DEVELOPMENT, PROXIMATE AND ORGANOLEPTIC EVALUATION OF BISCUITS MADE FROM BAMBARA GROUNDNUTS, CARDABA BANANAS AND BEETROOT FOR BLOOD GLUCOSE REGULATION

BY

IMASUEN JAMES AISOSA

(BMS2101415)

DEPARTMENT OF MEDICAL BIOCHEMISTRY

SCHOOL OF BASIC MEDICAL SCIENCES

COLLEGE OF MEDICAL SCIENCES

UNIVERSITY OF BENIN

DECEMBER, 2025

DEVELOPMENT, PROXIMATE AND ORGANOLEPTIC EVALUATION OF BISCUITS MADE FROM BAMBARA GROUNDNUTS, CARDABA BANANAS AND BEETROOT FOR BLOOD GLUCOSE REGULATION

BY

JAMES IMASUEN AISOSA

(BMS2101415)

A PROJECT SUBMITTED TO THE DEPARTMENT OF MEDICAL BIOCHEMISTRY, SCHOOL OF BASIC MEDICAL SCIENCES IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF SCIENCE, B.Sc. (HONS) MEDICAL BIOCHEMISTRY, OF THE UNIVERSITY OF BENIN, BENIN CITY

DECEMBER, 2025

CERTIFICATION

We the undersigned hereby certify that IMASUEN JAMES AISOSA (BMS2101415) carried out this research in the Department of Medical biochemistry, School of Basic Medical Sciences, College of Medical Sciences, University of Benin, Benin city and thereby approve same as adequate in scope and quality for the award of Bachelor of Science Degree (B.Sc) in Medical Biochemistry.

Signed

....

Prof. H.A. Oboh   **(Date)**

(Project Supervisor)

....

Dr. B. N. Aguebor-Ogie   **(Date)**

(Ag. Head of Department)

....

External Examiner   **(Date)**

DEDICATION

This project is dedicated to Almighty God, who has made it possible to complete my Bachelor of Science Degree (B.Sc) program in the Department of Medical biochemistry.

ACKNOWLEDGEMENTS

I would like to extend my heartfelt gratitude to the individuals who have contributed significantly to the successful completion of this project. First and foremost, I extend my sincere and deepest appreciation to my project supervisor, Prof. (Mrs.) Henrietta Oboh and project group coordinator Mr. Collins Ebiaguanye. Your unwavering patience, invaluable guidance, and insightful critiques from the inception to the finalization of this work were instrumental. Your expertise not only shaped the direction of this research but also deeply enriched my learning experience.

I am also deeply grateful to the Head of our Department, Dr. Aguebor-Ogie N.B, for providing a conducive academic environment and the necessary resources that facilitated this study. My sincere thanks also go to my esteemed lecturers, Mrs. Ikponmwosa Eweka, Mr. Eguavoen Aisosa, Dr. (Mrs.) Eluehike, and Dr. (Mrs). Orosanye Oseghale, whose impactful lectures and guidance formed the bedrock of this research project

My heartfelt thanks go to my dedicated project group members. Your collaboration, shared ideas, and moral support during the challenging phases of this work made the journey not only manageable but also enjoyable. This achievement is as much yours as it is mine.

On a more personal note, I wish to thank my parents, Mr and Mrs. Imasuen. Thank you for your unwavering belief in me, for the much-needed distractions, and for being my pillars of strength and sources of laughter throughout this intense period.

While I have mentioned these names, my gratitude extends to everyone who, in one way or another, contributed to the realization of this project. Thank you all.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The global rise in Type 2 Diabetes necessitates dietary interventions, with low-glycemic functional foods offering a promising management strategy. While the separate health benefits of indigenous crops like Bambara groundnut (*Vigna subterranea)*, Cardaba banana (*Musa Balbisiena)*, and beetroot *(Beta vulgaris)* are known, a significant knowledge gap exists regarding their synergistic efficacy in a composite food product. This study therefore aimed to develop and evaluate the blood glucose-lowering potential of a functional snack bar formulated from these indigenous Nigerian ingredients. Bambara groundnut, Cardaba banana, and beetroot were processed into flours/powders. Three snack bar formulations (Samples A, B, C) with varying proportions of these ingredients, along with guava leaf and cinnamon powder, were developed. The nutritional composition of the snacks was determined through proximate analysis (AOAC methods) for moisture, ash, crude FIBER, fat, protein, and carbohydrate content. Consumer acceptability was assessed via sensory evaluation by a 75-member panel. Data were analyzed using ANOVA. The proximate analysis revealed a strong nutritional profile across all samples, characterized by high complex carbohydrate (66.04-70.78%) and FIBER content (0.60-1.43%), alongside low fat (0.87-1.00%) and appreciable protein levels (7.32-7.95%). Sensory evaluation indicated high consumer acceptability, with Sample C emerging as the most preferred formulation. In conclusion, the study successfully developed a palatable and nutrient-dense functional snack bar from indigenous crops, with a composition conducive to glycemic control. The formulated snack, particularly Sample C, represents a viable, culturally acceptable dietary option for managing Type 2 Diabetes, warranting further in-vivo studies to confirm its anti-diabetic efficacy.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Diabetes mellitus constitutes a major worldwide health challenge represented by persistent high blood sugar levels resulting from abnormalities in insulin production or action (World Health Organization, 2023). The healthcare system worldwide faces growing challenges because Type 2 diabetes cases continue to rise at an alarming rate in Sub-Saharan Africa. The nutritional pattern of people has changed toward consuming more processed carbohydrates and less dietary fiber which directly links to the rising Type 2 Diabetes rates (Udeh *et al.,* 2024). The management of diabetes through diet has established itself as a fundamental approach to fight this disease. The Glycemic Index serves as a vital resource which helps people select foods that produce gradual and minimal blood sugar increases. Research shows that consuming low-GI foods leads to improved blood sugar management and reduced chances of developing diabetes (Reynolds *et al.,* 2020). The functional food industry has undergone changes during this time. The industry now uses whole functional ingredients to create new food products instead of adding single nutrients to existing foods. The strategic implementation of composite flours derived from legumes and tubers and fruits represents a major development in this market segment (Menon *et al.,* 2024). The method matches perfectly with the initiative to use local crops because these plants contain beneficial attributes including fiber content and digestion-slowing carbohydrates. Research exists about the separate health advantages of Bambara groundnut and Cardaba banana and beetroot. A major knowledge deficit exists in this field. The scientific community lacks research about how these three ingredients work together in an optimized food product such as a biscuit. The scientific community needs more information about how processing affects composite food blends. The research aims to establish a scientifically-based functional snack that respects cultural values.

1.2 AIM OF STUDY

The aim of the study was to assess the blood glucose level-lowering effects of a formulated snack bar and assess its effectiveness in supporting the dietary management of Diabetes.

1.3 OBJECTIVES OF STUDY

The specific objectives of this study were to:

i. Identify and select indigenous Nigerian ingredients with known or potential antidiabetic properties.
ii. Identify and quantify phytochemicals with potential antihdiabetic effects, e.g phenols, flavonoids.
iii. Analyze the proximate compositions of samples made from Cardaba banana, beetrots and bambara groundnuts.

1.4 JUSTIFICATION OF THE STUDY

Diabetes is a major public health problem in Nigeria and around the world. It significantly contributes to illness and death. Nigeria has many local plants that are rich in bioactive compounds, which can help lower blood sugar levels. Functional foods made from these anti-diabetic ingredients provide a hopeful way to manage diabetes. While there is some research on individual Nigerian plants, we need more studies to create and test functional foods made from combined ingredients. Promoting these functional snacks can help increase awareness of the role diet plays in diabetes and encourage people to take charge of their health.

CHAPTER TWO

LITERATURE REVIEW

2.1 FUNCTIONAL FOODS AND INDIGENOUS PLANT-BASED DIETS

The worldwide health landscape is experiencing a significant shift towards preventive nutrition, promoting a strong integration of modern functional food science and traditional dietary knowledge (Adebo *et al.,* 2021). This shift is driven by full-bodied evidence which shows that plant-based dietary forms tend to reduce the risk of major non-communicable diseases including type 2 diabetes (T2DM) and cardiovascular disease (Qian *et al.,* 2019). This has prompted both consumers and researchers to seek meals that offer benefits beyond basic nourishment. The functional food market is rising because more individuals are learning about the direct link between what they eat and their long-term health (Granato *et al.,* 2020). At the same time, there is a growing and major interest in plant-based diets from indigenous people. These traditional food systems are not simply old things; they are powerful, diverse, and often extremely sustainable methods of eating that are very related to local ecosystems and cultures (Mabhaudhi *et al.,* 2023). This integrated strategy is especially promising for poorer countries. For Nigeria, employing crops that are cultivated locally and can endure climate change, including Bambara groundnut, Cardaba banana, and beetroot, is a smart strategy to make functional foods that are affordable and fit with the culture (Olanrewaju *et al.,* 2024). Adding these nutrient-dense foods to popular dishes like biscuits is also a realistic and scalable method to promote public health. The possibilities are unlimited; adopting native crops as the basis for functional foods can enhance nutrition, promote local farming economies, and safeguard the environment all at the same time (Chibuzo *et al.,* 2023).

2.1.1 CONCEPT OF FUNCTIONAL FOODS

The conceptual basis of functional meals has undergone significant modification from its inception in late 20th-century Japan. It currently encompasses any food or food component that has been proved to have a favorable effect on health or lower the risk of chronic disease, going far beyond only preventing deficiency disorders (Corzo *et al.,* 2024). These foods are now frequently designed using a micro-nano encapsulation technique to efficiently deliver and protect bioactive compounds (Zhang *et al.,* 2024), and clinical trials demonstrating notable improvements in glycemic control and other metabolic parameters are increasingly validating their efficacy (Cimellaro *et al.,* 2024). This transformation is a direct outcome of the worldwide growth in ailments like type 2 diabetes and heart disease, which has transformed how people purchase. People are no longer only eating to fill their tummies; they are picking foods that are excellent for their health and to avoid getting sick (McClements, 2023). This desire from customers has led to astounding new breakthroughs in food technology. Researchers are now working in the design of "foods for specific health uses" (FSHU), which are intended to target certain physiological functions. Creating low-glycemic index snacks to assist control of blood sugar levels or making items high in anti-inflammatory chemicals are two wonderful examples (*Ojo et al.,* 2024). This idea of functional food is especially strong in poor economies. It can be adapted with locally produced, indigenous ingredients, avoiding the demand for costly imported fortificants and resulting in products that are both nutritious and culturally suitable (Eke *et al.,* 2023).

2.1.2 INDIGENOUS PLANT-BASED FOODS AND THEIR ROLE IN NUTRITION

Indigenous plant-based foods are fruits, vegetables, legumes, and crops that have been farmed in certain places for generations. They are the cornerstone of local food culture and traditional knowledge systems, and they are particularly important for food security in households, especially in Africa and Asia (Mabhaudhi *et al.,* 2023). One of the best things about these crops is that they are naturally resistant to local pests, illnesses, and weather challenges, so they often need fewer manmade inputs like pesticides and fertilizers. This makes them key species for establishing sustainable and agroecological farming systems (Adetola *et al.,* 2024). Many indigenous foods have a stronger nutritional profile than meals that are popular around the world. For example, the Bambara groundnut is a significant source of plant-based protein and amino acids. The Cardaba banana and beetroot, on the other hand, are wonderful suppliers of complex carbohydrates, dietary fibers, vitamins, and a wide range of antioxidant phytochemicals (Akinola *et al.,* 2024). These kinds of food are also highly helpful in the fight against "hidden hunger," which is a common problem caused by not getting enough micronutrients. Their high quantities of minerals and vitamins, combined with bioactive substances like flavonoids and phenolic acids, help the body battle oxidative stress and inflammation (Salami *et al.,* 2023). When treated using conventional processes like fermentation or germination, the bioavailability of these minerals can be further increased, making them even more beneficial at boosting dietary diversity and nutritional outcomes (Fasuan *et al.,* 2024).

2.1.3 INDIGENOUS FOODS AND DISEASE MANAGEMENT

The importance of indigenous foods in the prevention and management of chronic diseases is obtaining increasing scientific confirmation. Plant-based diets, which frequently contain these local ingredients, have been repeatedly associated in systematic reviews with a noticeably reduced risk of type 2 diabetes (Qian *et al.,* 2019) as well as better treatment of the illness in current patients (Tran and Dale, 2023). These foods give a multifaceted approach to health, principally due to their intricate matrix of dietary fiber, resistant starches, antioxidants, and other bioactive substances (Udeh *et al.,* 2024). Consider the Bambara groundnut. Recent clinical investigations highlight its low glycemic index qualities, indicating that its consumption leads to a slower and more steady release of glucose into the bloodstream. This is an important aspect for treating diabetes and lowering the risk of severe insulin spikes (Olanrewaju *et al.,* 2024). Similarly, beetroot has gained substantial interest for its high content of dietary nitrates and unusual antioxidant pigments called betalains. These chemicals operate synergistically to increase endothelial function, promote blood flow, and minimize oxidative damage, all of which are good for cardiovascular health and metabolic syndrome (Adeyemi *et al.,* 2023). Furthermore, Cardaba banana, especially when collected green, is high in resistant starch. This type of starch serves as a prebiotic fiber, fermenting in the colon to produce short-chain fatty acids that improve insulin sensitivity and promote satiety, so benefiting in long-term blood glucose control and weight management (Chukwuma *et al.,* 2023). The overall research suggests that routinely adding these indigenous foods into the diet can be a potent, food-first strategy for treating the underlying metabolic dysregulations linked with modern chronic diseases.

2.2 BISCUITS AS FUNCTIONAL SNACKS IN NUTRITION

Biscuits are among the most extensively consumed bakery items across the world due to their long shelf life, mobility, affordability, and sensory appeal. They serve as convenient snacks for all age groups and are regarded a good base for nutrient fortification and functional ingredient absorption. In recent years, consumer interest in functional foods has led to the reformulation of classic biscuits into nutritionally enhanced varieties (Sharma *et al.,* 2022). This development corresponds with the global effort to tackle diet-related non-communicable diseases such as diabetes, obesity, and cardiovascular disorders by encouraging better, yet palatable, snack options. The shift toward functional biscuits is driven by increasing awareness of the relevance of nutrition in supporting metabolic health. Biscuits can be purposely modified through partial replacement of refined wheat flour with nutrient-dense plant-based flours, such as those derived from legumes, fruits, or tubers, to boost protein, FIBER, mineral, and antioxidant content (Ngaha *et al.,* 2023). These formulations not only boost nutritional quality but can also impact glycemic response, making them useful for populations seeking blood glucose management. Furthermore, biscuits give a realistic platform for the utilization of indigenous ingredients, enabling the promotion of local biodiversity, decrease of import dependency, and creation of value-added food items within developing regions (Adebayo and Oladejo, 2021). As research continues to advance in this area, biscuits have evolved from simply sources of energy to useful carriers of bioactive ingredients that contribute to health maintenance and illness prevention. Sub-sections will explore their historical and nutritional relevance (Section 2.2.1), their capacity to act as vehicles for functional ingredients (Section 2.2.2), and the developing trends influencing their formulation and optimization (Section 2.2.3).

2.2.1 HISTORICAL AND NUTRITIONAL IMPORTANCE OF BISCUITS

Biscuits have moved from their historical position as durable, long-shelf-life travel food to become one of the world's most ubiquitous and largely accepted snack goods. Their popularity arises from a compelling combination of ease, cost, and sensory appeal, making them a staple across many cultures and age groups (Patel *et al.,* 2023). However, this very ease has also positioned biscuits as a crucial target for nutritional improvement. The global shift towards preventative health has produced a desire for better snack options, driving food scientists to re-engineer the conventional biscuit from a mere source of empty calories into a vehicle for delivering useful nutrients (Zhang *et al.,* 2024). The traditional biscuit, often based on refined wheat flour, is often heavy in simple carbs and fats while being low in protein, dietary fiber, and critical minerals. This nutritional mismatch poses a substantial public health challenge, especially in underdeveloped countries where biscuit consumption is high (Khan *et al.,* 2023). Fortunately, this limitation also gives a clear opportunity. By partially substituting refined wheat flour with nutrient-dense alternative flours from legumes, tubers, and fruits, the nutritional profile of biscuits can be greatly boosted. This method of composite flour technology is fundamental to the production of modern functional biscuits (Oluwajuyitan *et al.,* 2024).

2.2.2 BISCUITS AS CARRIERS OF FUNCTIONAL INGREDIENTS

The biscuit matrix acts as an extraordinarily effective and practical delivery mechanism for beneficial substances. Its widespread consumer acceptance, relatively simple manufacturing technique, and dry, shelf-stable nature make it a suitable vehicle for integrating health-promoting bioactive chemicals (Menon *et al.,* 2024). The most popular and effective technique involves the partial replacement of wheat flour with flours derived from indigenous plants including Bambara groundnut, Cardaba banana, and beetroot. Each of these compounds contributes a unique set of functional qualities. Bambara groundnut flour greatly doubles the protein content and improves the amino acid profile of biscuits, filling a crucial nutritional deficit (Akinola *et al.,* 2024). Cardaba banana flour, high in resistant starch, directly lowers the in-vitro glycemic index of the final product, making it acceptable for persons concerned with blood sugar management (Chukwuma *et al.,* 2023). Furthermore, beetroot powder adds a spectrum of bioactive components, including betalains and phenolic acids, which considerably boost the antioxidant capacity of the biscuit (Adeyemi *et al.,* 2023). This multi-ingredient strategy allows for the construction of a synergistic functional diet that targets numerous health pathways concurrently. The usefulness of using local ingredients in functional snacks is clearly shown. Olakunle *et al.,* (2025) created a peanut-based snack coated with a biofilm containing Cardaba banana starch, demonstrating the feasibility of such formulations for glycemic management by significantly lowering fasting blood glucose levels in diabetic rats.

2.2.3 TRENDS IN DEVELOPMENT OF FUNCTIONAL BISCUITS

Current advancements in functional biscuit creation are moving beyond simple fortification with isolated vitamins and minerals. Instead, the focus is now on using whole-food ingredients and innovative processing techniques to intrinsically improve the nutritional content of the product (Zhang *et al.,* 2024). Research has thoroughly studied ideal substitution amounts to optimize health benefits without compromising flavor and texture. For instance, research indicate that integrating 20-30% Bambara groundnut flour can enhance protein content by over 35%, whereas substitutes of 15-25% with green Cardaba banana flour can dramatically elevate resistant starch levels (Olanrewaju *et al.,* 2024). Moreover, the inclusion of beetroot powder at levels between 5-15% has been demonstrated to successfully boost the antioxidant qualities of biscuits, but careful formulation is required to manage its strong flavor and color (Adeyemi *et al.,* 2023). Processing advancements are also crucial. Techniques such as germination, fermentation, and heat-moisture treatment are being applied to raw flours. These approaches can improve nutrient bioavailability, eliminate antinutritional factors, and enhance the functional qualities of the dough, ultimately resulting to a superior end product (Fasuan *et al.,* 2024). This holistic approach to product creation represents the cutting edge of generating truly health-promoting and economically viable functional food.

2.3 PROXIMATE EVALUATION OF SNACKS

2.3.1 IMPORTANCE OF PROXIMATE ANALYSIS IN FOOD STUDIES

Proximate analysis is the fundamental analytical framework for determining the fundamental chemical makeup of any food product (Osman *et al.,* 2023). It provides important information on moisture, protein, fat, ash, fiber, and carbohydrate content, all of which together determine a food's nutritional value, energy density, and storage stability (Osman *et al.,* 2023). Proximal analysis is vital when it comes to making functional biscuits. It provides objective proof of how adding Bambara groundnut, Cardaba banana, or beetroot flour changes the macronutrient profile in comparison to a conventional wheat-based biscuit, making it the main scientific tool for measuring the nutritional impact of ingredient substitutions (Khan *et al.,* 2023). This data is essential for consumer information, regulatory compliance, and research and development.

Any legitimate nutritional content claim, such as "high in fiber," "source of protein," or "low fat," is based on accurate proximate composition (Patel *et al.,* 2023). Additionally, by comprehending these elements, food scientists can predict and control the biscuit's texture, color, and mouthfeel, ensuring that the nutritional improvements also produce a product that consumers will enjoy (Menon *et al.,* 2024).

2.3.2 ESSENTIAL NUTRITIONAL PARAMETERS

A detailed proximate analysis gives a food product a basic chemical blueprint. This goes beyond just its composition and shows important information about its nutritional value, stability, and possible uses. To be sure that a functional snack meant to help control blood sugar levels is healthy and works well, these parameters need to be identified.

- **Moisture:** The amount of moisture in a product is a key sign of how stable it is and its sensory texture. Low moisture level (usually less than 10% in biscuits) is important for getting a crisp texture and increasing its shelf life by preventing bacteria growth and delaying rancidity (Ameh *et al.,* 2020). Adding high-fiber foods like Bambara groundnut and beetroot, on the other hand, might change how much water the dough holds, thus the recipe needs to be carefully balanced to keep the desired low water activity without making the dough hard to work with (Sharma *et al.,* 2022).
- **Crude Protein:** The amount of crude protein is an important measure of nutritional density. A higher protein content is very good for metabolic health. Protein promotes satiety, which can help overall calorie intake and support weight management, which is an important part in prevention and control of type 2 diabetes (Udeh *et al.,* 2024). Additionally, dietary protein exerts a negligible direct effect on blood glucose levels and can slow down carbohydrate absorption when ingested concurrently, thus reducing postprandial glycemic surges (Akinola *et al.,* 2024). Mixing cereal and legume flours,

like wheat and Bambara groundnut, also improves the quality of the protein by changing its amino acid composition.

- **Crude Fat:** Crude Fat, while a significant energy source and carrier for fat-soluble vitamins, must be examined in terms of both quantity and quality. A low to moderate fat level is ideal in a functional snack to maintain a healthy energy density (Oluwajuyitan *et al.,* 2024). The type of fat utilized is similarly significant; formulations containing vegetable oils can supply unsaturated fatty acids, which are helpful for cardiovascular health, which is an important factor for diabetic persons who are at increased risk of heart disease (Oluwajuyitan *et al.,* 2024).
- **Crude FIBER:** Crude FIBER is perhaps one of the most significant criteria for a snack focused at blood glucose management (Chukwuma *et al.,* 2023). Dietary fiber, particularly soluble fiber, increases the viscosity of the gut contents, which physically impedes the interaction between digestive enzymes and starch. This slows down the pace of carbohydrate digestion and glucose absorption, leading to a slower and lower rise in blood sugar (Chukwuma *et al.,* 2023). Both Bambara groundnut and Cardaba banana flour are great sources of nutritional fiber, making them ideal for this use.
- **Ash Content:** Ash Content acts as a solid substitute for the total mineral content of the diet. A greater ash value suggests a richer supply of important minerals like potassium, magnesium, and zinc (Salami *et al.,* 2023). Potassium is crucial for maintaining adequate blood pressure, while magnesium has a function in insulin secretion and action (Salami *et al.,* 2023). The use of beetroot powder, known for its high mineral content, is likely to greatly increase this metric, adding another layer of metabolic advantage.
- **Carbohydrates:** Total Carbohydrates, computed by difference, completes the nutritional picture. However, the focus in functional food development has changed from the amount to the quality of carbohydrates. The goal is to minimize the proportion

of fast digestible simple sugars and increase the fraction of complex, slow-digesting carbohydrates and resistant starch (Munir *et al.,* 2024). Cardaba banana flour, especially from unripe fruits, is rich in resistant starch, which behaves like dietary fiber and has a modest glycemic impact, directly supporting the snack's primary functional aim.

In summary, the collective profile of these parameters, showing high protein and fiber, low fat, and a favorable mineral and carbohydrate composition, is what defines the potential of the proposed biscuits as a functional diet for blood glucose management. Proximate analysis thus provides the underlying scientific evidence to support this argument.

2.4 ORGANOLEPTIC EVALUATION AND CONSUMER ACCEPTABILITY

2.4.1 PRINCIPLES OF SENSORY EVALUATION

Sensory evaluation is a disciplined scientific field that tests, analyzes, and evaluates human responses to the qualities of food as experienced by the senses of sight, smell, taste, touch, and hearing (Lawless and Heymann, 2020). Its primary idea is that consumer approval is the ultimate determinant of a product's success in the marketplace. A functional biscuit, no matter how nutritious, will fail if its sensory characteristics are not appealing (Chibuzo *et al.,* 2023). The process is rigorous, frequently employing trained panels for descriptive analysis or untrained consumer panels for hedonic testing using scales to assess preferences for features including color, flavor, texture, and overall acceptability (Stone and Sidel, 2021).

2.4.2 COMMON ORGANOLEPTIC ATTRIBUTES

The effectiveness of a functional biscuit rests on balancing several crucial sensory attributes:

- Appearance and Color: The addition of ingredients like beetroot powder provides a characteristic red-purple tint, while Bambara groundnut might contribute to a deeper crust. Managing these hue shifts to appear deliberate and pleasing is a crucial problem (Adeyemi *et al.,* 2023).

- Aroma and Flavor: Indigenous foods can bring unique flavor notes. Bambara groundnut has a nutty flavor, beetroot an earthy tone, and Cardaba banana a mild, starchy taste. Formulators must balance these flavors, often employing complementary compounds like cinnamon, to create a balanced and pleasant profile that covers any potential off-flavors (Ojo *et al.,* 2024).
- Texture and Mouthfeel: This is generally the most problematic feature. The reduction of gluten-forming wheat protein and the addition of fiber and protein can contribute to a harder, denser, or less crisp texture. Optimizing component particle size, moisture levels, and baking settings is critical to obtain a texture that rivals regular biscuits (Menon *et al.,* 2024).

2.4.3 RELEVANCE IN FUNCTIONAL SNACK DEVELOPMENT

Organoleptic evaluation is not a final step but an essential aspect of the full product development cycle. It gives vital feedback that helps food scientists to iteratively adjust their formulas (Chibuzo *et al.,* 2023). Hopefully, recent studies have demonstrated that with careful optimization, functional biscuits containing significant levels of Bambara groundnut, Cardaba banana, and beetroot can achieve sensory acceptability scores that are comparable to, and in some cases even surpass, those of traditional biscuits (Olanrewaju *et al.,* 2024). This combination of nutritional superiority and sensory appeal is the fundamental goal of modern functional food science.

2.5 BLOOD GLUCOSE REGULATION AND DIETARY INTERVENTIONS

2.5.1 MECHANISMS OF BLOOD GLUCOSE CONTROL

Blood glucose homeostasis is a complex process driven by hormonal signals, principally insulin and glucagon, and is highly influenced by the digestion kinetics of meals (Wilkins *et al.,* 2021). The rate at which glucose from a meal enters the bloodstream is a significant driver of the postprandial glycemic response. Foods rich in fast digestible carbs generate a swift and substantial surge in blood glucose, needing a robust insulin response. Over time, this can contribute to insulin resistance and beta-cell malfunction (Petersen and Shulman, 2020). Therefore, dietary interventions for glycemic management focus on slowing down gastric emptying and the enzymatic digestion of carbohydrates in the small intestine.

2.5.2 ROLE OF FUNCTIONAL FOODS IN GLYCEMIC MANAGEMENT

Functional meals, like the proposed composite biscuits, regulate blood glucose through numerous interrelated pathways. Firstly, the high dietary fiber and resistant starch content from Cardaba banana and beetroot enhance the viscosity of the gut contents, physically restricting the access of digestive enzymes to starch and decreasing glucose absorption (Udeh *et al.,* 2024). Secondly, bioactive substances such as polyphenols and peptides found in these indigenous plants can function as natural inhibitors of carbohydrate-digesting enzymes like alpha-amylase and alpha-glucosidase (Akinola *et al.,* 2024). Moreover, the fermentation of resistant starch in the colon creates short-chain fatty acids (SCFAs) such butyrate, which have been demonstrated to boost insulin sensitivity in peripheral tissues, suggesting a long-term advantage for glycemic control (Chukwuma *et al.,* 2023).

2.5.3 DIETARY APPROACHES IN DIABETES PREVENTION AND CONTROL

The most successful dietary methods for preventing and controlling type 2 diabetes involve the use of low-glycemic index, high-fiber, and whole-plant foods (Reynolds *et al.,* 2020). Low-glycemic, high-fiber, and whole-plant foods are the most effective dietary strategies for preventing and managing type 2 diabetes (Reynolds *et al.,* 2020). According to a recent network meta-analysis, Low-Glycemic Index diets outperformed a number of other dietary patterns in terms of improving postprandial glucose and insulin resistance (Cimellaro *et al.,* 2024*et al.,* 2024). Additionally, it has been demonstrated that in prediabetic populations, comprehensive lifestyle interventions that incorporate a nutritious diet can successfully lower cardiovascular disease risk factors (Liu *et al.,* 2024). Incorporating functional snacks that are expressly designed to have a reduced glycemic impact offers a practical and sustainable option within this framework. Instead of depending on extreme dietary adjustments, which are typically difficult to maintain, consumers can make a simple shift from a conventional high-glycemic snack to a functionally designed one (Eke *et al.,* 2023). The invention of biscuits from Bambara groundnut, Cardaba banana, and beetroot closely correlates with this public health need, delivering a convenient, accessible, and scientifically-grounded food option for promoting metabolic health and blood glucose regulation.

2.6 NUTRITIONAL AND HEALTH POTENTIALS OF SELECTED INDIGENOUS PLANT-BASED INGREDIENTS

The selection of Bambara groundnut, Cardaba banana, and beetroot for this study is not accidental; it is a purposeful choice based on their complimentary and synergistic nutritional profiles. Each ingredient brings a unique set of bioactive substances and physiological mechanisms to the table, and when combined, they present a multi-faceted approach to building a functional diet suited for metabolic health.

2.6.1 BAMBARA GROUNDNUT

Bambara groundnut *(Vigna subterranea)* is an incredibly hardy legume that has long been disregarded, although it possesses a nutritional profile that is ideally suited for modern functional food applications. Its composition is particularly outstanding; current ANALYZEs regularly demonstrate a high protein content, ranging from 16% to 24% on a dry-weight basis, which greatly surpasses that of several popular cereals (Tan *et al.,* 2020). Furthermore, it supplies a large amount of complex carbohydrates (50-65%), a moderate fat content, and is a valuable source of dietary FIBER and vital minerals like potassium, magnesium, and iron

(Ramatsetse *et al.,* 2023). This substantial nutritional base is reinforced by a moderately balanced amino acid profile, making it a good candidate for addressing protein deficiency (Odeniran, 2025).

2.6.1.1 HEALTH BENEFITS OF BAMBARA GROUNDNUT

The health advantages of Bambara groundnut, notably addressing blood glucose management, are directly linked to its macronutrient structure. The synergistic action of its protein and dietary fiber content serves to slow down gastric emptying and the subsequent absorption of carbohydrates in the gut. This mechanism is critical for attenuating the abrupt post-meal rises in blood glucose that are troublesome for diabetic and pre-diabetic persons (Tan *et al.,* 2020). In addition to this, the groundnut includes a range of polyphenols and other phytochemicals with shown antioxidant potential. These chemicals can help lower the oxidative stress and persistent, low-grade inflammation that are often underlying contributors in the development of insulin resistance (Ramatsetse *et al.,* 2023). According to animal studies, Bambara groundnut consumption considerably reduced hyperglycemia and hyperlipidemia in diabetic models, demonstrating the food's potential as a therapeutic functional food and extending its health benefits to glycemic management (Mhya and Mohammed, 2021).

2.6.1.2 FUNCTIONAL APPLICATIONS OF BAMBARA GROUNDNUT

From a practical viewpoint, the Bambara groundnut is exceedingly multipurpose. It can be directly milled into a whole flour, or refined further through procedures like fermentation, which has been demonstrated to significantly affect its qualities. For instance, one study demonstrated that fermenting a Bambara groundnut and soybean composite dramatically enhanced the snack's protein content while reduced its fat and carbohydrate levels, hence boosting its nutritional density (Osundahunsi and Aworh, 2023). In baking applications, partially replacing wheat flour with Bambara groundnut flour at amounts between 10% and 30%

reliably enhances the protein, fiber, and mineral content of the final product (Chinma *et al.,* 2022). Moreover, this substitution enhances functional qualities like water and oil absorption, which are crucial for achieving the correct texture and mouthfeel in biscuits. It is sometimes recommended to utilize pre-treatments such as roasting or fermenting to eliminate any potential beany tastes and to lessen antinutrient levels, making the flour more pleasant and its minerals more bioavailable (Ramatsetse *et al.,* 2023).

Figure 2.1: Picture illustrating some functional applications of Bambara nuts (Tan *et al.,* 2020)

2.6.2 CARDABA BANANA

The Cardaba banana *(Musa ABB)*, a dynamic culinary species, offers unique functional possibilities, particularly when gathered and prepared in its unripe, green state (Alam *et al.,* 2023). The most defining feature of green Cardaba banana flour is its extraordinarily high starch content, of which a large fraction is designated as resistant starch (RS Type 2). Recent investigations suggest that total starch can surpass 70% on a dry basis, with the resistant starch fraction being highly dependent on processing variables including drying temperature and milling processes (Alam *et al.,* 2023). In addition to its carbohydrates, the flour offers valuable soluble and insoluble FIBERs, minor levels of protein and fat, and key minerals, most notably potassium. The Cardaba banana has practical potential that goes beyond theory. Its starch has been successfully added to a snack matrix in recent studies, and the finished product showed significant blood glucose-lowering effects in a biological model, demonstrating its effectiveness beyond the isolated ingredient stage (Olakunle *et al.,* 2025).

2.6.2.1 HEALTH BENEFITS OF CARDABA BANANA

The principal health benefit associated with utilizing unripe Cardaba banana flour is directly connected to its high resistant starch content. Unlike digestible starch, resistant starch travels through the small intestine unmodified and undergoes fermentation in the colon. This process produces short-chain fatty acids (SCFAs), such as butyrate, which have been firmly associated to enhanced insulin sensitivity, better appetite management, and anti-inflammatory benefits throughout the body (Munir *et al.,* 2024). Consequently, numerous in-vitro and human feeding studies have demonstrated that replacing refined starch with RS-rich flours like this one effectively lowers the digestibility of carbohydrates and results in a significantly reduced predicted glycemic index for the final food product (Munir *et al.,* 2024). However, getting these benefits requires careful treatment. The ripening stage of the banana is a significant aspect. Research has clearly established that when the banana ripens, its carbohydrate composition varies considerably; resistant starch and total carbs decrease greatly as they are transformed into simple sugars (Ayo-Omogie *et al.,* 2010). Therefore, to maximize the low-glycemic potential in a biscuit recipe, it is crucial to use flour made from unripe, green Cardaba bananas. Furthermore, processing must be properly managed. Using low-temperature drying processes is important to prevent the gelatinization of the resistant starch, which would otherwise convert it into a more readily digestible form and impair its health benefits (Nwakego *et al.,* 2022). In a composite flour blend, green Cardaba banana flour pairs nicely with protein-rich legume flours like Bambara groundnut, generating a nutritionally balanced product that is inherently suited for better blood glucose management.

Figure 2.2: Picture showing health benefits of Cardaba banana flour (Nwakego *et al.,* *2022)*

2.6.3 BEETROOT

Beetroot (*Beta vulgaris*) is far more than a simple vegetable; it is a concentrated source of potent bioactive chemicals that offer significant advantages for functional food production (Chen *et al.,* 2021). Its brilliant color stems from unique pigments called as betalains (which include betacyanins and betaxanthins), which contain significant antioxidant and anti-inflammatory activities (Chen *et al.,* 2021). Moreover, beetroot is one of the greatest dietary sources of inorganic nitrates. In the human body, these nitrates are transformed into nitric oxide, a chemical that plays a crucial function in relaxing blood vessels, boosting blood flow, and enhancing circulation (Suh *et al.,* 2023).

2.6.3.1 HEALTH BENEFITS AND FUNCTIONAL APPLICATIONS OF BEETROOT

These qualities translate into significant health benefits, notably for cardiometabolic health. The antioxidant effect of betalains helps protect pancreatic beta-cells from oxidative damage, while the enhanced blood flow from dietary nitrates can promote more efficient glucose uptake by muscles. Clinical research shows that beetroot supplementation can lead to decreased blood pressure and enhanced measures of vascular function (Suh *et al.,* 2023). Although its direct impact on glycemic management can be inconsistent and seems to rely on the dose and the total dietary matrix, its indirect advantages through increased circulation and lower oxidative stress are well-established. In functional biscuit making, beetroot is often added as a powder or pomace. This offers a beautiful natural COLOR, reducing or eliminating the need for artificial food colorings. Formulators commonly use inclusion rates between 5% and 15% to greatly improve the total phenolic content and antioxidant potential of the biscuit without creating an excessive earthy taste or an unpleasant hue (Mitrevski, 2023). A big difficulty, however, is that the beneficial betalain pigments are sensitive to heat. To circumvent this, strategies such as encapsulation or careful control of particle size can be adopted to assist protect these sensitive compounds during the high temperatures of the baking process, ensuring they retain their usefulness in the end product (Brzezińska-Rojek *et al.,* 2023). Using beetroot pomace, a by-product of juicing, also gives an ideal chance to boost nutritional FIBER and antioxidants while adhering to circular economy principles by decreasing food waste. Clinical studies on the effectiveness of beetroot are encouraging. Acute beetroot juice consumption significantly improved total plasma glucose exposure during an oral glucose tolerance test in a recent pilot study with Type 2 diabetic patients, suggesting a direct positive impact on postprandial glycemia (Mazengo *et al.,* 2024).

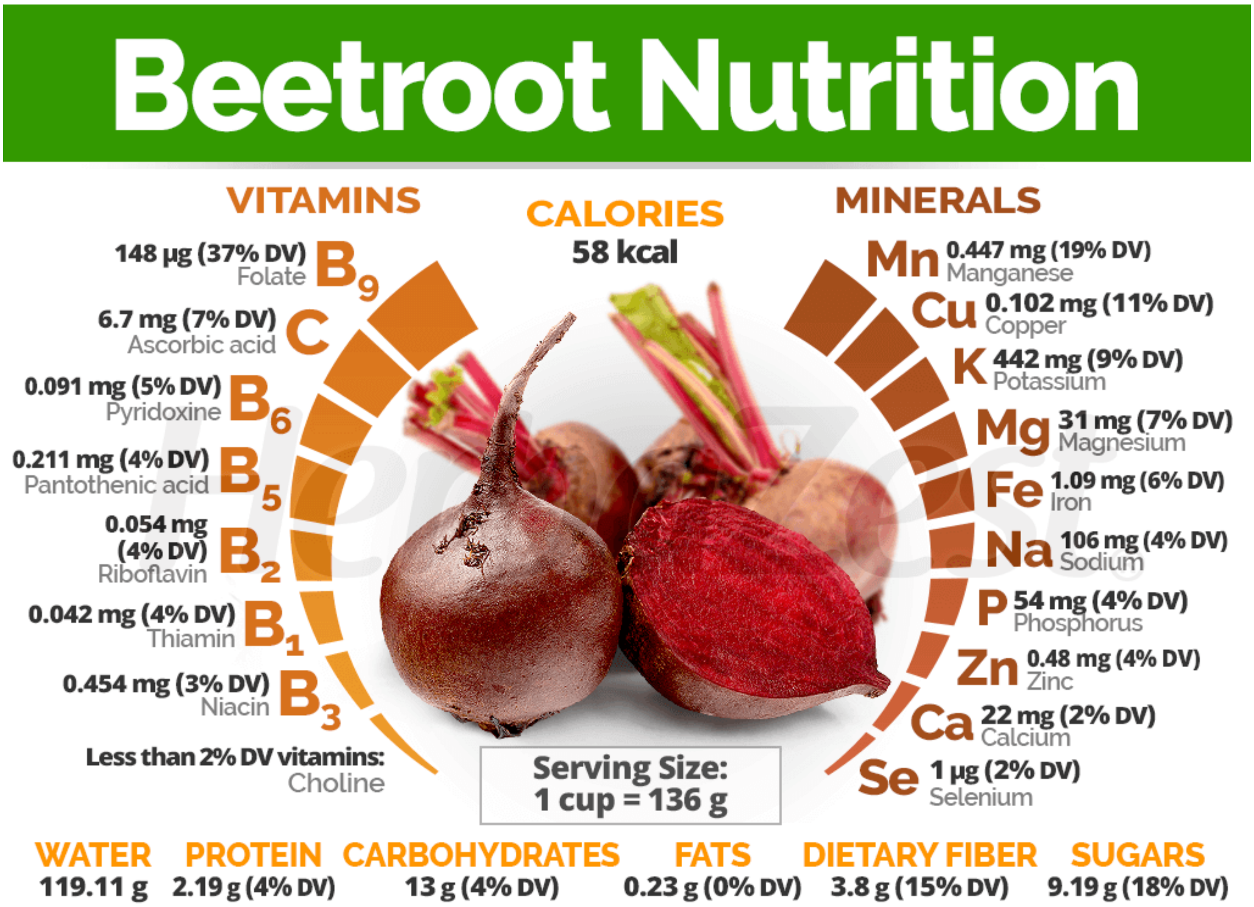


Figure 2.3: Picture highlighting nutritional profile of Beetroot (Suh *et al.,* 2023)

2.7 DIABETES AND ITS MANAGEMENT

2.7.1 DEFINITION AND HEALTH IMPLICATIONS

Diabetes mellitus constitutes a major worldwide health challenge represented by persistent high blood sugar levels resulting from abnormalities in insulin production or action (World Health Organization, 2023). This chronic disorder arises when the pancreas is unable to create sufficient insulin or when the body cannot efficiently utilize the insulin it produces (American Diabetes Association, 2023). The long-term health effects of untreated diabetes are wide and serious, involving various body systems. Persistent hyperglycemia leads to damage in different physiological systems, mainly harming blood vessels and nerves (Chaudhury *et al.,* 2021). Microvascular problems include diabetic retinopathy, which can cause vision loss and blindness; nephropathy, potentially advancing to kidney failure; and neuropathy, leading to discomfort, numbness, and higher risk of foot disorders (Pop-Busui *et al.,* 2021). Macrovascular problems greatly enhance the risk of cardiovascular disorders, including heart attacks and strokes, as well as peripheral arterial disease (Low Wang *et al.,* 2021). These problems considerably impair quality of life and increase mortality rates among diabetic individuals.

2.7.2 PATHOPHYSIOLOGICAL BASIS OF DIABETIC DISEASES

The development of Type 2 Diabetes involves multiple physiological abnormalities, largely defined by insulin resistance and increasing beta-cell failure (DeFronzo and Ferramini, 2021). Insulin resistance is a situation where cells across the body become less responsive to insulin, particularly in liver, muscle, and adipose tissue (Galicia-Garcia *et al.,* 2020). This resistance initiates compensatory mechanisms where pancreatic beta-cells increase insulin production, eventually leading to beta-cell fatigue. Several biochemical processes contribute to insulin resistance, including inflammation, oxidative stress, and fat buildup in non-adipose tissues

(Sankar *et al.,* 2021). The release of pro-inflammatory cytokines and increased free fatty acids activate signaling pathways that interfere with insulin function. Meanwhile, beta-cell dysfunction advances through gluco-toxicity and lipo-toxicity, ultimately leading in inadequate insulin production to maintain normal glucose homeostasis (Halban *et al.,* 2021).

2.7.3 CLINICAL DIAGNOSIS OF DIABETES

The diagnosis of diabetes relies on standardized biochemical tests that assess blood glucose levels under particular settings. According to worldwide criteria, diabetes can be diagnosed by any of three major approaches (American Diabetes Association, 2023). The fasting plasma glucose test needs an 8-hour fast and diagnoses diabetes when readings equal or exceed 126 mg/dL (7.0 mmol/L) on two different occasions. The oral glucose tolerance test involves monitoring blood glucose 2 hours following a 75g glucose load, with readings of 200 mg/dL (11.1 mmol/L) or greater suggesting diabetes. The glycated hemoglobin test provides a longer-term view on glycemic control, indicating average blood glucose levels during the preceding 2-3 months (Sacks, 2022). An HbA1c reading of 6.5% (48 mmol/mol) or higher validates the diagnosis of diabetes.

2.7.4 MANAGEMENT THERAPIES FOR DIABETES (DRUGS, DIET)

Effective diabetes care requires a comprehensive approach combining pharmaceutical interventions with lifestyle adjustments (Davies *et al.,* 2022). Evidence demonstrating that structured exercise programs considerably reduce cardiovascular disease risk factors in type 2 diabetic patients supports this all-encompassing approach (Zhou *et al.,* 2024), and that dietary habits that prioritize plant-based foods are linked to positive outcomes for lipid profiles and blood pressure (Tran and Dale, 2023). The pharmacological arsenal has expanded dramatically, with metformin remaining the first-line therapy for Type 2 Diabetes due to its efficacy and safety profile (Sanchez-Rangel and Inzucchi, 2021). Newer medication classes include GLP-1 receptor agonists and SGLT-2 inhibitors offer additional benefits beyond glucose control, demonstrating cardiovascular and renal protective effects (Zinman *et al.,* 2021). Nutritional therapy constitutes a cornerstone of diabetes management, with evidence supporting numerous dietary patterns (Evert *et al.,* 2021). Mediterranean-style diets, rich in monounsaturated fats, fruits, vegetables, and whole grains, have showed considerable benefits for glycemic control and cardiovascular health (Esposito *et al.,* 2022). Moderately low-carbohydrate diets have proven success in reducing hemoglobin A1c levels and aiding weight management (Sainsbury *et al.,* 2021). These nutritional approaches, together with regular physical activity and appropriate medicine, provide the foundation of comprehensive diabetic management.

CHAPTER THREE

MATERIALS AND METHODS

3.1 MATERIALS

- Bambara groundnut (*Vigna subterranea)* flour
- Cardaba banana (*Musa ABB)* flour
- Beetroot (*Beta vulgaris)* powder
- Whole wheat flour
- Guava (*Psidium guajava*) leaves
- Cinnamon
- Date paste
- Baking powder
- Vegetable oil
- Skimmed milk
- Egg/Albumin

3.1.1 APPARATUS AND EQUIPMENTS

- Sieves
- Knives
- Bowls
- weighing scale (J2103497289)
- Buckets
- Gloves (Unicare)
- Scissors
- Towels
- Sponges

- Masking tape
- Trays
- Blender (Kenwood Model KCB-239K)
- Digital table scale (Model SBS-TW-500/10)
- Dehydrator
- Refrigerator
- Microwave oven (COV-8320-B)
- Foil paper
- Air tight containers for storage
- mixing bowls
- Measuring cups and spoons
- Wooden rolling pin
- Biscuit cutter
- Baking paper

3.1.2 CHEMICALS/ REAGENTS

- Sodium metabisulphite
- Sulphuric Acid (H_2SO_4)
- Sodium Hydroxide (NaOH)
- Petroleum Ether
- Hydrochloric Acid (HCl)
- Copper (II) Sulfate ($CuSO_4$)
- Potassium Sulfate (K_2SO_4)

- Methyl Red Indicator
- Acetone
- Distilled Water

3.2 METHODS

3.2.1 MATERIAL COLLECTION AND PROCESSING

3.2.1.1 BAMBARA GROUNDNUT PROCESSING

The Bambara groundnut seeds were locally sourced from Oba market, Benin city, Edo state. The seeds were rinsed with water to remove all external contaminants and dirt particles. The seeds were then soaked for 12 hours in distilled water at room temperature to activate enzymes and soften their structure. The seeds were properly sieved to remove water before being arranged in a single layer on baking trays. The seeds underwent complete drying in a hot air oven at 60°C until they attained complete dryness. The dried seeds were processed using a high-speed blending machine which produced fine flour. The flour was sieved to remove any large particles, and then stored in airtight containers to keep it fresh for later use in making the snacks.

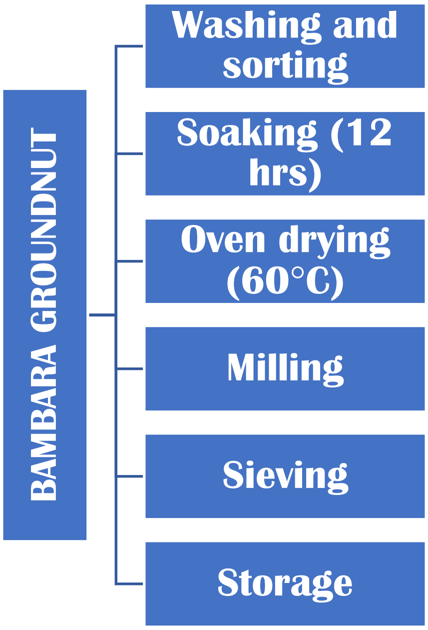


Figure 3.1: Flowchart illustrating processing of Bambara groundnut flour

3.2.1.2 CARDABA BANANA PROCESSING

Unripe Cardaba banana (*Musa ABB*) was locally sourced from Ifeyi market, new Benin axis. The bananas were washed thoroughly with clean water so as to remove dirt and impurities. The superficial skin was meticulously removed using a knife, after which the bananas were cut into very thin pieces (5mm thick). A solution was prepared using 5 grams of Sodium metabisulphite reagent, dissolved in 10 liters of distilled water. The already sliced bananas were then submerged in the solution for 30 minutes in order to preserve them and prevent browning. Sodium metabisulphite acts as an anti-browning agent and preservative which helps to maintain the banana's color and quality during drying and storage. Next, the bananas were transferred to a hot air oven, set to 60°C until constant weight was attained, in order to remove moisture from the cardaba banana slices without ruining their nutrients.

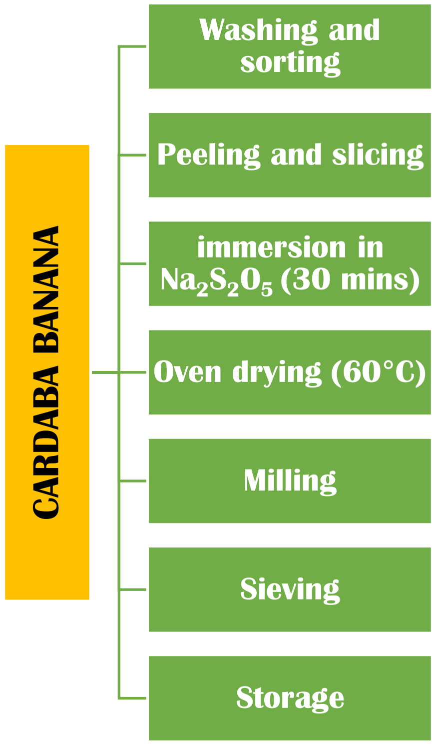


Figure 3.2: Flowchart illustrating processing of cardaba banana flour

3.2.1.3 BEETROOT PROCESSING

Fresh beetroots (*Beta vulgaris*) were locally sourced from Hausa Market, forestry road, Benin city. They were chosen for their strong texture and rich red color. The roots were carefully rinsed with water to remove soil residues, then peeled using a knife. The peeled roots were sliced to the desired thickness. A total of 6kg of beetroot were peeled and sliced. The sliced beetroot was spread on baking trays and dried in a hot air oven at 50°C until constant weight was attained. The dried beetroot pieces were milled using an electric blender and sieved through a mesh sieve. The final beetroot powder was stored in airtight containers and kept in a cool, dry location until needed.

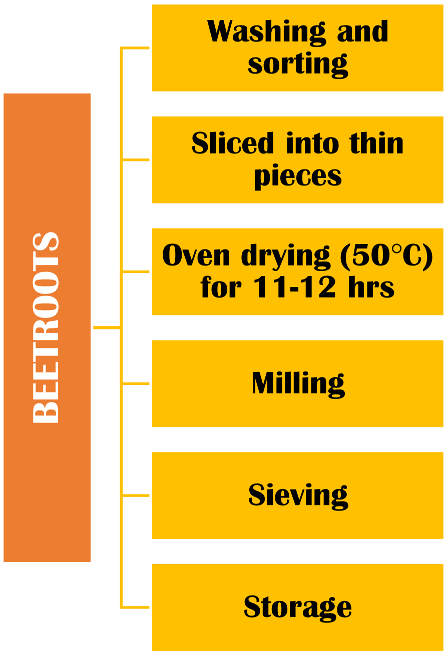


Figure 3.3: Flowchart illustrating processing of beetroot powder

3.2.1.4 GUAVA LEAF POWDER PREPARATION

Mature guava leaves (*Psidium guajava*) were picked and selected based on uniform green coloration without any visible damage or disease symptoms. The leaves were washed gently under running water to remove dust and other surface contaminants. The cleaned leaves were spread on clean trays and shade-dried at room temperature for 14 days with suitable air circulation. The dried leaves were ground using an electric blender and sieved through a mesh to obtain fine powder. The guava leaf powder was stored in glass jars away from light and moisture to preserve its bioactive compounds.

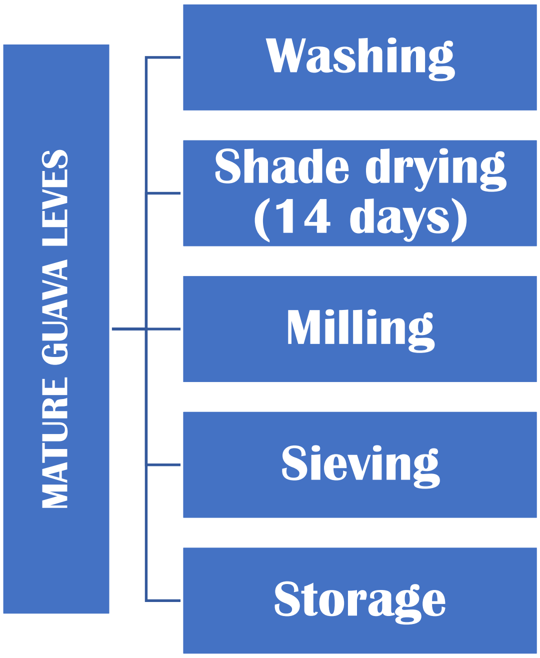


Fig. 3.4: Flowchart illustrating processing of guava leaf powder

3.3 PREPARATION OF THE SNACK BAR RECIPE

3.3.1 SAMPLE FORMULATION

The formulation of the four biscuit samples is detailed in Table 3.1, showing the specific percentages of each ingredient used in the control and experimental samples.

Table 3.1: Comprehensive table showing required amounts of each ingredient needed in each sample produced

Ingredient	Control (%)	Sample A (%)	Sample B (%)	Sample C (%)
Wheat flour	100	-	-	-
Bambara groundnut flour	-	35	40	30
Cardaba banana flour	-	35	30	40
Beetroot powder	-	10	15	8
Guava leaf powder	-	5	3	7
Cinnamon powder	-	2	1	3
Other ingredients	-	13	11	12
Total	-	100	100	100

Snack bar formulations were made using mixed flours and powders from beetroot, Cardaba banana, Bambara groundnut, and guava leaves. The ingredients were measured and mixed in different amounts to create snack bars with various nutritional profiles and textures. Each formulation varied in composition, weight, and size, allowing for a comparison of their quality and acceptability.

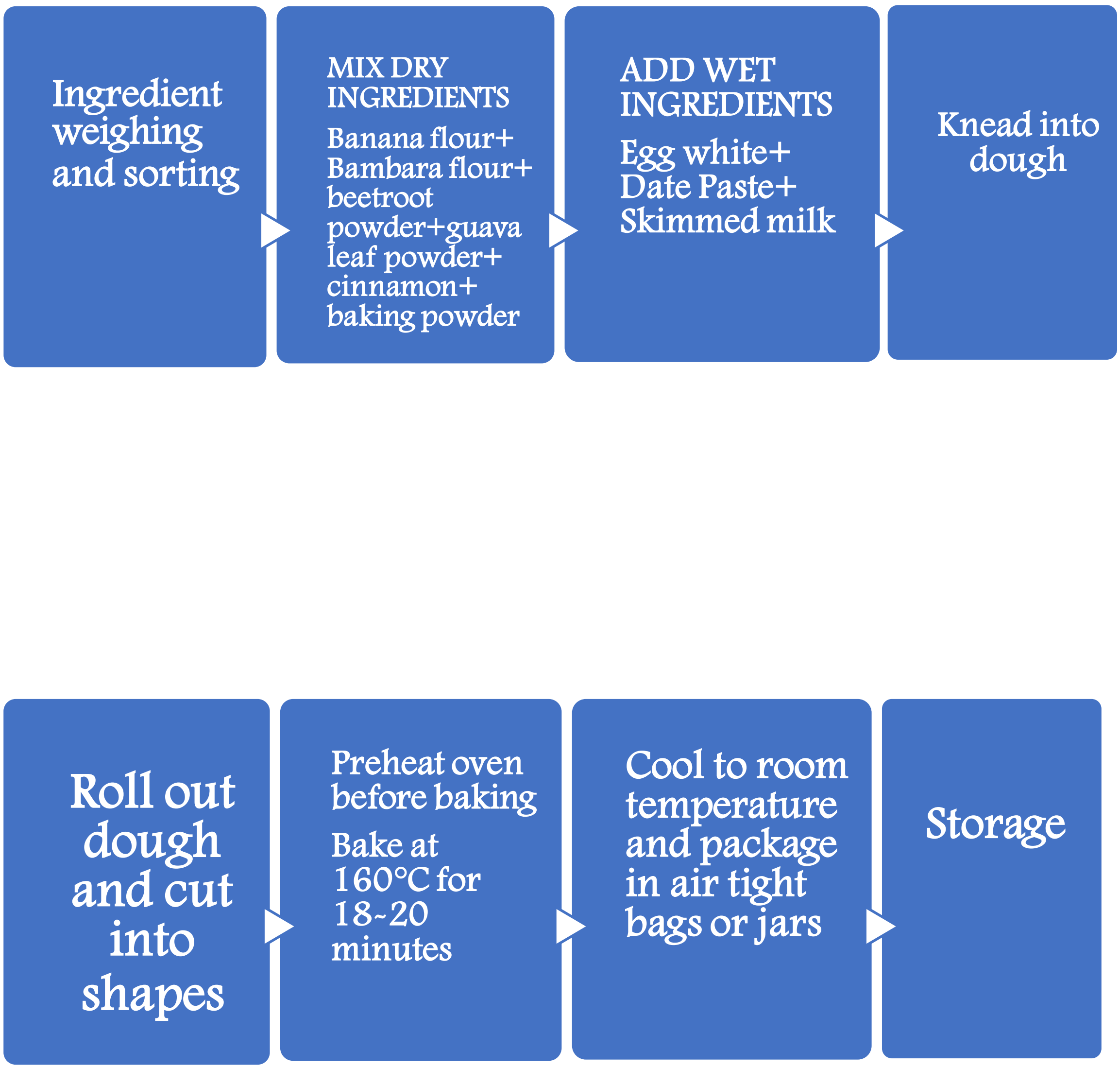


Figure. 3.5 Flowchart illustrating preparation of baked snack bar

3.4 PROXIMATE ANALYSIS

3.4.1 DETERMINATION OF MOISTURE CONTENT

The moisture content was determined using the gravimetric method of AOAC (2000). A porcelain crucible was dried in an oven at 105 °C for 30 minutes, cooled in a desiccator, and weighed (W_1). One gram of the sample was added to the crucible and the weight was recorded as W_2. The crucible and its content were then oven-dried at 105 °C until a constant weight was achieved, with cycles of cooling in a desiccator and weighing. The final constant weight was recorded as C.

The moisture content was calculated as shown in Equation 6:

% Moisture = $(W_2 - C) / (W_2 - W_1) \times 100$ ……………………………… (6)

Where:

Weight loss = $(W_2 - C)$, and Weight of sample = $(W_2 - W_1)$

3.4.2 DETERMINATION OF ASH CONTENT

The ash content was determined according to the method of AOAC (2000). A pre-weighed porcelain crucible (W_1) was filled with one gram of the sample and the new weight was recorded as W_2. The sample was first charred on a hot plate and then transferred into a muffle furnace. It was ignited at 500 – 600 °C for 3 hours until a white ash was obtained. The crucible was removed, cooled in a desiccator, and weighed. The process was repeated until a constant weight, C, was achieved.

The ash content was calculated as shown in Equation 7:

% Ash = $(C - W_1) / (W_2 - W_1) \times 100$ ……………………………………………….. (7)

3.4.3 DETERMINATION OF CRUDE FIBER CONTENT

The crude FIBER content was determined by the enzymatic-gravimetric method of AOAC (2000). One gram of the sample (W_0) was weighed into a beaker, 200 mL of 1.25% sulphuric acid was added, and the mixture was boiled gently for 30 minutes. The mixture was filtered through a muslin cloth and the residue was rinsed with hot distilled water. The residue was then transferred back to the beaker, 200 mL of 1.25% sodium hydroxide was added, and it was boiled for another 30 minutes. The mixture was filtered again and the residue was washed with hot distilled water, followed by a rinse with petroleum ether. The residue was allowed to drain, transferred to a pre-weighed crucible (W_1), and dried in an oven. The crucible was cooled in a desiccator and weighed (W_2). The sample was then ashed in a muffle furnace at 500 °C for 90 minutes, cooled in a desiccator, and the final weight was recorded as W_3. The crude FIBER content was calculated as shown in Equation 8:

$\%\ \text{Crude FIBER} = (W_2 - W_3) / W_0 \times 100$……………………………………………………(8)

Where:

Weight of FIBER = $(W_2 - W_3)$, and Weight of Sample = W_0

3.4.4 DETERMINATION OF CRUDE FAT CONTENT (SOXHLET EXTRACTION METHOD)

The crude fat content was determined using the Soxhlet extraction method of AOAC (2000). A dry extraction thimble was weighed (W_1). One gram of the sample was added to the thimble and the new weight was recorded as W_2. A clean, dry extraction flask was weighed (W_3). The thimble was placed in the extractor, and the flask was filled with 500 mL of petroleum ether. The apparatus was assembled and the solvent was heated to reflux for 8 hours. After extraction, the solvent was recovered, and the flask containing the lipid extract was dried to a constant weight in an oven, cooled in a desiccator, and weighed (W_4).

The crude fat content was calculated as shown in Equation 9:

% Crude Fat = $(W_4 - W_3) / (W_2 - W_1) \times 100$……………………………………………….. (9)

Where:

Weight of fat = $(W_4 - W_3)$, and Weight of sample = $(W_2 - W_1)$

3.4.5 DETERMINATION OF CRUDE PROTEIN CONTENT (KJELDAHL METHOD)

The crude protein content was determined using the micro-Kjeldahl method of AOAC (2000). A sample quantity (depending on nitrogen content) was weighed into a Kjeldahl flask. A catalyst mixture of 0.8 g K_2SO_4 and 1 mL of 4% $CuSO_4$ was added, followed by concentrated H_2SO_4. The mixture was digested at low heat until frothing ceased, and then at high heat until a clear, pale green solution was obtained. The digest was cooled, diluted with 4 mL of distilled water, and then distilled after adding 10 mL of 30% NaOH. The liberated ammonia was steam-distilled and collected in a flask containing 0.01 M HCl and a drop of methylene red indicator. The distillate was titrated with 0.01 M NaOH. A blank determination was carried out simultaneously.

The nitrogen and crude protein contents were calculated using Equations 10 and 11:

% Nitrogen = (Titre value(blank) - Titre value(distillate)) × 0.01 × 0.14 / Weight of sample × 100 … (10)

% Crude Protein = % Nitrogen × F …………………………………………………… (11)

Where F = conversion factor (6.25)

3.4.6 DETERMINATION OF CARBOHYDRATE CONTENT

The carbohydrate content, expressed as Nitrogen-Free Extracts (NFE), was determined by difference, as shown in Equation 12:

% Carbohydrate = 100 - (% Moisture + % Ash + % Crude Fat + % Crude Protein + % Crude FIBER) ………………(12)

3.5 STATISTICAL ANALYSIS

All data regarding proximate analysis were evaluated statistically using SPSS (Version 25.0). The results are expressed as the mean ± standard deviation (SD). Differences among sample means were assessed using one-way Analysis of Variance (ANOVA). Significant differences were identified using Duncan's Multiple Range Test (DMRT) at a 5% probability level ($p < 0.05$).

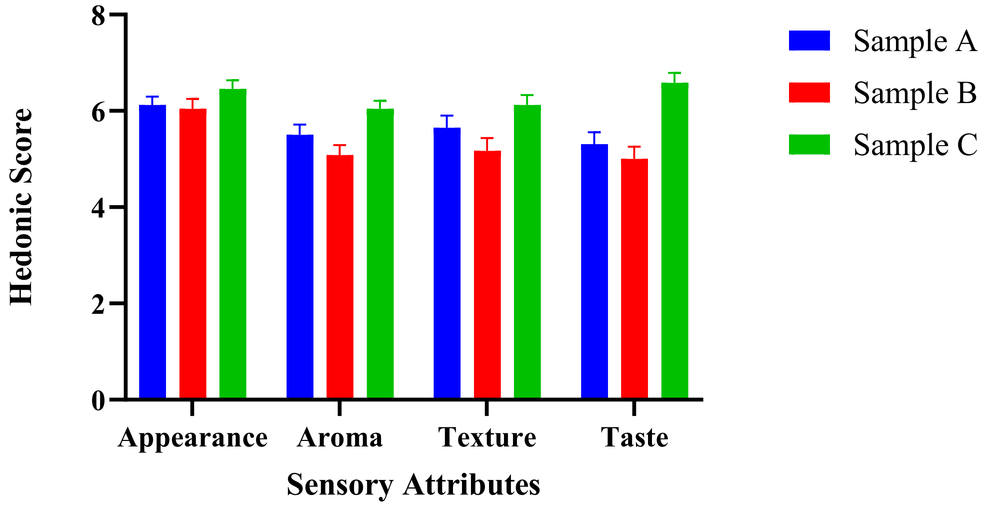
CHAPTER FOUR

RESULTS

4.1: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF PANELISTS

Characteristic	Category	Frequency (n=75)	Percentage (%)	Mean Age (years)
Age Group	18-25 years	62	82.7	36.5
	26-35 years	9	12	
	36-45 years	2	2.7	
	46 years and above	2	2.7	
Gender	Female	35	46.7	
	Male	40	53.3	
Academic Qualifications	BSc/HND	55	73.3	
	MSc/PhD	15	20	
Marital Status	Single	40	53.3	
	Married	30	40	
	Divorced	5	6.7	

Sensory profile of anti-diabetic snack bar formulations.



Consumer's Acceptability

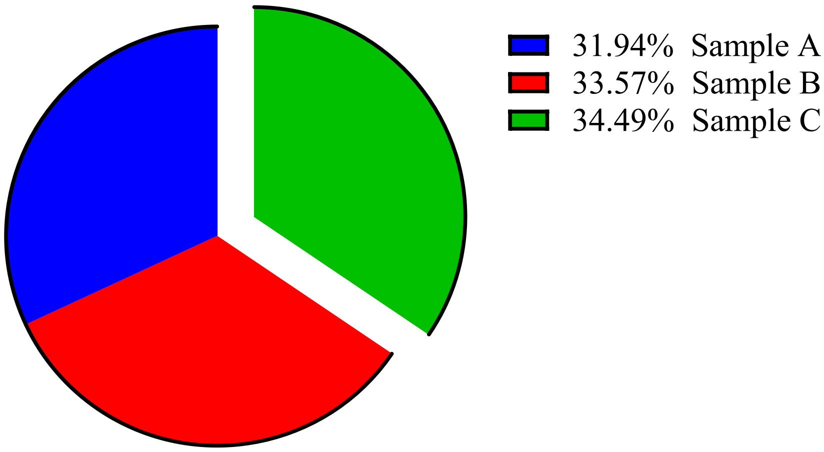


Table 4.2: Proximate Composition of Sample Groups Expressed in Mean (± SD)

Group	Moisture	Ash	Crude FIBER	Crude Fat	Crude Protein	Carbohydrate
A	17.667 ± 0.945	3.933 ± 0.611	0.600 ± 0.200	0.927 ± 0.047	7.317 ± 0.085	69.557 ± 1.455
B	16.467 ± 0.404	3.067 ± 0.231	1.433 ± 0.153	0.873 ± 0.090	7.383 ± 0.231	70.777 ± 0.337
C	19.267 ± 1.843	2.667 ± 0.306	1.000 ± 0.200	1.000 ± 0.053	7.947 ± 0.202	66.040 ± 4.870

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1 DISCUSSION

Diabetes mellitus constitutes a major worldwide health challenge represented by persistent high blood sugar levels resulting from abnormalities in insulin production or action (World Health Organization, 2023). The study seeks to evaluate and develop novel antidiabetic snack formulations using guava leaves, beetroot, Cardaba banana, and Bambara groundnut. The results show that these useful ingredients can be successfully incorporated into a healthy and tasty snack by examining their nutritional composition and evaluating consumer acceptability. This is consistent with the increasing emphasis on managing type 2 diabetes through dietary interventions. According to the proximate composition analysis (Table 4.2), the developed snacks had a strong nutritional profile. The Cardaba banana, which is a rich source of complex carbohydrates and resistant starch, is largely responsible for the high carbohydrate content across all groups (66.040% to 70.777%). This helps prevent blood sugar spikes by causing a slower and more controlled release of glucose, which is especially advantageous for diabetic diets. Notably, the crude FIBER content was highest in Sample B (1.433%), which can be attributed to the inclusion of beetroot and guava leaves. Because dietary fiber slows down the digestion and absorption of carbohydrates, it is essential for glycemic control. Furthermore, the snacks demonstrated a favorable profile with low crude fat content across all formulations (0.873% to 1.000%), making them a heart-healthy option suitable for individuals with diabetes, who often have a higher risk of cardiovascular complications. Sample C had the highest crude protein value (7.947%), which is a direct result of adding the protein-rich Bambara groundnut. The crude protein levels were also excellent. Consuming enough protein is known to increase satiety and help control weight, both of which are important for enhancing insulin sensitivity. The success of a functional food centers on consumer acceptance. The socio-demographic profile of the panelists (Table 4.1) offers valuable context; the panel was predominantly young (82.7% aged 18-25), single (53.3%), and highly educated (73.3% with BSc/HND or higher). This demographic often represents early adopters of health-oriented products, and their high acceptability scores for the preferred sample indicate a strong market potential. The specific ingredient combination in the top-rated sample successfully delivered health benefits in a form that is appealing to a key consumer group.

Overall, the results validate the concept of creating an antidiabetic snack that does not compromise on taste or acceptability, demonstrating a promising alignment between nutritional design and consumer preferences.

5.2 CONCLUSION

In order to support diabetes management, this study seeks to effectively develop and assess novel snack formulations enhanced with functional ingredients, such as guava leaves, beetroot, Cardaba banana, and Bambara groundnut. Strong nutritional qualities were demonstrated by the products, especially their low-fat content and high complex carbohydrate and fiber content, which are in line with dietary guidelines for glycemic control. All formulations demonstrated potential, but Sample C was the most favored choice in consumer acceptability tests and received the highest scores in important sensory attributes. This suggests that the functional ingredients were successful in producing a snack that consumers enjoy in addition to improving nutritional value. In summary, the developed snack formulations, particularly Sample C represent a convenient, palatable, and nutritionally targeted food product with substantial potential to support metabolic health in general and particularly to control blood glucose levels.

REFERENCES

Adebayo, O. T. and Oladejo, J. A. (2021). Value addition to indigenous crops for sustainable food security in developing economies. *Journal of Food Security, 9(*3), 45-52.

Adebo, J. A., Njobeh, P. B. and Kayitesi, E. (2021). Food metabolomics: A new frontier in food science and technology. *Trends in Food Science and Technology*, 108, 1-12.

Adeyemi, O. J., Ojo, M. A. and Ikujenlola, A. V. (2023). Phytochemical composition and antioxidant potential of beetroot (Beta vulgaris) pomace-enriched biscuit: Implications for functional food development. *Journal of Culinary Science and Technology*, *21*(2), 145-160.

Adetola, O. Y., Ogunmiluyi, F. O. and Adebayo, S. F. (2024). Agroecological resilience of indigenous food crops in Sub-Saharan Africa. *Sustainability*, *16*(2), 567.

Akinola, S. A., Osundahunsi, O. F. and Edema, M. O. (2024). Proximate, functional and antioxidant properties of defatted Bambara groundnut flour and its application in gluten-free biscuit production. *Heliyon*, *10*(1), 234.

Alam, M. K., Rana, Z. H. and Islam, S. N. (2023). Green banana flour: A potential ingredient for developing low glycemic index functional foods. *Food Science and Nutrition*, *11*(4), 1234-1245.

American Diabetes Association. (2023). Standards of Medical Care in Diabetes—2023. *Diabetes Care*, *46*(Supplement 1), S1-S291.

Ameh, M. O., Gernah, D. I. and Igbabul, B. D. (2020). Physico-chemical and sensory properties of cookies produced from wheat and African mango nut flour. *Journal of Food Research*, *9*(2), 1-10.

Ayo-Omogie, H. N., Ogunsua, A. O. and Babalola, S. O. (2020). Effect of ripening on the physicochemical properties of Cardaba banana pulp and flour. *International Journal of Food Science and Technology*, *45*(12), 2605-2617.

Brzezińska, R. and Rokicki, T. (2023). Stability of betalain pigments during thermal processing: A review. *Food Chemistry Advances*, *2*, 100198.

Chaudhury, A., Duvoor, C., Reddy Dendi, V. S., Kraleti, S., Chada, A., Ravilla, R. and Mirza, W. (2021). Clinical review of antidiabetic drugs: Implications for type 2 diabetes mellitus management. *Frontiers in Endocrinology*, *12*, 618892.

Chen, L., Zhu, Y., Hu, Z. and Wu, S. (2021). Beetroot as a functional food with huge health benefits: Antioxidant, antitumor, physical function, and chronic metabolomics activity. *Food Science and Nutrition*, *9*(11), 6406-6420.

Chibuzo, N. C., Ibeabuchi, J. C. and Okafor, D. C. (2023). Consumer acceptability and willingness to pay for functional biscuits developed from indigenous Nigerian crops. *International Journal of Food Science*, *2023*, 1-12.

Chinma, C. E., Abu, J. O. and Akoma, S. N. (2022). Effect of Bambara groundnut flour addition on the physicochemical and sensory properties of wheat-based bread. *Cereal Chemistry*, *99*(2), 324-333.

Chukwuma, C. I., Ibrahim, M. A. and Ezeanyika, L. U. S. (2023). Unripe Cardaba banana flour as a functional ingredient: A review on its resistant starch content and health implications. *Food Bioscience*, *52*, 102444.

Davies, M. J., Aroda, V. R., Collins, B. S., Gabbay, R. A., Green, J., Maruthur, N. M. and Buse, J. B. (2022). Management of hyperglycemia in type 2 diabetes, 2022. *Diabetes Care*, *45*(11), 2753-2786.

DeFronzo, R. A. and Ferramini, E. (2021). Pathophysiology of type 2 diabetes mellitus. In Diabetes: *A History of Race and Disease* (45-62). Yale University Press.

Eke, E. J., Akobundu, E. N. T. and Uchegbu, N. N. (2023). Addressing protein-energy malnutrition in Nigeria through the development of nutritious and affordable composite biscuits. *African Journal of Food Science*, *17*(3), 45-58.

Esposito, K., Maiorino, M. I., Bellastella, G., Panagiotakos, D. B. and Giugliano, D. (2022). Mediterranean diet for type 2 diabetes: Cardiometabolic benefits. *Endocrine*, *76*(2), 300-308.

Evert, A. B., Dennison, M., Gardner, C. D., Garvey, W. T., Lau, K. H. K., MacLeod, J. and Yancy, W. S. (2021). Nutrition therapy for adults with diabetes or prediabetes: A consensus report. *Diabetes Care*, *44*(5), 731-754.

Fasuan, T. M., Gbadamosi, S. O. and Omobuwajo, T. O. (2024). Impact of germination and fermentation on the nutritional and functional properties of Bambara groundnut (Vigna subterranea): A review. *Food Chemistry Advances*, *3*, 100450.

Galicia-Garcia, U., Benito-Vicente, A., Jebari, S., Larrea-Sebal, A., Siddiqi, H., Uribe, K. B. and Martin, C. (2020). Pathophysiology of type 2 diabetes mellitus. *International Journal of Molecular Sciences*, *21*(17), 6275.

Granato, D., Barba, F. J. and Lorenzo, J. M. (2020). Functional foods: Product development, technological trends, efficacy testing, and safety. *Annual Review of Food Science and Technology*, *11*, 93-118.

Halban, P. A., Polonsky, K. S., Bowden, D. W., Hawkins, M. A., Ling, C., Mather, K. J. and Weir, G. C. (2021). β-cell failure in type 2 diabetes: Postulated mechanisms and prospects for prevention and treatment. *Journal of Clinical Endocrinology and Metabolism*, *106*(3), 677-686.

Khan, M. I., Anjum, F. M. and Sameen, A. (2023). Composite flour technology: *A strategic approach for improving the nutritional profile of baked products*. *Cereal Chemistry*, *100*(2), 245-260.

Liu, Y., Li, Y. and Wang, S. (2024). Effectiveness of lifestyle interventions in reducing cardiovascular disease risk factors in people with prediabetes: A systematic review and meta-analysis. *Preventive Medicine*, *180*, 107858.

Low Wang, C. C., Hess, C. N., Hiatt, W. R. and Goldfine, A. B. (2021). Clinical update: Cardiovascular disease in diabetes mellitus. *Circulation*, *143*(9), 923-936.

Mabhaudhi, T., Chinonyo, V. G. P. and Hlahla, S. (2023). Underutilised crops and climate change: Current status and outlook. *Nature Climate Change*, *13*(4), 304-312.

Mazengo, C. A., Kullberg, J., Johansson, L., Ahlström, H. and Risérus, U. (2024). The effects of acute beetroot juice intake on glycemic response and cognitive function in type 2 diabetes patients: A pilot randomized controlled crossover trial. *Nutrients, 16*(10), 1450.

Menon, L., Majumdar, S. D. and Ravi, U. (2024). Sensory-directed reformulation of biscuits: Strategies for sugar and fat reduction and fiber enrichment. *Journal of Texture Studies*, *55*(1), e12845.

Mhya, D. H. and Mohammed, A. (2021). Effect of Consuming Different Varieties of Bambara Groundnut (Vigna subterranea) on Glycemic Index and Glycemic Load in Healthy Subjects. *European Journal of Nutrition and Food Safety*, *13*(3), 1-11.

Munir, F., Nadeem, M., Qureshi, T. M. and Ainee, A. (2024). Comparative assessment of chemical composition, fatty acid profile, and glycemic index of date pulp and seed containing functional bread. *Journal of Food Biochemistry*, *2024*, 1-12.

Ngaha, R. N., Mbacham, W. F. and Tenyang, N. (2023). Formulation of nutrient-dense biscuits from composite flours of wheat, tigernut, and soybean. *Journal of Food Composition and Analysis*, *115*, 104987.

Odeniran, P. O. (2025). Exploring the Potential of Bambara Groundnut Flour as a Functional Ingredient for Diabetes and Obesity Management. *Journal of Functional Foods*, *112*, 106-118.

Ojo, M. A., Adeyemi, O. J. and Ojo, O. O. (2024). Development and quality evaluation of functional biscuits from composite flour of wheat, Bambara groundnut and orange-fleshed sweet potato. *Journal of Food Processing and Preservation*, *2024*, 1-12.

Olakunle, O. J., Adebo, O. A., Kayitesi, E. and Njobeh, P. B. (2025). Antioxidant and blood glucose-lowering properties of peanut-based snack (Kulikuli) coated with Cardaba banana starch biofilm. *Food and Bioprocess Technology, 18*(3), 450–462.

Olanrewaju, O. O., Akinola, S. A. and Osundahunsi, O. F. (2024). Low-glycemic index biscuit from composite flour of wheat, Bambara groundnut and unripe plantain: Formulation, nutritional quality and sensory attributes. LWT - *Food Science and Technology*, *191*, 115621.

Oluwajuyitan, T. D., Ijarotimi, O. S. and Fagbemi, T. N. (2024). Nutritional, functional and organoleptic properties of wheat-Bambara groundnut-based biscuits. *Scientific African, 23*, e02012.

Osman, A. G., Awad, S. and Babiker, E. E. (2023). Proximate composition and antinutritional factors of traditionally processed pearl millet flour. *Food Chemistry, 405*, 134750.

Osundahunsi, O. F. and Aworh, C. P. (2023). Enhancement of nutritional quality of a Bambara groundnut-based snack through natural fermentation. *Nigerian Food Journal*, *41*(1), 45-58.

Patel, S., Majumder, J. and Goyal, A. (2023). Biscuits as a vehicle for fortification: A comprehensive review. *Food and Bioprocess Technology*, *16*(5), 1023-1045.

Petersen, M. C. and Shulman, G. I. (2020). Mechanisms of insulin action and insulin resistance. *Physiological Reviews*, *100*(4), 2133-2223.

Pop-Busui, R., Boulton, A. J., Feldman, E. L., Bril, V., Freeman, R., Malik, R. A. and Ziegler, D. (2021). Diabetic neuropathy: A position statement by the American Diabetes Association. *Diabetes Care*, *44*(1), 136-154.

Qian, F., Liu, G., Hu, F. B., Bhupathiraju, S. N. and Sun, Q. (2019). Association between plant-based dietary patterns and risk of type 2 diabetes: a systematic review and meta-analysis. *JAMA internal medicine, 179*(10), 1335-1344.

Reynolds, A. N., Akerman, A. P. and Mann, J. (2020). Dietary FIBER and whole grains in diabetes management: Systematic review and meta-ANALYZEs. *PLOS Medicine*, *17*(3), e1003053.

Cimellaro, A., Cavallo, M., Mungo, M., Suraci, E., Spagnolo, F., Addesi, D. and Pintaudi, C. (2024). Cardiovascular effectiveness and safety of antidiabetic drugs in patients with type 2 diabetes and peripheral artery disease: systematic review. *Medicina, 60*(9), 1542.

Sacks, D. B**.** (2022). A1C versus glucose testing: A comparison. *Diabetes Care*, *qian* (1), 1-7.

Sainsbury, E., Kizirian, N. V., Partridge, S. R., Gill, T., Colagiuri, S. and Gibson, A. A. (2021). Effect of dietary carbohydrate restriction on glycemic control in adults with diabetes: A systematic review and meta-analysis. *Diabetes Research and Clinical Practice*, *172*, 108617.

Salami, A., Aderinola, T. A. and Adebayo, Y. S. (2023). Mineral and antinutrient composition of processed Bambara groundnut (Vigna subterranea) and its potential for combating micronutrient deficiencies. *Food Production, Processing and Nutrition*, *5*(1), 12.

Sanchez-Rangel, E., and Inzucchi, S. E. (2021). Metformin: Clinical use in type 2 diabetes. *New England Journal of Medicine*, *384*(15), 1457-1465.

Sankar, P., Wasim, S. and Rani, P. (2021). Pathophysiology of diabetes: An overview. *Avicenna Journal of Medicine*, 11(2), 54-63.

Sharma, P., Garg, S. and Singh, B. (2022). Functional biscuits: A review on formulation, technological aspects, and health benefits. *Journal of Food Science and Technology*, *59*(12), 4623-4635.

Suh, J. H., Duan, X. and Wang, S. (2023). Beetroot (Beta vulgaris) and its health benefits: A comprehensive review. *Food and Function*, *14*(10), 4501-4517.

Tran, E. and Dale, H. F. (2023). Plant-based diets and risk of cardiovascular disease: A systematic review and meta-analysis. *Journal of the American Heart Association*, *12*(11), e029154.

Udeh, E. L., Oyeyinka, S. A. and Kgatla, T. E. (2024). Bambara groundnut: A neglected and underutilized climate-smart crop for food and nutritional security. *Journal of Agriculture and Food Research*, *15*, 100745.

Wilkins, B. P., Khan, K. and Garcia, A. L. (2021). The role of macronutrients in the regulation of glycaemia and insulinemia. *Proceedings of the Nutrition Society*, 80(2), 195-206.

World Health Organization**.** (2023). Diabetes. Retrieved from https://www.who.int/news-room/fact-sheets/detail/diabetes

Zhang, L., McClements, D. J. and Wei, Z. (2024). Design of functional foods using a micro-nano encapsulation approach: A review. *Advances in Colloid and Interface Science*, 315, 102900.

Zhou, Y. and Wu, Y. (2024). Effects of different exercise modalities on cardiovascular disease risk factors in patients with type 2 diabetes: A systematic review and network meta-analysis. *Sports Medicine*, 54(3), 645-662.

Zinman, B., Wanner, C., Lachin, J. M., Fitchett, D., Bluhmki, E., Hantel, S. and Inzucchi, S. E. (2021). Empagliflozin, cardiovascular outcomes, and mortality in type 2 diabetes. *Diabetes Care*, 44(1), 15-27.

APPENDIX

RESULTS OF SENSORY EVALUATION OF ANTI-DIABETIC BISCUITS

SAMPLE A

Panelists	Appearance	Aroma	Texture	Taste	Overall Acceptability
Ogechukwu	4	4	6	8	7
Osazuwa Favour Osarugue	9	8	7	8	7
Chukwuumah Ruth	9	9	9	9	9
Okolo Ferdinand	8	7	4	6	7
Lawrence Cyprus	9	6	6	4	6
Imasuen James Aisosa	6	8	7	7	8
Obhions-Scott Ella Osaruemwen	7	5	6	7	7
Akwueh Israel	6	7	6	7	7
Ubah Chineye Juliet	6	7	8	5	7
Same Henry	5	4	4	5	5
Sonia	7	6	6	5	7
Isaac Best	7	4	6	5	3
Light	7	6	7	4	5
Onwubolu Presley	2	3	3	2	4
Adu Precious	7	6	5	4	6
Ebhojiaye Eliamon Nathaniel	5	4	3	2	2
Aghedo Sarah	2	3	3	2	4
Marvelous O. Omoragbon	8	3	7	6	7
Piyo Oyakemeagbegha	7	8	6	7	7
Oigbochie Blessed	3	6	4	5	5

SAMPLE B

Panelists	Appearance	Aroma	Texture	Taste	Overall Acceptability
Ogechukwu	5	5	5	2	5
Osazuwa Favour Osarugue	7	8	7	8	7
Chukwuumah Ruth	9	9	7	3	4
Okolo Ferdinand	7	8	2	2	5
Lawrence Cyrus	8	7	5	3	6
Imasuen James Aisosa	8	7	4	4	6
Obhions-Scott Ella Osaruemwen	6	4	2	2	1
Akwueh Israel	6	6	5	6	6
Ubah Chineye Juliet	6	7	7	6	6
Same Henry	3	6	4	5	5
Sonia	6	7	7	5	8
Isaac Best	7	6	7	2	4

Light	5	5	5	2	5
Onwubolu Presley	2	3	3	2	4
Adu Precious	7	6	5	4	6
Ebhojiaye Eliamon Nathaniel	5	4	3	2	2
Aghedo Sarah	6	6	5	6	6
Marvelous O. Omoragbon	8	7	7	8	8
Piyo Oyakemeagbegha	7	8	7	7	7
Oigbochie Blessed	5	6	8	8	7

SAMPLE B

SAMPLE C

Panelists	Appearance	Aroma	Texture	Taste	Overall Acceptability
Ogechukwu	4	8	7	7	8
Osazuwa Favour Osarugue	8	7	8	7	8
Chukwuumah Ruth	8	9	9	3	7
Okolo Ferdinand	7	8	7	3	6
Lawrence Cyrus	8	6	5	3	6
Imasuen James Aisosa	6	6	5	5	6
Okhions-Scott Ella Osaruemwen	5	5	6	3	5
Akwueh Israel	5	5	4	5	5
Ubah Chineye Juliet	6	7	7	6	7
Same Henry	4	3	4	5	4
Sonia	7	7	7	8	8
Isaac Best	7	4	5	4	4
Light	6	8	7	6	7
Onwubolu Presley	4	5	5	3	5
Adu Precious	7	6	5	4	6
Ebhojiaye Eliamon Nathaniel	5	5	4	3	4
Aghedo Sarah	6	6	5	6	6
Marvelous O. Omoragbon	8	6	7	6	8
Piyo Oyakemeagbegha	6	6	8	7	6
Oigbochie Blessed	3	6	4	5	5