpenoids,saponins, phenolic acids (gallic), alkaloids, steroids, tannins and sugars (Knez *et al.*, 2022). The betalains, including betacyanins and betaxanthins found in beetroot are higher in the peels than in the flesh. These pigments are known for their anti-inflammatory and antioxidant properties which they possess (Thiruvengadam *et al.*, 2024).High concentration of nitrates have also been found in this root vegetable, which contributes to respiratory and cardiovascular health, making it beneficial in supporting systems (Baiao *et al.*, 2020). The by-products gotten from beetroot are also abundant in bioactive chemicals such as kaempferols, quercetins, caffeic acid, chlorogenic acid and carotenoids, which aassists in scavenging reactive oxygen species (ROS), thereby inhibiting spoilage of food and promote stomach coupled with liver health.



(Wang *et al.*, 2025)

Figure 2.2: Main bioactive phytochemicals in Beetroot juice.

2.1.3. The role of beetroot in nitric oxide production.

Nitric oxide (NO) is a low molecular weight compound that is found in gaseous form, having a short half-life and being able to diffuse through the lipid bi-layer of cells. It is highly reactive due to the fact that it has an unpaired electron in its valence shell which makes it possible to oxidize to nitrate (NO_3^-) and nitrite (NO_2^-) (Karwowska and Kononiuk, 2020). Due to the incidence of aging and cardiovascular diseases, the search for healthy diets has increased significantly, making the regular intake of vegetables to be more appealing (Thakur *et al.*, 2020) and this has made beetroot to gather much attention due to the presence of nitrates (Bangar *et al.*, 2022). The nitrates in beetroot can be reduced to nitric oxide in the body, which acts as an effective vasodilator, helping to lower blood pressure and improve

endothelial function. The production of nitric oxide from ingested inorganic nitrates, relies on its conversion to nitrite influenced by the presence of facultative bacteria (Morou-Bermudez *et al.*, 2022). Experimental studies have demonstrated that regular intake of beetroot juice can drastically help to reduce systolic blood pressure, improve the flow of blood and oxygen supply to the muscles (Benjamin *et al.*, 2023).

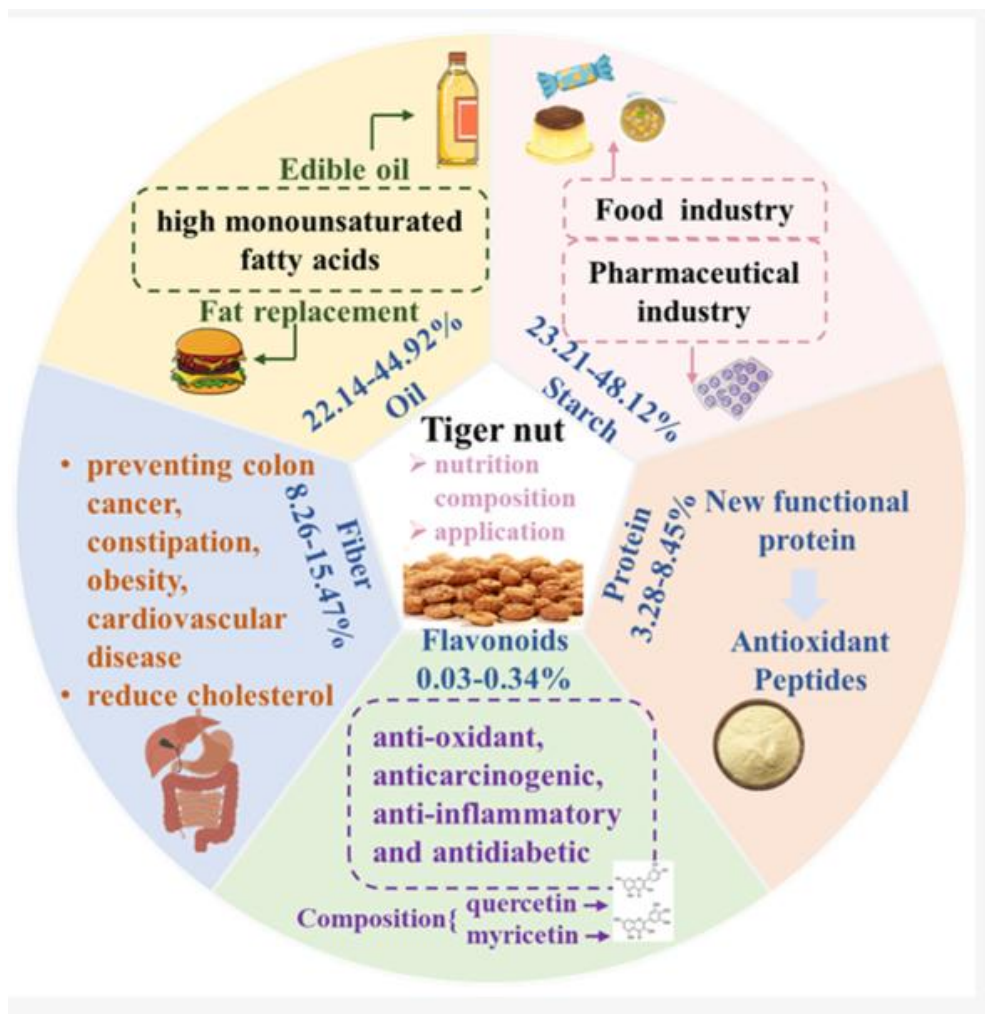
2.1.4. Tigernuts, its local names and proximate composition

Tigernut (*Cyperus esculentus*) is an almond-like tuber crop that possesses an irregular appearance, usually taking the size of a peanut (Maksim *et al.*, 2021; Adenowo and Kazeem, 2020). Tigernuts can be eaten raw or soaked in water for few hours before it is eaten depending on an individual's preference. It contains a lot of beneficial qualities that makes it incorporated into many food formulations. For instance, it aids in the circulation of blood and also helps in regulating various physiological processes (Oteng and Kersten, 2020). In countries such as Spain and that of North Africa, tigernut is usually part of their regular diets (Hassan *et al.*, 2021). For Spain, a local beverage product called "horchata de chufa" is produced from tigernuts while in Egypt, tigernuts are roasted to serve as "sweet meat" (Yang *et al.*, 2022). In northern Nigeria, it is used as a nutritious and healthy beverage popularly known as "Kunnu aya" (Ogbuagu and Airaodion, 2020). Tigernut contains some antioxidant properties due to its flavonoid content and this is useful in 'mopping up' free radicals in the human body thereby promoting overall health of an individual (Samuel *et al.*, 2023). The oil extracted from tigernuts has been found to contain minerals such as calcium, potassium, magnesium, including vitamins such as vitamin C and E, which are also strong antioxidants. Other experiments have indicated the presence of unsaturated fatty acids which assists in boosting cardiovascular health, as the lipid profiling is similar to that of olive oil, which is considered the most suitable fat for human consumption (Ahaotu *et al.*, 2020; Touria *et al.*,

2022). Tigernut flour has been seen as a perfect food formulation product, even introduced in making biscuits with improved nutritional and health benefit (Djomdi *et al.*, 2020).

Table 2.1: Proximate composition of Tigernuts

Nutrient	Amount (per 100g)	References
Carbohydrates	47	Bamigboye <i>et al.</i> , 2020
Protein	5.08	Funmilayo and Smart, 2020
Ash	2.23	Pelegriin <i>et al.</i> , 2022
Crude fiber	14.80	Funmilayo and Smart, 2020
Reducing sugar	27.62	Bazine and Arslanoglu, 2020
Starch content	15.47	Bamigboye <i>et al.</i> , 2020
Sucrose	13.55	Bamigboye <i>et al.</i> , 2020



(Edo *et al.*, 2023)

Figure 2.3: The main nutrition composition and nutrient-based applications of tiger nut.

2.1.5. Tigernuts and its impact on Cardiovascular health .

The nutritional profile of tigernuts actually depends on a variety of factors such as soil composition, method of cultivation and storage conditions utilized (Dey *et al.*, 2020). Tigernuts contain a high carbohydrate content and the protein content is not comparable to that of rice (Edo *et al.*, 2023). It is also a rich source of saturated and unsaturated fatty acids.

The oleic acid found in tigernuts plays a vital role in preventing heart attack by reducing blood pressure (Novor and Donkor, 2024) and the consumption of tigernuts can positively help to regulate the number of inflammatory cells that take part in the progression of atherosclerosis (Onyibe *et al.*, 2021). The high fiber content present in tigernuts is responsible for regulating blood sugar, thereby reducing glucose levels (Selma-Royo *et al.*, 2022). Tigernut has been shown to possess several health benefits which spans across the cardiovascular system, bringing about metabolic improvements. Its composition made of macronutrients, mono and polyunsaturated fatty acids, makes it a great deal in managing hypertension (Yu *et al.*, 2022). Several studies indicate that the polyphenolic compounds present in tigernuts have proved effective in decreasing the incidence of oxidative stress, which can result to a variety of health issues including cardiovascular diseases and cancer.

2.1.6. *Justicia carnea*, traditional uses and its common names

Medicinal plants have been greatly utilized in the production of novel drug components, as they serve as rich sources of secondary metabolites. The various parts of a medicinal plant possesses potential bioactive substances which can be found in the stem, bark, leaves, flowers, fruits and roots (Madhayan *et al.*, 2022). Around 80% of the world's population still rely on medicinal plant for their basic medical needs (Anarado *et al.*, 2021).

Justicia carnea is a medicinal plant whose botanical name was gotten from a Scottish man named "James Justice". There are several hundreds of species of *Justicia carnea* which have been introduced into the traditional setting for the management of several health complications (Anarado *et al.*, 2021). For decades, it has been utilized effectively as a blood tonic, in replenishing amounts of blood which could have being lost through menstruation, surgery process or sustained injuries (Okocha *et al.*, 2023). In Nigeria, it is commonly used as a blood booster and has several names in different local dialects. In the Igbo culture, it is

known as “ogwu obara”, for Yoruba, it is called “ewe eje” while it has several English names such as pink Jacobinia, flamingo flower, pine-bur begonia, hospital far away plant, etc (Asakizi *et al.*, 2020).



(Jabar *et al.*, 2025)

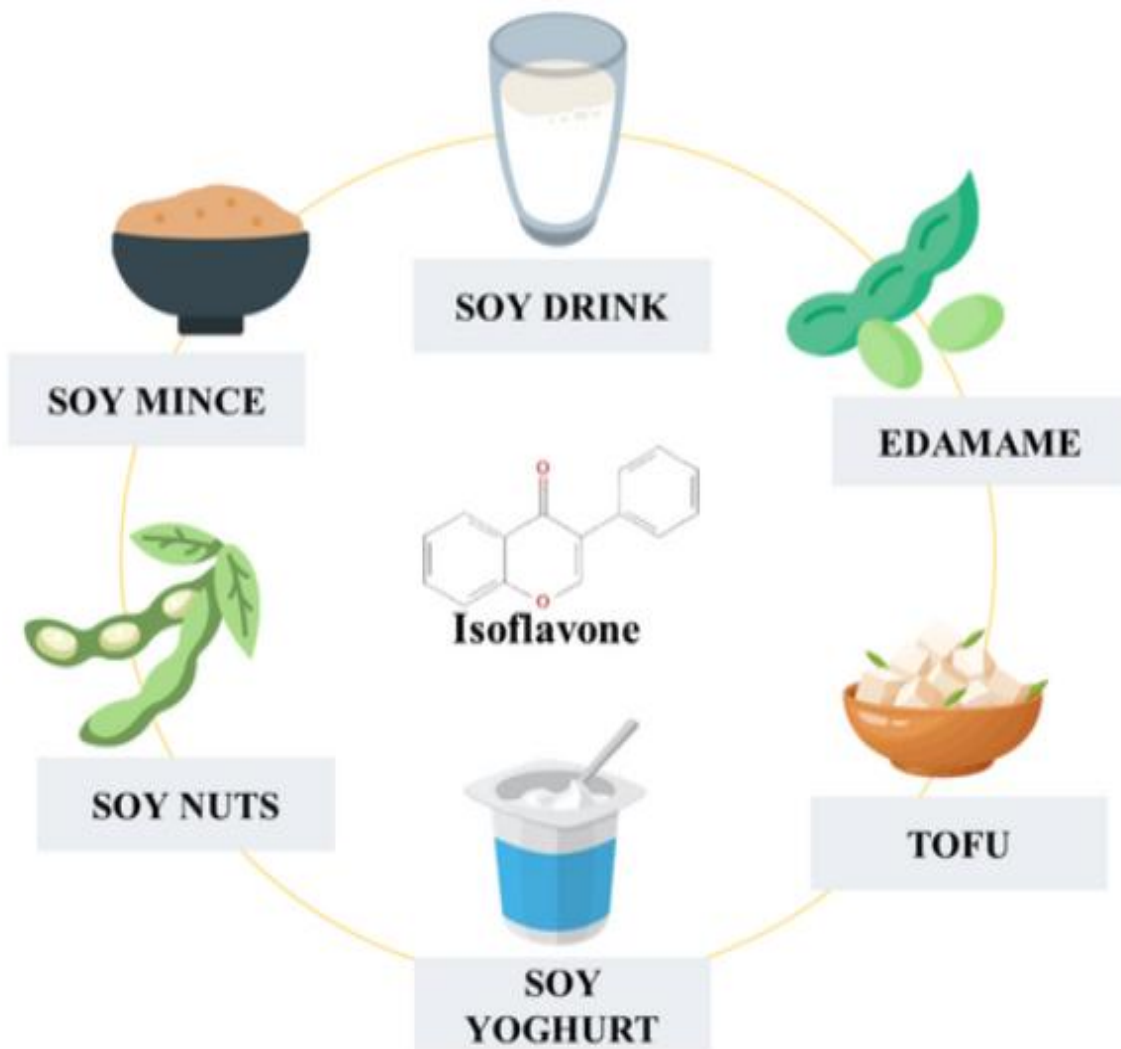
Fig 2.4: Brazilian Plume (*Justicia carnea*) leaf

2.1.7. Phytochemical properties and health benefits of *Justicia carnea*

Justicia carnea possesses some essential micronutrients such as folic acid, zinc, copper, iron, (Asogwa *et al.*, 2020) and active phytochemicals such as tannins, alkaloids, flavonoids, terpenoids, which carry out anti-cancer, anti-oxidant, anti-inflammatory and also pain-relieving activities (Ukpabi-ugo *et al.*, 2023). Its leaf extracts have been explored and found to treat various health complications such as fever, liver diseases, diabetes, gastrointestinal disorders and anaemia (Anarado *et al.*, 2021).

2.1.8. Soya beans and its effect on blood pressure

ACE which stands for Angiotensin Converting Enzyme, is a crucial enzyme that catalyzes the conversion of angiotensin I to a potent angiotensin II that brings about the vasoconstriction of blood vessels, potentially causing hypertension. Hypertension itself, is a primary risk factor for stroke, end-stage renal failure (Mujtaba *et al.*, 2021) and the inhibition of ACE (angiotensin converting enzyme), serves as the fundamental goal of managing hypertension disease in individuals (Singh, 2025). Soyabeans is rich in proteins, lipids and contain isoflavones, which are functional components. These isoflavones contain antioxidant properties that prevent and also manage various diseases such as hyperlipidemia, diabetes, obesity, high blood pressure and inflammation (Kim, 2021). It can be consumed in several ways such as in the form of soy mik, soy cheese and soy yoghurt (Kim *et al.*, 2021). Genistin, a prominent isoflavone, has shown cardioprotective effects and can also reduce the risk of bone diseases (Islam *et al.*, 2020).



(Hassan *et al.*, 2025)

Figure 2.5: Different natural sources of Isoflavones

2.2. Overview and Biochemistry of Hypertension.

All over the world, hypertension has continued to be the most frequent cardiovascular disease, also becoming one of the leading causes of death (Kuneinen *et al.*, 2024). According to global statistics, the ratio of hypertension in men is 1:4 while in women is 1:5 but this disease can be managed through healthy eating habits and the employment of advanced technological tools (Shah and Yadav, 2022). In the United States, it has been observed that the highest mortality rate comes from the African-American population (Abrahamowicz *et al.*, 2023) and most women are usually diagnosed with stage 2 hypertension which comes as a result of menopause (Ko and Kim, 2020). Hypertension can be diagnosed when a patient's systolic blood pressure is higher than 140mmHg with the diastolic blood pressure higher than 90mmHg (Unger *et al.*, 2020). Some factors which can predispose an individual to hypertension include smoking, intake of alcohol, age, diabetic condition, etc (Swain and Banerjee, 2021). Smoking in particular, has been seen as a prevalent case in young individuals having hypertension (Perry, 2023). When factors such as this are properly addressed, it can go a long way in alleviating the deleterious impact of hypertension on human health and productivity otherwise, it can impose both direct and indirect costs on individuals and the society at large. Direct costs related to hypertension could come in the form of medical and hospital bills while the indirect costs could include disability or even premature death particularly in China, where cardiovascular diseases and mortality have posed significant health concerns (Rehman *et al.*, 2022).

The development and management of hypertension is greatly influenced by the Renin-angiotensin-aldosterone system (RAAS). This Renin-angiotensin-aldosterone system (RAAS),

consists of a network of hormones that interconnects the renal, adrenal and cardiovascular systems to maintaining electrolyte balance and blood pressure (Ghafar, 2020). Its components include renin, angiotensinogen, angiotensin I, angiotensin converting enzyme (ACE), angiotensin II and aldosterone synthase, which all have a link to hypertension (Wibowo *et al.*, 2021). The kidneys release renin which initiates the conversion of angiotensinogen to angiotensin I. Angiotensin converting enzyme (ACE) then converts angiotensin I into angiotensin II which is a vasoactive peptide that causes the constriction of blood vessels, leading to blood pressure elevation. Angiotensin II also causes the secretion of aldosterone from the adrenal cortex, which further leads to the retention of sodium and water in the kidneys, which in turn, increases blood pressure. All these occur in an enzymatic chain of events coupled with receptor interactions.

2.2.1. Bariatric surgery (surgical interventions for hypertension).

In the past few years, bariatric surgery has become popular due to the increasing incidence of obesity and nearly two-thirds of patients who undergo this process, experience massive improvement in blood pressure control (Altieri *et al.*, 2021; Tajeu *et al.*, 2022). Bariatric surgery procedures which include sleeve gastrectomy (SG) and Roux-en-y gastric bypass (RYGB), have demonstrated great success in reducing the risk of mortality but is mostly underutilized due to lack of education amongst the patients and clinicians on its safety and efficacy (English *et al.*, 2020). Before bariatric surgery is carried out, it is very important that the patient's psychological and nutritional health status is properly checked before proceeding with the surgery (Glazer and Biertho, 2020). This surgical process can sometimes be accompanied by gall stone formation and rapid weight loss (Alsallamin *et al.*, 2023).

2.2.2. Current anti-hypertensive treatments

The treatment of hypertension through pharmacological means has become a cornerstone in the management of the disease. Varieties of drugs have been developed and established with proven efficiency in managing hypertension and they work by the blockade of the renin-angiotensin-aldosterone system. Drugs recommended for the treatment of hypertension include diuretics, ACE inhibitors, beta adrenergic receptor blockers, calcium channel blockers, etc (Unger *et al.*, 2020). The current anti-hypertensive treatments are discussed below:

- RAAS blockers

Two groups of renin-angiotensin-aldosterone system blockers exist, which are the angiotensin converting enzyme inhibitors (ACEI) and the angiotensin II receptor blocker (ARB). The angiotensin converting enzyme inhibitor (ACEI) group incorporates a wide range of agents such as captopril, lisinopril, ramipril, which decrease the production of angiotensin II and aldosterone, and then further increase the level of bradykinin, a vasodilator. Drugs in the angiotensin II receptor blocker (ARB) group include losartan, olmesartan, valsartan, which all promote vasodilation and reduce the production of catecholamines.

- Beta adrenergic receptor blockers

They work by decreasing the rate of cardiac output and are particularly effective in patients with rapid heartbeat and contractility. Normally, these drugs are usually given in line with diuretics (Mancia *et al.*, 2022). They also help to reduce cardiovascular risks but are not really effective in reducing the risk of stroke occurrence.

- Calcium channel blockers (CCB)

These set of drugs work by blocking calcium entry into excitable cells and reducing vascular resistance, thereby producing a relaxation effect. The two main classes of this drug include the dihydropyridines(amlodipine) and non-dihydropyridines such as verapamil.

- Diuretics

They inhibit the sodium\chloride pump and also facilitate the excretion of sodium. It was observed that patients who received diuretics such as thiazides experienced a lower occurrence of cardiovascular disorders (Ishani *et al.*, 2022).

2.2.3. Formulation of a snack bar with diet as a management strategy

Various bioactive compounds have been identified as potential therapeutic substances for the prevention and management of cardiovascular disorders (Ud Din *et al.*, 2023). Much focus has been placed on functional foods and supplements due to high presence of plant-based bioactive components (Mocanu *et al.*, 2022). The prevalence of chronic diseases such as hypertension currently, is majorly caused by poor eating lifestyle and this has increased the need and demand for foods enriched with health beneficial components such as polyphenols, probiotics, vitamins , minerals, etc (Simon *et al.*, 2021;Ahmad and Gani, 2021). The formulation of a snack bar with the purpose of managing a disease like hypertension should be carried out in strict adherence to hygienic practices as this will help to preserve the value of the product. Most snack bar options sold in the market are usually loaded with additives and saturated fat which are not beneficial to cardiovascular health (Klerks *et al.*, 2022).It is therefore necessary to preserve the bioactive compounds contained in functional foods by processing the functional products minimally in order to ensure it is friendly with the gut system (Plamada and Vodnar, 2022). Good and adequate lifestyle changes remain one of the

antidote for the prevention and treatment of hypertension (Cheema *et al.*, 2022). Diet plays a very important role in the proper functioning of the body system. Dietary Approaches to Stop Hypertension (DASH), low sodium and Mediterranean diet, have been popularly accepted due to their numerous benefits in assisting to reduce blood pressure (Filippou *et al.*, 2020). The DASH (Dietary Approaches to Stop Hypertension) diet is rich in macronutrients and micronutrients, emphasizing on the consumption of vegetables, fruits and meals that contain low saturated fat and cholesterol (Unger *et al.*, 2020). It was observed that when this diet was incorporated, it brought about a significant reduction in blood pressure (Filippou *et al.*, 2020). For the case of vegetarian diet, it contains a high proportion of plant-based protein and glutamic acid which also possesses blood pressure lowering effects (Dasinger *et al.*, 2020). Moreover, evidence suggests that a diet composed of high concentration of fiber, potassium and antioxidants, all contribute to lowering blood pressure readings (Soeters, 2020).

2.3. Hydrogen Peroxide activity in Oxidative stress and Cell damage

Much focus has been placed on the study of oxidative stress due the role it plays in the development of chronic diseases such as diabetes, kidney failure and hypertension (Taslami *et al.*, 2020). Oxidative stress can be indicated through an uneven level of reactive oxygen species (ROS) as compared to the antioxidant defenses, which then initiates the damage of DNA, bringing about a disruption in the functions of the cell (Rahman *et al.*, 2025). Humans are continuously exposed to reactive oxygen species which can occur endogenously or exogenously. The end-products of metabolic processes and respiration can all contribute to the formation of radicals, leading to stress in the body systems (Turkan *et al.*, 2020). Once the level of reactive oxygen species exceeds the defense makeup of the antioxidants present in the body, it can lead to damage of body tissues, quickening of cell death and occurrence of

many diseases (Apak *et al.*, 2022). Amongst the reactive oxygen species is hydrogen peroxide (H_2O_2), a compound that is involved in many reactions and processes in humans. Hydrogen peroxide acts as a messenger and works with nitric oxide (NO) radical to activate specific oxidations which lead to damage of cells and tissues (Andres *et al.*, 2022). It has an unpleasant odour and can decompose into oxygen and water, releasing a huge amount of heat. At very low concentrations, hydrogen peroxide can be reactive while at high concentrations, it can destroy energy-transforming cell systems and this singular act can lead to the inactivation of glyceraldehyde-3-phosphate dehydrogenase which further causes complications related to diabetes (Hyslop and Chaney, 2022).

2.4. Health benefits of Antioxidants.

Antioxidants are compounds with low molecular weights which assist in the elimination of reactive oxygen species (Al-Mamary and Moussa, 2021). The reactive oxygen species include radicals such as hydroxyl radical, superoxide anion radical and non-radical molecules such as hydrogen peroxide and they all demonstrate different forms of reactivity and properties within biological systems (Kozlov *et al.*, 2024). It has been validated that antioxidants remove the missing electrons which characterizes radicals, as this helps to decrease or slow down damage to cells found within the body (Al-Mamary and Moussa, 2021). It is therefore imperative that balance must be maintained between the production of reactive oxygen species and the antioxidant defense mechanisms in order to prevent the occurrence of oxidative stress which can further progress to chronic diseases. Antioxidants can be of two forms-enzymatic and non-enzymatic. Essential enzymatic antioxidants include catalase, glutathione peroxidase, glutathione reductase and superoxide dismutase while the non-enzymatic antioxidants include glutathione, vitamins C and E (Chapa-Dubocq *et al.*, 2023). Antioxidants such as polyphenols and flavonoids found in vegetables, fruits and other

plants are said to have the ability of reducing cardiovascular risk. They help to shield the blood vessels from radical attack and improve good cholesterol level (Rodriguez-Graciani *et al.*, 2022). Once these antioxidants neutralize harmful free radicals, they help to prevent chronic diseases such as liver and heart failure (Zhang *et al.*, 2023). Antioxidants such as lutein, zeaxanthin and vitamin C, have been shown to be beneficial to the eyes, as they help to preserve visual function (Kushwah *et al.*, 2023). Antioxidants also play a role of reducing inflammation in the body and enhancing exercise, which promotes the overall health of the body (Higgins *et al.*, 2020).

2.5. The role of Nitric Oxide in Cardiovascular health

The regulation of blood pressure and maintenance of vascular health forms an important component of cardiovascular function with nitric oxide (NO) carrying out a vital role. Nitric oxide is a signaling molecule involved in endothelial function (Abolfazli *et al.*, 2024). Nitric oxide assists in enhancing the integrity of vascular networks and preventing inflammation which leads to cell damage (Dri *et al.*, 2023). Due to its action on vascular smooth muscle, Nitric oxide functions as a powerful blood pressure regulator and can be utilized by clinicians in managing hypertensive patients. It is a small gaseous molecule which has been found to influence various key processes that occur in the nervous and cardiovascular system and can be synthesized through the oxidation of L-arginine catalyzed by the enzyme nitric oxide synthase. This molecule is very reactive, aiding in vasorelaxation (Cyr *et al.*, 2020)

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. MATERIALS

- Beetroot
- Cardaba banana
- Soyabeans
- Justicia carnea leaves
- Tigernuts
- Date paste (natural sweetener)
- Honey
- Cooking butter
- Cinnamon
- Vegetable oil
- Skimmed milk
- Eggs

3.1.1. APPARATUS AND EQUIPMENTS

- Foil paper
- Black tarpaulin cover
- Cooking cutter
- Rolling pin
- Baking paper
- Kitchen scale

- Ziploc bag
- Packaging nylon
- Measuring cup
- Air tight glass jars
- Dehydrator
- Oven (Century Electric Oven, COV-8320-C)
- Weighing balance
- Refrigerator (National spread, NSBP-150K)
- Blender (Kenwood blender, UK Standard, KC-241B)
- Rubber bowls
- Sieve
- Filter
- Scissors
- Buckets
- Hand gloves

3.1.2. Chemicals and Reagents

- Sodium metabisulfite ($\text{Na}_2\text{S}_2\text{O}_5$)
- Sodium nitroprusside
- Phosphate buffer
- Griess' reagent
- Reagent solution (0.6M sulphuric acid, 28mM sodium phosphate and 4mM ammonium molybdate).
- Methanol

- Phosphomolybdate reagent solution
- Hydrogen peroxide
- Ascorbic acid
- BHT (Butylated Hydroxyl Toluene)

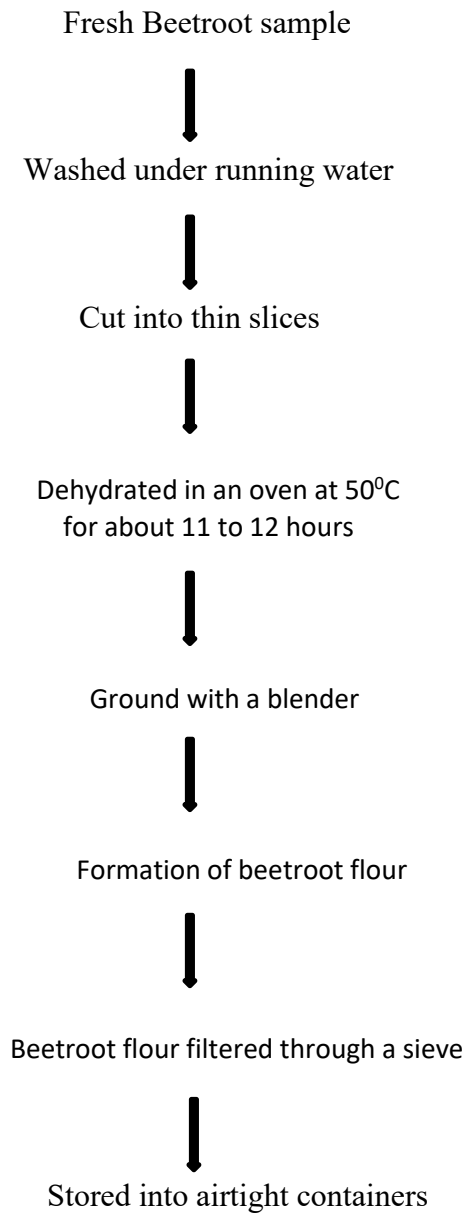
3.2. METHODS

3.2.1. Preparation of Beetroot flour

The beetroot which was used in this undergraduate project research study was locally obtained from Hausa market, situated along Forestry road in Benin City, Edo State. The amount of beetroot purchased was 6kg and it was thoroughly washed under running water in order to remove any form of contamination. The beetroot sample was further peeled using a sterile sharp knife and cut into thin slices before being rinsed again to ensure it was free from impurities. The sliced beetroot was weighed on a weighing balance and the measurement given was about 2.04kg. Due to interruption in light supply, the sliced beetroot samples were placed on foil papers and allowed to air-dry. The air-drying process lasted for about 2days and it was carefully done with proper ventilation. Electricity supply was restored and the samples were transferred to a dehydrator to ensure that the samples were free from every moisture. The dehydrator temperature was fixed at 50⁰C for about 11 to 12 hours. The essence of the drying process is to remove every moisture content, to make it suitable for blending into a flour. After a confirmation that the samples were completely dried, a blender was used to convert the beetroot

samples into a fine beetroot flour and were further stored in an air tight container.

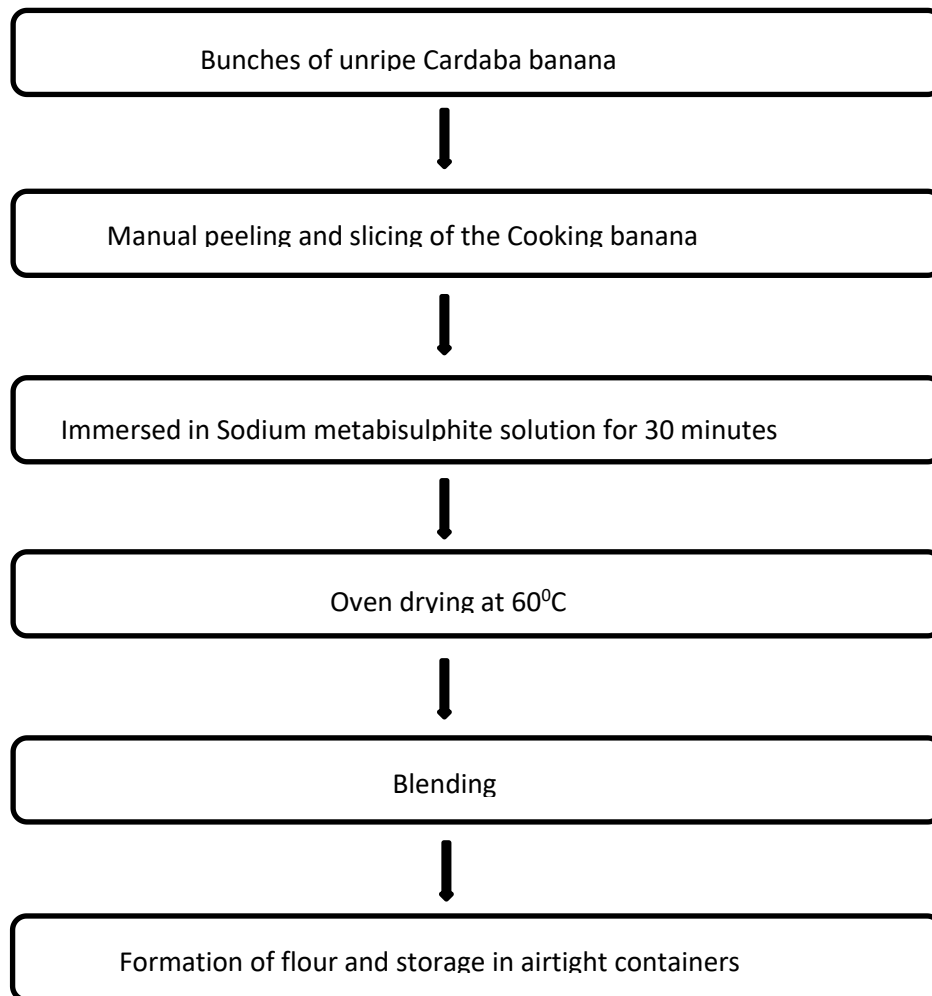
Figure 3.1: Flowchart for the preparation of Beetroot flour



3.2.2. Preparation of Cardaba banana flour

The unripe Cardaba bananas were locally obtained from Efehi market situated around New Benin axis in Benin City after they were previously ordered from an Akure village located in Ondo state, Nigeria. The unripe Cardaba bananas were peeled and cut into thin slices using a sterile knife. The thin slices of the unripe Cardaba banana were soaked in 10litres of water and 5grams of sodium metabisulfite ($\text{Na}_2\text{S}_2\text{O}_5$) was added for about 30minutes. This reagent acts as an anti-browning and anti-microbial agent. Essentially, it helps to prevent the influence of enzymes and other external factors which induce an unappealing brown colour on the banana. It also prevents the growth of microorganisms such as bacteria, fungi, thereby assisting in extending the shelf-life of the banana product. The soaked banana was then transferred into a filter to drain the excess water and afterwards placed in an oven, regulated at a temperature of 60^0 C for proper drying to remove every moisture. The dehydrated thin slices of Cardaba banana was blended into a fine flour and stored in an airtight container under regulated conditions.

Figure 3.2.: Flowchart for the preparation of Cardaba banana flour

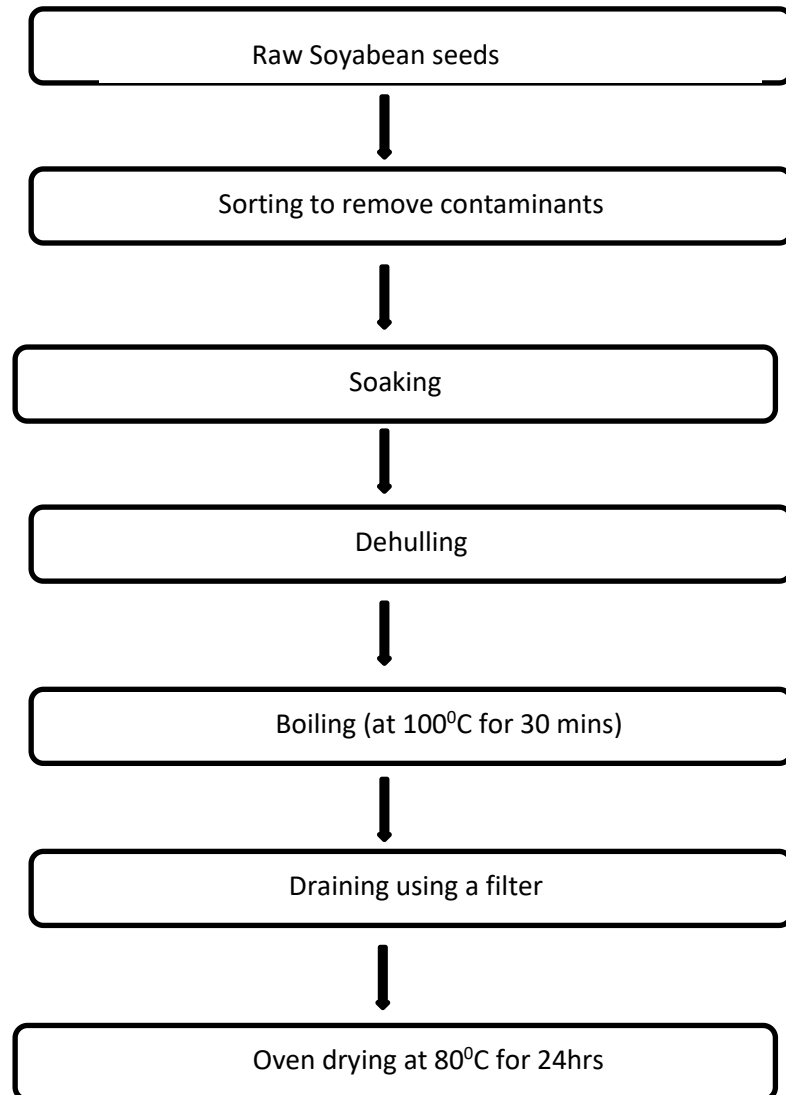


3.2.3. Preparation of Soyabean flour

Three rubbers of Soyabeans was locally purchased at “rice line” around the New Benin axis in Benin City, Edo State. Firstly, the soyabeans was hand-picked to remove dirt before it was soaked in a bowl of water for about 24hours. The outer seed coats of the soya beans (husks) was removed and afterwards boiled, with the boiling process lasting for about 30 minutes for each Kilogram before finally being transferred to the oven at a temperature of

80°C. The different set of soyabeans were dried to the point where they demonstrated constant weights of 0.5kg on each tray before they were finally blended into a flour and stored in an airtight container.

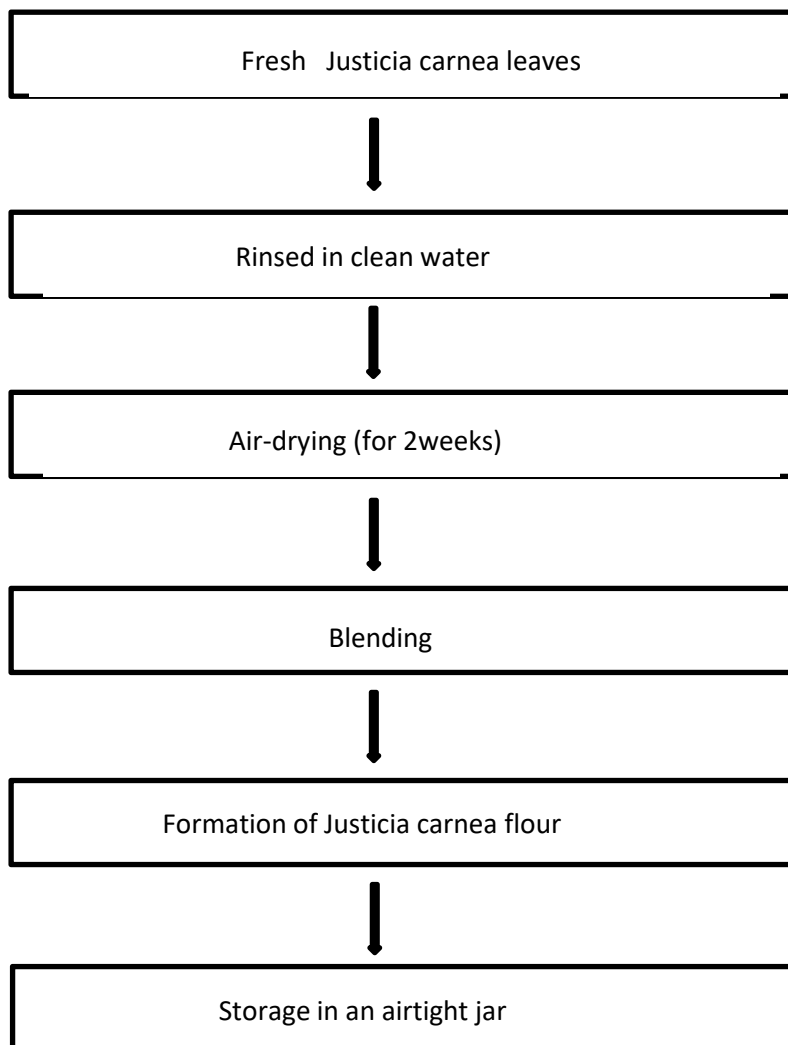
Figure 3.3.: Flowchart for the preparation of Soyabeans



3.2.4. Preparation of *Justicia carnea* flour

The *Justicia carnea* plant was sourced from an ornamental garden situated at Supply and Transport barracks opposite Uselu market in Benin City, Edo State. The leaves of *Justicia carnea* (blood leaf) was hand picked and rinsed in water. It was then air-dried for up to two weeks and this was to ensure that it was ground in a blender to produce a smooth flour with no presence of moisture. Afterwards, it was stored in an air-tight glass jar.

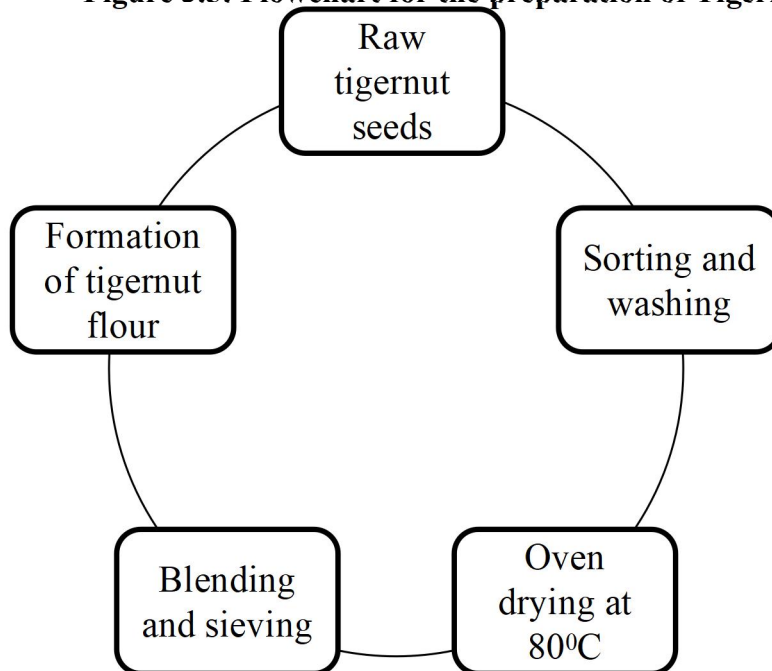
Figure 3.4: Flowchart for the preparation of *Justicia carnea* flour



3.2.5. Preparation of Tigernut flour

Two rubbers of tiger nut were locally purchased at lagos street, located within Benin City also. We ensured that dirt in the form of stones were separated from the tigernuts before it was rinsed in a bowl of water. Afterwards, it was placed in an oven set at 80°C and the drying process lasted for 10 hours. After the dehydration process, it was blended into a fine flour and stored in an air-tight container.

Figure 3.5: Flowchart for the preparation of Tigernut flour



3.3. Functional anti-hypertensive snack bar preparation(baking Process)

The formulation of the functional snack bar was done using the flours of Cardaba banana, beetroot, Justicia carnea, soya beans and tigernuts. Several ingredients were also combined in varying proportions altogether in four samples namely: Control sample, sample A, sample B and sample C.

Table 3.1: Different formulations for Control, Sample A, Sample B and Sample C

Ingredients	Control	Sample A	Sample B	Sample C
All –purpose flour	60g
Cardaba banana flour	60g	77g	90g
Beetroot flour	37g	37g	25g	27g
Tiger nut flour	52g	52g	52g	40g
Soyabeans flour	27g	27g	27g	24g
Vegetable oil	15g	15g	10g	10g
Justicia carnea flour	2g	2g	2g	2g
Date paste	5g	5g	5g	5g
Baking powder	2g	2g	2g	2g
Total	200g	200g	200g	200g

3.4.1. Nitric oxide scavenging assay

The nitric oxide radical scavenging capacity was carried out on the different functional food materials. 1ml of 10 mM sodium nitroprusside was mixed with 1ml of extract prepared in a phosphate buffer. The mixture was incubated at 25°C for 150 minutes. To 1ml of the incubated solution, 1ml of Griess' reagent was added. An absorbance was calculated and read at 546nm (Makhija *et al.*, 2011). The percentage nitric oxide scavenging capacity was calculated as shown below:

$$\text{Nitric oxide scavenging activity(\%)} = \frac{A_{\text{control}} - A_{\text{extract}}}{A_{\text{control}}} \times 100$$

3.4.2. Total Antioxidant Capacity (TAC)

The total antioxidant capacity (TAC) of the extracts was evaluated using the phosphomolybdenum method based on the procedure described by Prieto *et al.*(1999). The assay is based on the reduction of Mo(+6) to Mo(+5) by the extracts and subsequent formation of green phosphate Mo(+5) complex at an acidic pH. Briefly, 0.3mL of graded concentrations of the extracts was mixed with 3mL of reagent solution (0.6M sulphuric acid, 28mM sodium phosphate and 4mM ammonium molybdate). The absorbance of the reaction mixture was measured at 695nm using a spectrophotometer against a blank after cooling to room temperature. Methanol (0.3mL) in the place of the extract was used as the blank. The TAC was expressed as milligram equivalents of ascorbic acid and calculated as shown below:

$$\text{TAC (mg AAE/g extract)} = \frac{C \times V}{m}$$

Where C= Concentration of ascorbic acid in mg/mL, extrapolated from the standard calibration curve

V= Volume of extract in ml

m= weight of crude plant extract in grams

3.4.3. Hydrogen Peroxide Scavenging Activity

The scavenging activity of hydrogen peroxide (H₂O₂) by the sample extracts was determined by the method Lcin (2005). The Ultra Violet light absorption of hydrogen peroxide can be easily measured at 230nm. On scavenging of hydrogen peroxide by the sample extracts, the absorption decreases at this wavelength, which property can be utilized to quantify their H₂O₂ scavenging activity.

The extract was dissolved in methanol to prepare various concentrations and to the assay, reaction mixture containing sample (100μl), 1.5 ml of phosphate buffer (0.05M, pH 7.4) and 0.6ml of H₂O₂ are added. The percentage were calculated from the absorbance of the control (Ac) and the sample (As) by the equation:

$$\text{Inhibition (\%)} = (1 - A_s) / A_c \times 100$$

3.5. Statistical Analysis

All the data regarding hydrogen peroxide activity, nitric oxide analyses and total antioxidant capacity (TAC) were analyzed statistically using SPSS (Version 25.0). The results are expressed as the mean \pm standard deviation (SD). Differences among sample means were assessed using one-way Analysis of Variance (ANOVA). Significant differences were identified using the Duncan's Multiple Range Test (DMRT) at a 5% probability level ($p < 0.05$).

CHAPTER 4

4.0. RESULTS

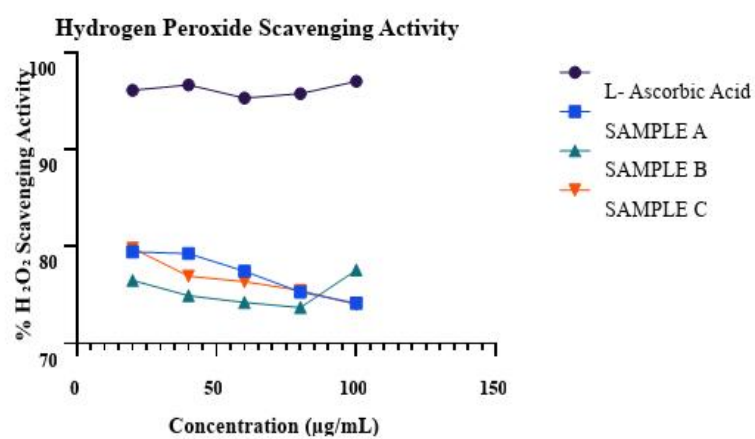


Figure 4.1: Hydrogen peroxide scavenging activity

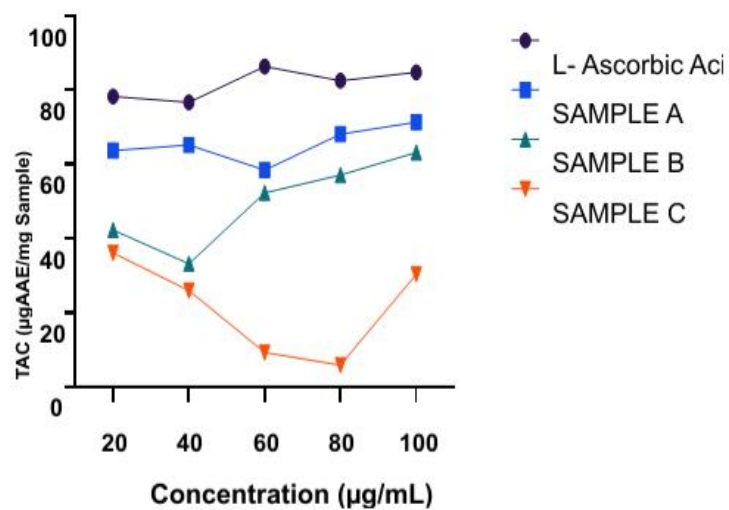


Figure 4.2: Total antioxidant capacity (TAC)

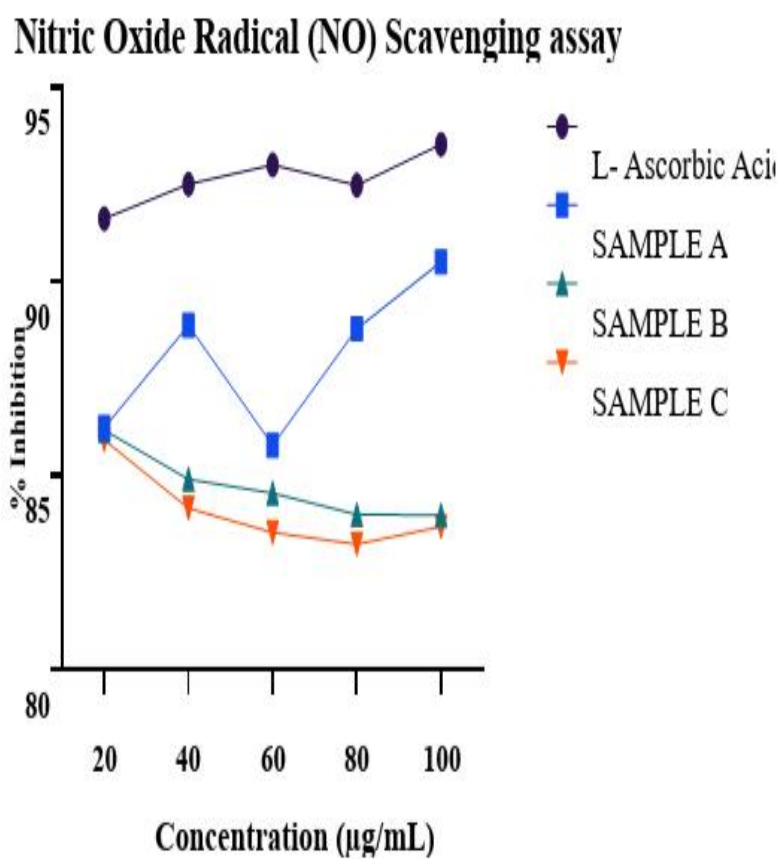


Figure 4.3: Nitric Oxide Radical Scavenging activity

Table 4.1: Nitric Oxide (NO) Scavenging Activity (IC₅₀) of Sample *Formulations*

Sample Formulation	IC₅₀ Value (mg/ml)	Activity Classification
Control (L-Ascorbic acid)	<0.001	Standard
Sample A	0.0006	Potent
Sample B	0.031	Very Strong
Sample C	0.288	Moderate

CHAPTER 5

5.0. DISCUSSION AND CONCLUSION

5.1. Discussion

The rising global incidence of hypertension has intensified the search for functional foods as complementary or preventive strategies. This study successfully developed a novel snack bar incorporating flours from Cardaba banana, beetroot, tigernut, soyabean, and *Justicia carnea* leaves, and evaluated its potential through key *in vitro* assays related to oxidative stress and vascular function. The results unequivocally demonstrate that the incorporation of the selected functional flours significantly enhanced the bioactivity of the snack bars compared to the control formulated with conventional all-purpose flour. The observed dose-dependent increase in activity across Samples A, B, and C, which corresponded with an increasing proportion of Cardaba banana flour, highlights the synergistic contribution of the composite ingredients. The superior H₂O₂ scavenging activity of the experimental samples, especially Sample A, indicates a potential ability to neutralize this reactive oxygen species (ROS). H₂O₂, while a weak oxidant itself, can be converted into a highly damaging hydroxyl radical in the presence of metal ions via the Fenton reaction. This radical is implicated in lipid peroxidation, protein denaturation, and DNA damage, all of which contribute to endothelial dysfunction and the pathogenesis of hypertension (Rahman *et al.*, 2025). The high scavenging activity can be attributed to the rich phytochemical profile of the ingredients. *Justicia carnea* is known for its flavonoids and tannins, beetroot is rich in betalains, and tigernuts contain phenolic compounds. These compounds can donate electrons to stabilize and neutralize H₂O₂, thereby reducing oxidative stress and potentially protecting vascular tissues. The phosphomolybdenum assay revealed that Sample A had the highest Total Antioxidant Capacity. This assay provides a cumulative measure of the reducing

capacity of all antioxidants present in the sample, including phenolics, ascorbic acid, and tocopherols. The high TAC value for Sample A suggests a high concentration of electron-donating compounds. Cardaba banana is a significant source of polyphenols and flavonoids (Swargiary *et al.*, 2021), while soyabeans contribute isoflavones like genistin (Kim, 2021). The combination of these ingredients creates a complex mixture of antioxidants that can act through various mechanisms to combat oxidative stress, a key driver of hypertension by promoting vasoconstriction and inflammation. Furthermore, this *in vitro* activity complements the known mechanism of beetroot, which is rich in dietary nitrate. Upon consumption, nitrate is converted to nitrite and then to NO in the body, promoting vasodilation and lowering blood pressure (Bahrami *et al.*, 2021). Thus, the formulated snack bar may offer a dual benefit: scavenging harmful free radicals *in vitro* while providing a dietary precursor for beneficial NO production *in vivo*. The superior performance of Sample A suggests that the 90g formulation of Cardaba banana flour provided an optimal matrix that enhanced the bioavailability or synergistic interaction of the bioactive compounds from all the ingredients.

5.2 Conclusion

This study successfully developed a functional snack bar from Cardaba banana, beetroot, tigernuts, soya bean, and *Justicia carnea* leaves. The *in vitro* analyses confirmed that the formulated snacks, particularly Sample A, possess significant antioxidant properties, as evidenced by their strong hydrogen peroxide scavenging activity, high total antioxidant capacity, and potent nitric oxide radical inhibition. These properties are crucial for mitigating oxidative stress, a key factor in the development and progression of hypertension. The findings provide a strong scientific basis for the potential of this portable snack as a dietary strategy for managing blood pressure.

REFERENCES

- Abolfazli, S., Mortazavi, P., Kheirandish, A., Butler, A.E., Jamialahmadi, T. and Sahebkar, A. (2024). Regulatory effects of Curcumin on nitric oxide signaling in the Cardiovascular System. *Nitric Oxide: biology and chemistry*,143:16-28
- Abrahamowicz, A.A., Ebinger, J., Whelton, S.P., Commodore-Mensah, Y. and Yang, E. (2023). Racial and ethnic disparities in hypertension: *Barriers and opportunities to improve blood pressure control. Current Cardiology Report*, 25(1): 17–27.
- Adenowo, A.F. and Kazeem, M.I. (2020). Tigernut as a functional food, pharmacological and industrial agent: A mini review. *Annals of Science and Technology*, 5(1): 31–38.
- Ahmad, M. and Gani, A. (2021). Development of novel functional snacks containing nano-encapsulated resveratrol with anti-diabetic, anti-obesity and antioxidant properties. *Food Chemistry*, 352: 129–323.
- Ahmad, F. and Gani, A. (2021). Bioactive polysaccharides and their role in functional foods: A review. *Food Reviews International*, 37(6): 665–700.
- Al-Mamary, A.M. and Moussa, Z. (2021). Antioxidant activity: The presence and impact of hydroxyl groups in small molecules of natural and synthetic origin. *Antioxidants-Benefits, sources, mechanisms of action*, 253.
- Alsharif, N.S., Clifford, T., Alhebshi, A., Rowland, S.N. and Bailey, S.J. (2023). Effects of dietary nitrate supplementation on high-intensity exercise: *A systematic review and meta-analysis. Antioxidants*, 12(6): 1194.
- Alsallamin, I., Chakhachiro, D., Bawwab, A., Nassar, M. and Alsallamin, A. (2023). Prevalence of symptomatic gallbladder disease after bariatric surgery: *A literature review. Cureus*, 15(4): 37777.
- Altieri, M.S., Irish, W., Pories, W.J., Shah, A. and DeMaria, E.J. (2021). Examining the rats of obesity and bariatric surgery in the United States. *Obesity surgery*, 31(11):4754-4760.

- Anarado, C., Ajiwe, V., Obumselu, O.F., Umedum, N.L. and Okafor, S.E. (2021). Phytochemistry, ethnomedicinal and pharmacological uses of *Justicia carnea*: A review. *South Asian Research Journal of Natural Products*, 4(4): 85–93.
- Andres, C.M.C., De la Lastra, J.M.P., Juan, C.A., Plou, F.J. and Perez-Lebena, E. (2022). Chemistry of Hydrogen Peroxide formation and elimination in Mammalian cells and its role in various Pathologies. *Stresses*, 2(3):256-274.
- Apak, R., Calokerinos, A., Gorinstein, S., Segundo, M.A., Hibbert, D.B., Gulcin, I., Cekic, S.D., Guclu, K., Ozyurek, M., Celik, S.E., Magalhaes, L.M. and Arancibia-Avila, P. Pure and Applied Chemistry, 94(1):87-144.
- Asare, P.A., Kpari, R.K., Adu, M.O., Afutu, Emmanuel. And Adewumi, A.S. (2020). Phenotypic Characterization of Tigernuts (*Cyperus esculentus* L.) from major growing areas in Ghana. *The Scientific World Journal*, 2020(1):7232591.
- Ayo-Omogie, H.N. (2023). Unripe banana and defatted sesame seed flours improve nutritional profile, dietary fibre and functional properties of gluten-free sorghum cookies. *Food production, Processing and Nutrition*, 5(1):41.
- Ayo-Omogie, H.N., Johnson, O.O., Awolu, O.O. and Oluwajuyitan, T.D. (2022). Physicochemical, functional, pasting properties and Fourier Transform Infrared Spectroscopy of pure and modified Cardaba banana (*Musa ABB*) starches.
- Bahrami, L.S., Arabi, S.M., Feizy, Z. and Rezvani, R. (2021). The effect of beetroot inorganic nitrate supplementation on cardiovascular risk factors. A systematic review and metaregression of randomized controlled trials, 115: 8-22.
- Baiao, D.D.S., da Silva, D.V.T. and Paschoalin, V.M.F. (2020). Beetroot: Its nitrate and phytochemical contents for cardiovascular support. *Antioxidants*, 9(10): 960.
- Baiao, D.D.S., da Silva, D.V.T. and Paschoalin, V.M.F. (2021). Dietary strategies to deliver nitric oxide: Beetroot formulations. *Foods*, 10(4): 859.
- Bahadoran, Z., Mirmiran, P., Kabir, A., Azizi, F. and Ghasemi, A. (2017). The nitrate-independent blood pressure-lowering effect of beetroot juice. *Advances in Nutrition*, 8(6): 830–838.

- Bangar, S.P., Sharma, N., Sanwal, N., Lorenzo, J.M. and Saliu, J.K. (2022). Beetroot bioactive components and their applications. *Food Research International*, 158: 111556.
- Benjamim, C.J.R., Porto, A.A., Valenti, V.E., Sobrinho, A.C.S., Garner, D.M., Gualano, B. and Bueno Junior, C.R. (2023). Nitrate from beetroot juice lowers blood pressure: A meta-analysis. *Frontiers in Nutrition*, 9: 823039.
- Carreon-Hidalgo, J.P., Franco-Vasquez, D.C., Gomez-Linton, D.R. and Perez-Flores, L.J. (2022). Betalain sources, biosynthesis and applications. *Food Research International*, 151: 110821.
- Chapa-Dubocq, X.R., Rodriguez-Graciani, K.M., Escobales, N. and Javadov, S. (2023). Mitochondrial volume Regulation and Swelling Mechanisms in Cardiomyocytes. *Antioxidants*, 12(8):1517.
- Cheema, K.M., Dicks, E., Pearson, J. and Samani, N.J. (2022). Long-term trends in the epidemiology of cardiovascular diseases in the UK: insights from the British Heart Foundation Statistical Compendium. *Cardiovascular resource*, 118:2267-2280
- Chen, Z., Liang, W., Liang, J., Dou, J., Guo, F., Zhang, D., Xu, Z. and Wang, T. (2023). Probiotics: functional food ingredients with the potential to reduce hypertension. *Frontiers in Cellular and Infection Microbiology*, 13:1220877.
- Clarke, R., Zarezaeh, M. and colleagues (2023). Effects of probiotic supplementation on blood pressure: A systematic review and meta-analysis. *Food Science and Nutrition*, 11(3): 1202–1216.
- Cyr, A.R., Huckaby, L.V., Shiva, S.S. and Zuckerbraun, B.S. (2020). Nitric Oxide and Endothelial Dysfunction. *Critical Care Clinics*, 36(2):307-321
- Daliri, E.B.M., Ofosu, F.K., Chelliah, R., Lee, B.H., An, H., Elahi, F., Barathikannan, K., Kim, J.H. and Oh, D.H. (2020). Effects of fermented soy protein on hypertension and gut microbiota. *Food Research International*, 39(4): 199–208.
- Dasinger, J.H., Fehrenbach, D.J. and Abais-Battad, J.M. (2020). Dietary protein: Mechanisms influencing Hypertension and renal diseases. *Current hypertension reports*, 22(2):13.

- Dey, A., Gupta, S. and Azad, M. (2020). Functional properties and cardiovascular implications of tigernut. *Journal of Food Biochemistry*, 44(12): 13582.
- Djomdi, H.B., Gilbert, O., Tran, T., Delattre, C., Pierre, G., Michaud, P., Ejoh, R. and Ndjouenkeu, R. (2020). Innovation in tigernut milk production via in situ starch hydrolysis. *Polymers*, 12(6): 1404.
- Dri, E., Lampas, E., Lazaros, G., Lazarou, E., Theofilis, P., Tsioufis, C. and Tousoulis, D. (2023). Inflammatory mediators of Endothelial Dysfunction, 13(6):1420
- Edo, G.I., Onoharigho, F.O., Jikah, A.N., Oloni, G.O., Samuel, P.O., Rapheal, O.A., Ikpekoru, O., Akpoghelie, P.O., Agbo, J.J., Ekokotu, H.A., Ugbune, U., Ezekiel, G.O., Abere, G.A., Oghroro, E.E.A., Ojulari, A.E., Okoronkwo, K.A., Owheru, J.O. and Akpoghelie, E.O. (2023). Cyperus esculentus (tigernuts): an insight into its bioactive compounds, biological activities, nutritional and health benefits. *Food Chemistry Advances*, 3:100511.
- English, W.J., De Maria, E.J., Hutter, M.M., Kothari, S.N., Mattar, S.G. and Brethauer, S.A. (2020). ASMBS estimate of metabolic and bariatric procedures in the United States. *Surgery for Obesity and Related Diseases*, 16(4): 457–463.
- Falodun, A.J., Ayo-Omogie, H.N. and Awolu, O.O. (2025). Techno-functional and nutritional variations of Cardaba banana flour. *Journal of Food Measurement and Characterization*, 19: 1–12.
- Filippou, C.D., Tsioufis, C. and Thomopoulos, C. (2020). Effects of functional foods on blood pressure. *Current Hypertension Reports*, 22: 72.
- Ghafar, M.T. (2020). RAAS pathways and genetic polymorphisms in essential hypertension. *Steroids*, 163: 108701.
- Glazer, S. and Biertho, L. (2020). Bariatric surgery: Selection and preoperative Workup. 1-10
- Granato, D., Barba, F.J., Bursac Kovacevic, D., Lorenzo, J.M., Cruz, A.G. and Putnik, P. (2020). Functional food product development: Trends and safety. *Foods*, 11: 93.
- Goorani, S., Zangene, S. and Imig, J.D. (2025). Hypertension as a global public health issue. *International Journal of Molecular Sciences*, 26(1): 123.

- Hassan, S.M., Ahmed, Z., Ateye, M.D., Yasin, N.D. and Jerar, H.M. (2025). Optimization of nutritional and anti-nutritional factors in Somali wheat injera fortified with chickpea and soybean using response surface methodology. *Next Reseach*, 2(1):100153.
- Hastuti, P., Wibowo, A. and Susanti, V. (2021). ACE I/D and AGT M235T polymorphisms and essential hypertension: *A meta-analysis*. *Hypertension Research*, 44: 1023–1035.
- Health Canada / Obesity Canada (2020). Bariatric surgery: Selection and pre-operative workup. *Canadian Adult Obesity Clinical Practice Guidelines*.
- Higgins, M.R., Izadi, A. and Kaviani, M. (2020). Antioxidants and Exercise Performance with a focus on Vitamin E and C supplementation. *International Journal of Environmental research and public health*, 17(22):8452.
- Hyslop, P.A. and Chaney, M.O. (2022). Mechanism of GAPDH Redox Signalling by Hydrogen Peroxide Activation of a Two-Cysteine Switch. *International Journal of Molecular Science*, 23(9):4604
- Ishani, A., Cushman, W.C., Leatherman, S.M., Lew, R.A., Woods, P., Glassman, P.A., Taylor, A.A. et al. (2022). Intensive blood pressure control in CKD. *New England Journal of Medicine*, 387(26): 2401–2410.
- Islam, M.S., Muhyidiyn, I., Islam, M.R., Hasan, M.K., Hafeez, A.G., Hosen, M.M., Saneoka, H., Ueda, A., Liu, L., Naz, M., Barutcular, C., Lone, J., Raza, M.A., Chowdhury, M.K., Sabagh, A.E. and Erman, M. (2022). Soybean and sustainable agriculture for food security. *Soybean-recent advances in research and applications*.
- Jabar, J.M., Oluwasina, O.O., Agunloye, O.M., Akinmoladun, A.C., Akande, O.A., Ojo, E.T. and Olojuolawe, H.O. (2025). Brazilian Plume (*Justicia carnea* L.) Leaf Wine-Colored Extract for Natural Dyeing of Mordant-Functionalized Cellulosic Fabric:Color Strength, Coordinates and Fastness. *Chemistry*, 7(1):23
- Jakovljevic, M., Westerman, R., Sharma, T. and Lamnisos, D. (2020). Aging and global health. In *Handbook of Global Health*. Springer.
- Karwowska, M. and Kononiuk, A. (2020). Nitrates and nitrites in food: Risks and benefits. *Antioxidants*, 9(3): 241.

- Kim, I.S., Kim, C.H. and Yang, W.S. (2021). Physiologically active molecules and functional properties of soybeans in human health-A current perspective. *International journal of molecular sciences*, 22(8):4054
- Klerks, M., Roman, S., Verkerk, R. and Sanchez-Siles, L.M. (2022). Healthiness of cereal bars versus chocolate bars in Germany. *Journal of Functional Foods*, 89: 104940.
- Ko, S.H. and Kim, H.S. (2020). Menopause-associated lipid metabolic disorders and foods beneficial for post menopausal women. *Nutrients*, 12(1):202.
- Knez, E., Kadac-Czapska, K., Dmochowska-Slezak, K. and Grembecka, M. (2022). Root Vegetables-Composition, health effects and contaminants. *International journal of environmental research and public health*, 19(23):15531.
- Kuneinen, S.M., Kautiainen, H., Ekblad, M.O. and Korhonen, P.E. (2024). Multifactorial prevention program for cardiovascular disease in primary care: hypertension status and effect on mortality. *Journal of Human Hypertension*, 38(4): 322-328.
- Kushwah, N., Bora, K., Maurya, M., Pavlovich, M.C. and Chen, J. (2023). Oxidative stress and Antioxidants in Age-related Macular Degeneration. *Antioxidants*, 12(7):1379
- Lobine, D., Rengasamy, K.R.R. and Mahomoodally, M.F. (2021). Marine functional foods and future perspectives. *Critical Reviews in Food Science and Nutrition*, 62(21): 5794–5823.
- Loutradis, C., Price, A., Ferro, C.J. and Sarafidis, P. (2021). RAS blockade in CKD: Challenges and benefits. *Clinical Kidney Journal*, 14(8): 1–11.
- Madhayan, K., Balamurugan, V. and Suganya, S. (2022). Phytochemical screening, antioxidant and anti-inflammatory properties of *Litsea floribunda* Gamble, leaf and bark extract. *Turkish journal of Agricultural Food Science*, 10(4):719-725.
- Mancia, G., Kjeldsen, S.E., Kreutz, R., Pathak, A., Grassi, G. and Esler, M. (2022). Individualized beta-blocker treatment for hypertension. *Hypertension*, 79(6): 1153–1166.
- Martirosyan, D. (2025). Functional food science and bioactive compounds. *Bioactive Compounds in Health and Disease-Online*, 8(6): 218-229.

- Mirmiran, P., Houshialsadat, Z., Gaeini, Z., Bahadoran, Z. and Azizi, F. (2020). Functional properties of beetroot (*Beta vulgaris*) in management of cardio-metabolic diseases. *Nutrition and metabolism*, 17(1):3.
- Mocan, O., Radulescu, D. and Buzdugan, E. (2021). Association between RAAS polymorphisms and essential hypertension. *Biomedical Reports*, 15(4): 1–2.
- Mocanu, M.L. and Amariei, S. (2022). Elderberries as a source of antiviral bioactive compounds. *Plants*, 11(6): 740.
- Mondal, S., Soumya, N.P.P., Mini, S. and Sivan, S.K. (2021). Bioactive compounds in functional food and their role as therapeutics. *Bioactive compounds in Health and Disease-Online*, 4(3):24-39.
- Morou-Bermudez, E., Torres-Colon, J.E., Bermudez, N.S., Patel, R.P. and Joshipura, K.J. (2022). Pathways linking oral bacteria, nitric oxide metabolism and health. *Journal of Dental Research*. 101(6):623-631.
- Mujtaba, N., Jahan, N., Bushra, S. and Zia, M.A. (2021). Isolation and characterization of antihypertensive peptides from soybean protein. *Brazilian Journal of Pharmaceutical Sciences*, 57:19061.
- Ocampo, D.A.B., Díaz, A.C., Rincón, M.C.B., Santos, L.S., Marangoni, A.G. and Parra, D.F. (2018). Dietary nitrate from beetroot juice for hypertension. *Biomolecules*, 8(4): 134.
- Okocha, B.I., Orié, K.J., Duru, R. and Ngochindo, R.L. (2023). Metabolites of *Justicia carnea*. *African Journal of Biomedical Research*, 26(1): 109–117.
- Olawoye, B. and Gbadamosi, S.O. (2020). Sensory profiling and mapping of gluten-free cookies made from blends Cardaba banana flour and starch. *Journal of Food Processing and Preservation*, 44(9):14643
- Olawoye, B., Fagbohun, O.F., Gbadamosi, S.O. and Akanbi, C.T. (2022). Resistant starch improvement in Cardaba banana starch. *Journal of Food Processing and Preservation*, 46(7): 16234.

- Olumese, F.E. and Oboh, H.A. (2020). Aqueous beetroot juice extract improves renal function and some biochemical parameters in carbon tetrachloride-induced toxicity in Sprague Dawley rats. *Annals of Tropical Pathology*, 11(2):171-175.
- Oluwakemi, A.A., Ireunmi, A.F., Joshua, S.K. and Iweunor, N.D. (2021). Mineral and phytochemical content of tigernut. *World Journal of Applied Chemistry*, 6(3): 36–40.
- Oteng, A.B. and Kersten, S. (2020). Nutrient metabolism in health. *Advances in Nutrition*, 11(3): 697–708.
- Pavitt, M.J., Lewis, A., Buttery, S.C., Fernandez, B.O., Mikus-Lelinska, M., Banya, W.A.S. et al. (2022). Dietary nitrate supplementation and exercise capacity in COPD. *Thorax*, 77(10): 968–975.
- Perry, M. (2023). Hypertension: An overview. *Journal of Clinical Hypertension*, 25(4): 345–352.
- Plamada, D. and Vodnar, D.C. (2022). Polyphenols–gut microbiota interactions. *Nutrients*, 14(1): 137.
- Rahman, M.D.A., Khatun, M.S.T., Mim, A.K., Khandocar, M.D.P., Rahman, A., Hasan, M.D.H., Shimki, A.I., Hossain, M.D.S., Shoily, M.S.T., Faraque, A., Amin, M.D.F., Ferdous, R. and Islam, M.D.S. (2025). *Cell Biochemistry and Biophysics*, 1-20.
- Rehman, S., Rehman, E., Mumtaz, A. and Jianglin, Z. (2022). Cardiovascular mortality in China: A grey relational assessment. *International Journal of Public Health*, 67: 215–228.
- Rison, S.C.G., Carvalho, C., Rull, G. and Robson, J. (2022). Investigating hypertension in younger patients. *BMJ*, 376:067924
- Rodriguez-Graciani, K.M., Chapa-Dubocq, X.R., Ayala-Arroyo, E.J., Chaves-Negron, I., Jang, S., Chorna, N., Maskrey, T.S., Wipf, P. and Javadov, S. (2022). Effects of Ferroptosis on the metabolome in cardiac cells: The Role of Glutaminolysis. *Antioxidants*, 11(2):278.
- Samakosky, M.J. and Norris, S.A. (2024). Precision prevention for hypertension. *Global Health Action*, 17(1): 2422169.

- Samuel, P.O., Edo, G.I., Emakpor, O.L., Oloni, G.O., Ezekiel, G.O., Essaghah, A.E.A., Agoh, E. and Agbo, J.J. (2023). Lifestyle modifications for cardiovascular disease prevention. *Sport Sciences for Health*, 20(1): 23–36.
- Selma-Royo, M., Garcia-Mantrana, I., Collado, M.C. and Perez-Martinez, G. (2022). Intake of Natural, Unprocessed Tiger Nuts (*Cyperus esculentus* L.) Drink Significantly Favors Intestinal Beneficial Bacteria in a Short Period of Time. *Nutrients*. 14(9):1709.
- Senefeld, J.W., Wiggins, C.C., Regimbal, R.J., Dominelli, P.B., Baker, S.E. and Joyner, M.J. (2020). Ergogenic effect of nitrate supplementation. *Medicine and Science in Sports and Exercise*, 52(10): 2250–2261.
- Sentkowska, A. and Pyrzynska, K. (2023). Red beet as a functional food. *Applied Sciences*, 13(13): 7445.
- Shah, S.S. and Yadav, R. (2022). Latest strategies to tackle hypertension. *International Journal of Science Health Care Research*, 4(1): 1–7.
- Shakir, B.K. and Simone, V. (2024). Betalain content in beetroot peel powder. *Italian Journal of Food Science*, 36(1): 53–57.
- Shariq, O.A. and McKenzie, T.J. (2022). Obesity-related hypertension. *Gland Surgery*, 9(1): 80–95.
- Shuaibu, B.S., Aremu, M.O. and Kalifa, U.J. (2021). Phytochemicals and antioxidant activity of beetroot peel. *Food Science and Nutrition*, 9(3): 1234–1242.
- Simon, E., Calinoiu, L.F., Mitrea, L. and Vodnar, D.C. (2021). Probiotics, prebiotics and synbiotics in IBS. *Nutrients*. 13(6): 2112.
- Singh, A.(2025). Response of Soybean to Variable Irrigation Levels in Eastern Nebraska Using the AquaCrop Model.
- Soeters, P.B. (2020). Current opinion in Clinical Nutrition and Metabolic Care. 23(2):151-153.

- Sukrasno, S., Rizaldy, D., Kurniati, N.F., Raihanah, C. and Iman, A.A. (2025). Protease-aided soybean tempeh hydrolysates inhibit ACE activity. *Preventive Nutrition and Food Science*, 30(4): 379–390.
- Swain, P. and Banerjee, D. (2021). Prevalence and risk factors of hypertension in India. *Journal of Preventive Medicine and Holistic Health*, 3(2): 45–57.
- Thakur, N., Raigond, P., Singh, Y., Mishra, T., Singh, B., Lal, M.K. and Dutt, S. (2020). Bioaccessibility of phytonutrients. *Trends in Food Science and Technology*, 97: 366–380.
- Thiruvengadam, M., Chung, I.M., Samynathan, R., Chandar, S.R.H., Venkidasamy, B., Sarkar, T., Rebezov, M., Gorelik, O., Shariati, M.A. and Simal-Gandara, J. (2024). Comprehensive review of beetroot bioactive compounds. *Critical Reviews in Food Science and Nutrition*, 64(3): 708–739.
- Touria, L., Wafae, L., Francesco, C. and Farida, S. (2022). Set of internal and external factors influencing olive oil (*Olea europaea* L.) composition : A review. *European Food Research and Technology*, 21:3947.
- Ud Din, S.R., Saeed, S., Khan, S.U., Kiani, F.A., Alsuhaibani, A.M. and Zhong, M. (2023). Bioactive compounds for cardiovascular disease prevention. *Current Problems in Cardiology*, 48(7): 101664.
- Udedi, S.C., Umeohia, M.C., Asogwa, K.K. and Ubaaji, K.I. (2020). Effects of Ethanol Leaf Extracts of *Justicia carnea* on Reproductive Function of Male Wistar Albino Rats. *Journal of Pharmacy and Biological Science*, 15(5):9-20.
- Ukpabi-Ugo, J., Chigozue, L. and Uhuo, E.N. (2023). Subacute toxicity of methanol extract of *Justicia carnea*. *Animal Research International*, 20: 4862–4875.
- Unger, T., Borghi, C., Charchar, F., Khan, N.A., Poulter, N.R., Prabhakaran, D., Ramirez, A., Schlaich, M., Stergion, G.S., Tomaszewski, M., Wainford, R.D., Williams, B. and Schutte, A.E. (2020). Global hypertension practice guidelines. *Hypertension*, 75(6): 1334–1357.

- WHO, (2023). Global report on hypertension: the race against a silent killer. World Health Organization, 2023.
- Wibowo, A., Hastuti, P. and Susanti, V. (2021). The Association of Angiotensin – converting enzyme I/D and Angiotensinogen M235T Polymorphism genes with EH. A meta- analysis. *Macedonian Journal of Medical Sciences*, 9(F):739-746.
- Yang, X., Niu, L., Zhang, Y., Ren, W., Yang, C., Yang, J., Xing, G., Zhong, X., Zhang, J., Slaski, J. and Zhang, J. (2022). Morphological and biochemical characterization of tigernuts. *Plants*, 11(7): 923.
- Yu, Y., Lu, X., Zhang, T., Zhao, C., Guan, S., Pu, Y. and Gao, F. (2022). Tigernut: Nutrition, processing, function and applications. *Foods*, 11(4): 601.
- Zhang, C.Y., Liu, S. and Yang, M. (2023). Antioxidant and Anti-inflammatory agents in chronic liver diseases. Molecular mechanisms and therapy. *World Journal of Hepatology*, 15(2):180.

APPENDIX

The raw percentage inhibition values of Hydrogen Peroxide activity, Total antioxidant capacity and Nitric oxide analyses are expressed below:

H2O2		Abs			H2O2
Abs2	Abs3	Aver	A0	%	% Inhib
0.498	0.498	0.4963	1.626	100	69.4752
0.501	0.499	0.4993	1.626	100	69.2907
0.521	0.555	0.5292	1.626	100	67.4539
0.562	0.572	0.564	1.626	100	65.3137
0.586	0.591	0.5827	1.626	100	64.1656
0.546	0.552	0.5447	1.626	100	66.5027
0.582	0.564	0.57	1.626	100	64.9446
0.582	0.577	0.5817	1.626	100	64.2271
0.594	0.59	0.59	1.626	100	63.7146
0.56	0.563	0.5757	1.626	100	64.5961
0.485	0.508	0.4903	1.626	100	69.8442
0.543	0.539	0.537	1.626	100	66.9742
0.549	0.546	0.5467	1.626	100	66.3797
0.561	0.561	0.561	1.626	100	65.4982
0.579	0.586	0.585	1.626	100	64.0221
0.068	0.061	0.063	1.626	100	96.1255
0.058	0.049	0.0537	1.626	100	96.6995
0.073	0.078	0.0757	1.626	100	95.3465
0.065	0.072	0.0683	1.626	100	95.7975
0.051	0.045	0.0477	1.626	100	97.0685

	TAC		Aver	TAC (mg)
Abs 1	Abs 2	Abs 3	Abs	
0.712	0.722	0.784	0.7393	3.7107
1.07	1.09	0.1061	0.7554	5.2233
1.168	1.119	1.194	1.1603	43.428
1.1	1.135	1.137	1.124	40
1.158	1.197	1.172	1.1757	44.874
0.632	0.81	0.732	0.7247	2.327
1.082	1.026	1.047	1.0517	33.176
1.244	1.227	1.292	1.2543	52.296
1.302	1.307	1.307	1.3053	57.107
1.36	1.38	1.37	1.37	63.208
0.313	0.338	0.301	0.3173	-36.1
0.4	0.471	0.404	0.425	-25.94
0.739	0.638	0.428	0.6017	-9.277
0.714	0.856	0.716	0.762	5.8491
1.03	0.997	1.04	1.0223	30.409
1.518	1.495	1.484	1.499	75.377
1.512	1.466	1.45	1.476	73.208
1.507	1.355	1.389	1.417	67.642
1.514	1.475	1.402	1.4637	72.044
1.48	1.522	1.554	1.5187	77.233

	NITRIC	OXIDE	Aver			Nitric
Abs 1	Abs 2	Abs 3	Abs	A0	%	% Inhib
0.224	0.23	0.229	0.2277	1.654	100	86.2354
0.24	0.256	0.257	0.251	1.654	100	84.8247
0.256	0.256	0.266	0.2593	1.654	100	84.3208
0.274	0.27	0.262	0.2687	1.654	100	83.7565
0.262	0.278	0.271	0.2703	1.654	100	83.6558
0.228	0.224	0.234	0.2287	1.654	100	86.1749
0.254	0.254	0.241	0.2497	1.654	100	84.9053
0.253	0.256	0.258	0.2557	1.654	100	84.5425
0.262	0.262	0.27	0.2647	1.654	100	83.9984
0.263	0.268	0.264	0.265	1.654	100	83.9782
0.237	0.236	0.226	0.233	1.654	100	85.9129
0.26	0.264	0.262	0.262	1.654	100	84.1596
0.271	0.275	0.271	0.2723	1.654	100	83.5349
0.279	0.277	0.276	0.2773	1.654	100	83.2326
0.263	0.272	0.275	0.27	1.654	100	83.6759
0.139	0.135	0.142	0.1387	1.654	100	91.6163
0.12	0.126	0.126	0.124	1.654	100	92.503
0.121	0.118	0.108	0.1157	1.654	100	93.0069
0.133	0.129	0.111	0.1243	1.654	100	92.4829
0.109	0.106	0.106	0.107	1.654	100	93.5308