

**INVESTIGATION OF RAW WHEAT FOR SELECTED
PHYTOCHEMICAL AND PHYSICOCHEMICAL PROPERTIES**



BY

AYOVUNEFÉ OMAMOKE FREDÁ

PSC2105213

THE DEPARTMENT OF CHEMISTRY,

FACULTY OF PHYSICAL SCIENCE,

UNIVERSITY OF BENIN,

UGBOWO, BENIN CITY,

EDO STATE,

NIGERIA.

NOVEMBER, 2025

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**A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF
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CERTIFICATION

This is to certify that this research project was carried out by **AYOVUNEFE OMAMOKE FREDA** with matriculation number **PSC2105213** in the Department of Chemistry, Faculty of Physical Sciences, University of Benin.

DR. DIBIE

(PROJECT SUPERVISOR)

DATE

PROF.E.E. IRABOR

(HEAD OF DEPARTMENT)

DATE

AYOVUNEFE OMAMOKE FREDA

DATE

DEDICATION

I dedicate this project to the Almighty God for His abundant grace, boundless love, and continuous mercy during my time in the university and also to my parents Mr and Mrs Ayovunefe.

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First and foremost, I express deep gratitude to Almighty God for His boundless grace, mercy, and benevolence that has accompanied me on this journey.

I extend my heartfelt appreciation to my project supervisor, Dr. Dibia, For his invaluable academic guidance, professional expertise, and nurturing mentorship.

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I am profoundly thankful to my beloved parents Mr and Mrs AYOVUNEFE, and my siblings for their unwavering support, fervent prayers, and constant encouragement

Gratitude is extended to my dear friends, course mates, project colleagues, relatives, and mentors, including AYOVUNEFE OGHENEDORO, AYOVUNEFE ERHUMU, MANAGER PROSPER and all those who have contributed to my successful journey at the University of Benin. May God richly bless you all in Jesus name, AMEN.

ABSTRACT

This study evaluated the phytochemical and physicochemical properties of raw wheat grains (*Triticum aestivum L.*) sourced from Warri, Delta State, to provide region-specific data on its nutritional and functional potential. Although wheat is a globally important staple, localized compositional data for Southern Nigeria are limited; this research addresses that gap by characterizing bioactive constituents, proximate composition, mineral content, and vitamin C level in locally obtained grain. The objectives were to qualitatively screen for major phytochemicals, determine proximate composition (moisture, ash, crude fat, crude fibre, crude protein, carbohydrate), quantify selected minerals (Na, K, Mg, Ca, Fe, Zn), and measure vitamin C content. Standard laboratory protocols were used: reagent-based qualitative assays for phytochemicals (e.g., Wagner's, Salkowski, ferric chloride, Fehling's tests), AOAC procedures for proximate analysis, atomic absorption spectrophotometry for mineral quantification following acid digestion, and a titrimetric method for vitamin C.

Key findings show the presence of glycosides, saponins, alkaloids, phenolics, terpenoids, flavonoids, and reducing sugars, while tannins and steroids were absent. Proximate values were: moisture 12.78%, ash 2.15%, crude fat 1.92%, crude fibre 2.39%, crude protein 10.81%, and carbohydrate 69.95%. Mineral concentrations (mg/kg) were: K 3650, Mg 1635.5, Ca 272, Fe 67, Zn 28.51, and Na 62.86. Vitamin C was low (mean 0.260 ± 0.01 mg/100 g). These results indicate that the wheat sample is energy-dense, storage-stable (moisture <14%), and rich in bioactive phenolics and flavonoids that confer antioxidant and potential cardioprotective benefits. The absence of tannins suggests reduced antinutritional effects, although mineral bioavailability may still be influenced by other factors (e.g., phytates).

Implications include supporting promotion of whole-wheat consumption to maximize intake of fibre, minerals, and phytochemicals, and recommending dietary complementation with vitamin C-rich foods to improve micronutrient utilization. The study provides data for Warri-sourced wheat and underscores the need for quantitative phytochemical assays, bioavailability studies post-processing, and region-wide comparisons or biofortification efforts.

CHAPTER ONE

1.1. INTRODUCTION

1.1.1 Background of Study

Wheat (*Triticum aestivum L.*) is the most widely cultivated cereal grain after maize and rice, accounting for about 20% of the total calories consumed worldwide (Shewry and Hey, 2015). It is a staple food crop in both developed and developing countries due to its versatility, adaptability, and high nutritional value. The grain is mainly used for bread, pasta, biscuits, noodles, and other bakery products, while wheat bran and germ are also utilized in animal feed and functional food industries (Kent and Evers, 1994; Shewry, 2009).

Nutritionally, wheat is a rich source of carbohydrates, proteins, dietary fiber, vitamins (notably vitamin B-complex and vitamin E), and essential minerals such as iron, zinc, and selenium (Poutanen *et al.*, 2014). Beyond its macronutrient composition, wheat is increasingly recognized for its bioactive compounds, phytochemicals that exert antioxidant, antimicrobial, anti-inflammatory, and cholesterol-lowering effects (Okarter and Liu, 2010; Liu, 2011). These include phenolic acids (ferulic, caffeic, vanillic acids), flavonoids, alkaloids, saponins, and tannins, most of which are concentrated in the bran and germ fractions of the grain.

In addition to phytochemicals, the physicochemical properties of wheat, such as moisture content, pH, bulk density, and proximate composition, are essential indicators of grain quality. They influence storage stability, milling yield, processing suitability, and overall consumer acceptability (Hoseney, 2010). For example, moisture content determines susceptibility to microbial contamination, while bulk density affects packaging and transportation. Proximate analysis (protein, fat, fiber, carbohydrate, and ash content) provides an overview of wheat's nutritional value and energy contribution (Shahzadi *et al.*, 2005).

Globally, research has focused on wheat breeding and processing to improve yield and gluten quality. However, limited attention has been paid to the detailed analysis of phytochemical and physicochemical properties of raw wheat varieties, particularly in developing nations like Nigeria, where wheat is increasingly being consumed but largely imported (Ayo *et al.*, 2014). Characterizing these properties in raw wheat is critical for food security, industrial applications, and health promotion.

Wheat (*Triticum aestivum L.*) is one of the world's major staple crops, providing essential nutrients and bioactive compounds important for human health. Whole wheat is a significant source of dietary fiber, minerals, vitamins, and phytochemicals such as phenolics, flavonoids,

carotenoids, and tocopherols. These phytochemicals exhibit beneficial health properties, including antioxidant, anti-inflammatory, and antiproliferative effects, which contribute to the prevention of chronic diseases like cardiovascular diseases, diabetes, and certain cancers. The physicochemical properties of wheat, including protein content, moisture, ash, fat, starch characteristics, and functional properties like water and oil absorption capacity, determine its suitability for food processing and product quality. Recent research has shown that processing methods such as germination can enhance the bioavailability and concentration of these health-promoting phytochemicals and improve antioxidant activity in wheat flour. Investigating the photochemical and physicochemical properties of raw wheat is vital for understanding its nutritional potential and improving its usage in food products.

Wheat (*Triticum aestivum L.*) is widely consumed in various forms like breads, biscuits, cookies, cakes, pasta, noodles, chapatti and it is a convenient source of carbohydrates, proteins, essential amino acids, minerals, vitamins and health beneficial phytochemicals (Kaur *et al.*, 2022).

Whole wheat is an important source of dietary fiber, the consumption of which is known to lower the risk of colon cancer, diabetes mellitus and cardiovascular disease (Zhang *et al.*, 2023). But whole wheat also has some anti-nutrients, which are substances that can prevent the absorption of nutrients and inhibit digestive enzymes (Owolabi *et al.*, 2022). Germination is one of the processes which could increase the content of bio-accessible minerals and nutrients in plant foods for absorption in human body and thus improve the nutritive quality of whole wheat flour (Rahman *et al.*, 2021). Germination also reduces anti-nutrients like phytic acid thus possible improving the bioavailability of wheat nutrients (Azeke *et al.*, 2011).

Germination of grains causes increased activities of hydrolytic enzymes thus causing improvements in the contents of total proteins, total sugars, Vitamin C, B-group vitamins and folate (Hefni 2011, Zhang *et al.*, 2023) In germinated wheat flour the carbohydrates are modified to contain more resistant starch (Van Hung *et al.*, 2012) along with increased proteins and fibers as compared with non-germinated wheat potentially affecting glycemic response and is beneficial for diabetic patients (Nelson *et al.* 2013). In vivo studies indicate blood glucose effects are improved following germinated-wheat consumption compared with non-germinated wheat, in healthy adults (Andersen *et al.* 2008, Rahman *et al.*, 2021). Germinated wheat is being promoted for traditional use as a fresh sprouted grain and also as flour to be used in different

foods including breakfast items, salads, soups, casseroles, pasta, and baked products. The flour can also be supplemented with normal flour in the preparation of unleavened pancake like chapattis and specialty breads (Lemar and Swanson 1976, Sharma *et al.*, 2024)

Bread is one of the several wheat-based products largely consumed worldwide. Bread is convenient source of energy and other nutrients. However the content of nutrients and their bioavailability is low in traditional breads (Swieca *et al.* 2017).

1.1.2 Statement of Problem

Despite wheat's important role as a staple crop and source of bioactive compounds, variations in phytochemical profiles and physicochemical properties among wheat varieties and processing conditions remain inadequately characterized. This limits the optimization of wheat utilization in health-focused food applications. There is a need for systematic investigation of raw wheat's photochemicals and physicochemical characteristics to better understand their variations, health benefits, and implications for food quality. Furthermore, challenges exist in analyzing wheat's complex biochemical composition and linking these properties to functional and nutritional outcomes in food systems.

AACC (American Association of Cereal Chemists International) has defined whole wheat flour as being prepared from wheat (other than durum) such that the proportions of the intact grain – the bran, germ, and endosperm – remain unaltered (AACC International, 1999). Whole wheat flour contains substantially more vitamins, minerals, antioxidants and other nutrients than regular wheat flour, since these compounds are concentrated in the outer portions of the grain (Zhou *et al.*, 2022). Some of these nutrients are replaced in the enrichment process of wheat flour, which is mandatory in 64 countries around the world (Flour Fortification Initiative, 2012), although many nutritional components are still lower, especially minerals and dietary fiber.

With the advent of modern roller mills during the industrial revolution, whole wheat flour production all but disappeared during much of the twentieth century. In the US, whole wheat flour production was about 2% of total wheat flour production in 2000 (Li *et al.*, 2024) and only about 7% of the population consumed at least 3 servings of whole grains per day [US Department of Agriculture (USDA, 2024).

Food industries have responded to growing consumer demand and scientific evidence supporting whole grain intake by increasing the variety and market availability of whole grain products. Between 2010 and 2023, global launches of whole grain and high-fiber foods more than doubled, driven by health-conscious consumers and government fortification programs (Mintel Global Food Trends Report, 2023; Flour Fortification Initiative, 2021). In the United States and parts of Europe, production of whole wheat flour has continued to expand, supported by the baking industry's shift toward clean-label and nutritionally enriched formulations (Zhou *et al.*, 2022; Liu *et al.*, 2023).

Despite the global importance of wheat, there is limited comprehensive data on the phytochemical composition and physicochemical properties of raw wheat varieties grown in specific regions. Most studies focus on processed wheat products, overlooking the raw grain's inherent properties. Variations in wheat composition due to genetic diversity, soil conditions, and climate can affect its nutritional quality and industrial applications. Furthermore, the lack of standardized data on phytochemicals, such as phenolic acids and flavonoids, limits the ability to harness wheat's health-promoting potential in functional food development. This study seeks to address these gaps by analyzing the phytochemical and physicochemical properties of raw wheat, providing a foundation for improved utilization in food and health industries. Milling procedures for whole grain flours remain less standardized than those for refined flours, leading to variations in particle size, functional properties, and baking performance (Jha *et al.*, 2021; Li *et al.*, 2024). Furthermore, whole wheat flour contains higher enzymatic activity, lipids, and antioxidant compounds compared to refined flour, which can influence dough rheology, end-use quality, and storage stability (Zhou *et al.*, 2022; Ghosh *et al.*, 2023). These compositional factors make whole wheat flour more prone to rancidity and textural deterioration during storage (Kaur *et al.*, 2022).

1.1.3 Justification of Study

This study aims to address gaps in understanding raw wheat's phytochemical and physicochemical attributes by profiling selected phytochemicals and quantifying key physicochemical parameters. Insights from this investigation will support enhancement of

wheat's nutritional quality, guide selection of wheat varieties for specific functional purposes, and inform food processing techniques that preserve or enhance beneficial compounds. Improved knowledge in this area is critical for leveraging wheat's full potential in promoting public health via dietary means and for advancing food science technology and product development.

Wheat (*Triticum aestivum L.*) is widely consumed in various forms like breads, biscuits, cookies, cakes, pasta, noodles, chapatti and it is a convenient source of carbohydrates, proteins, essential amino acids, minerals, vitamins and health beneficial phytochemicals (Kaur *et al.*, 2022; Zhang *et al.*, 2023).

However, whole wheat also contains anti-nutritional factors such as phytic acid and tannins, which can limit the absorption of minerals and inhibit digestive enzymes (Owolabi *et al.*, 2022). Germination is one of the processes which could increase the content of bio-accessible minerals and nutrients in plant foods for absorption in human body and thus improve the nutritive quality of whole wheat flour (van Hung *et al.*, 2012). Germination also reduces anti-nutrients like phytic acid thus possible improving the bioavailability of wheat nutrients (Azeke *et al.* 2011; Rahman *et al.*, 2021).

Germination of grains causes increased activities of hydrolytic enzymes thus causing improvements in the contents of total proteins, total sugars, Vitamin C, B-group vitamins and folate (Hefni and Witthoft 2011). In germinated wheat flour the carbohydrates are modified to contain more resistant starch (Van Hung *et al.* 2012) along with increased proteins and fibers as compared with non-germinated wheat potentially affecting glycemic response and is beneficial for diabetic patients (Nelson *et al.* 2013). In vivo studies indicate blood glucose effects are improved following germinated-wheat consumption compared with non-germinated wheat, in healthy adults (Andersen *et al.* 2008). Germinated wheat is being promoted for traditional use as a fresh sprouted grain and also as flour to be used in different foods including breakfast items, salads, soups, casseroles, pasta, and baked products. The flour can also be supplemented with normal flour in the preparation of unleavened pancake like chapattis and specialty breads (Lemar and Swanson 1976).

Bread is one of the several wheat-based products largely consumed worldwide. Bread is convenient source of energy and other nutrients. However the content of nutrients and their bioavailability is low in traditional breads (Swieca *et al.*, 2017).

This study was aimed to evaluate the effect of germination on physiochemical and antioxidant properties of whole wheat, and to formulate and analyze breads prepared with replacement of whole wheat flour with germinated wheat flour at different levels.

1.1.4 Scope of Work

This research will focus on analyzing raw wheat grains to determine their phytochemical constituents, including phenolic compounds, flavonoids, and antioxidants, as well as assessing physicochemical properties such as moisture content, protein, ash, fat, water and oil absorption capacities, and starch characteristics. The study will consider different wheat samples and employ standard analytical methods for compositional and functional property evaluation. The scope also includes reviewing relevant literature to contextualize findings within current scientific knowledge.

Selected phytochemicals (alkaloids, tannins, flavonoids, phenols, and saponins).

Physicochemical properties such as, pH, bulk density, swelling index, ash content, crude protein, crude fat, crude fiber, and carbohydrate content.

The study will not cover advanced molecular characterization of phytochemicals or processing effects on wheat.

1.1.5 Limitations

Potential limitations include variability in wheat samples due to genetic and environmental factors that may influence phytochemical and physicochemical measurements. The study may also be limited by the availability of advanced analytical instrumentation and the focus on selected phytochemicals rather than a comprehensive profiling of all bioactive compounds. Furthermore, the research may not extend into the effects of processing beyond the raw state or on in vivo bioactivity.

Some expected limitations include:

Constraints in accessing advanced analytical equipment such as HPLC and GC-MS, which could provide a more detailed profile of phytochemicals.

Time limitations restricting the study to raw wheat without considering processed forms (e.g., flour, bread).

Possible variations in wheat quality due to environmental and storage conditions.

1.1.6 Aim and Objectives

Aim: To investigate the phytochemical content and physicochemical properties of raw wheat grains (*Triticum aestivum L*) obtained in an open market, Warri, Delta state;

Objectives:

To quantify selected phytochemicals such as phenolics and flavonoids in raw wheat.

To assess physicochemical parameters including moisture content, crude protein, crude fibre, ash content, fat content, determination of mineral content (Zn, Mg, Al, K, Na, Fe)

To determine the vitamin C content (ascorbic acid) in wheat samples.

To review current literature on wheat phytochemicals and physicochemical properties to support findings and identify gaps

Whole wheat is an important source of dietary fiber, the consumption of which is known to lower the risk of colon cancer, diabetes mellitus and cardiovascular disease (Koehler *et al.* 2017). But whole wheat also has some anti-nutrients, which are substances that can prevent the absorption of nutrients and inhibit digestive enzymes (Raes *et al.* 2014). Germination is one of the processes which could increase the content of bio-accessible minerals and nutrients in plant foods for absorption in human body and thus improve the nutritive quality of whole wheat flour (van Hung *et al.* 2012). Germination also reduces anti-nutrients like phytic acid thus possible improving the bioavailability of wheat nutrients (Azeke *et al.*, 2011).

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compared with non-germinated wheat potentially affecting glycemic response and is beneficial for diabetic patients (Nelson *et al.* 2013). In vivo studies indicate blood glucose effects are improved following germinated-wheat consumption compared with non-germinated wheat, in healthy adults (Andersen *et al.*, 2008). Germinated wheat is being promoted for traditional use as a fresh sprouted grain and also as flour to be used in different foods including breakfast items, salads, soups, casseroles, pasta, and baked products. The flour can also be supplemented with normal flour in the preparation of unleavened pancakes like chapattis and specialty breads (Lemar and Swanson 1976).

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This study was aimed to evaluate the effect of germination on physicochemical and antioxidant properties of whole wheat, and to formulate and analyze breads prepared with replacement of whole wheat flour with germinated wheat flour at different levels.

1.2 Literature Review

Whole wheat is recognized for its rich content of bioactive phytochemicals, predominantly phenolic acids and flavonoids, which are linked to significant antioxidant properties. Phenolic compounds exist chiefly in bound forms attached to cell wall polymers; the bran fraction of wheat shows the highest phenolic content, followed by whole seed, germ, and endosperm. Germination and other bioprocessing techniques enhance these phytochemical concentrations and antioxidant activities by releasing bound phenolics and synthesizing additional antioxidants like vitamins C and tocopherols. Physicochemical properties of wheat vary with cultivar and processing methods and influence wheat's functional behavior in food applications, including water and oil absorption, pasting characteristics, and protein digestibility. Variability in shear and puncture forces between hard and soft wheat cultivars has implications for milling and product texture. Literature also points to challenges in preserving whole wheat flour quality during milling and storage, related to enzyme activity and moisture content. Overall, comprehensive understanding of wheat's phytochemical and physicochemical profiles is essential for optimizing its health benefits and industrial uses.

Research has extensively documented the phytochemical profile of wheat, which includes phenolic acids (e.g., ferulic acid), flavonoids, saponins, alkaloids, and antioxidant vitamins such as vitamin E (tocopherols and tocotrienols). These compounds exhibit antioxidant, anti-inflammatory, and cytoprotective properties that can mitigate oxidative stress and reduce the risk of chronic diseases like cardiovascular disease and cancer. Whole wheat, in particular, shows higher concentrations of these beneficial compounds compared to refined wheat.

Various extraction and measurement techniques have been employed, including solvent extraction and spectrophotometric assays like Folin-Ciocalteu for total phenolics, aluminum chloride methods for flavonoids, and radical scavenging assays (DPPH, ABTS) for antioxidant activity. Saponins and alkaloids, which contribute to additional bioactivities, have also been identified in significant amounts.

Physicochemical properties critical to wheat quality and processing include moisture (which affects shelf life), ash (mineral content), protein content (nutritional and functional role). These parameters directly affect wheat's functional behavior in baking and food formulation. For example, protein content and grain hardness determine gluten .

Bioprocessing techniques like germination and fermentation have been shown to enhance the phytochemical profile and antioxidant activity of wheat, while also modifying physicochemical properties such as starch digestibility and protein content. These modifications can improve wheat's health benefits and processing qualities.

Despite extensive studies, challenges remain in standardizing phytochemical and physicochemical measurements across diverse wheat varieties and environmental conditions. This underscores the need for ongoing targeted research to provide baseline data for wheat quality improvement and functional food.

1.2.1 Phytochemicals in Wheat

(a) Phenolic Compounds

Phenolic acids are the predominant phytochemicals in wheat, accounting for more than 80% of the total polyphenols. They are concentrated in the bran and germ fractions (Okarter & Liu, 2010; Kaur *et al.*, 2022,). Ferulic acid, vanillic acid, and p-coumaric acid are among the most

abundant, contributing strong antioxidant activity and free radical scavenging capacity (Adom and Liu, 2002; Zhang *et al.*, 2023). These compounds reduce oxidative stress and modulate pathways involved in inflammation and chronic disease development.

(b) Flavonoids

Flavonoids, including catechins, quercetin, and apigenin, are important secondary metabolites found in wheat (Liyana-Pathirana and Shahidi, 2007; Sharma *et al.*, 2024)). They exhibit diverse bioactivities such as anti-inflammatory, anticancer, and cardioprotective effects (Li *et al.*, 2024). Studies have shown that regular consumption of flavonoid-rich foods helps maintain vascular health and reduce risks of atherosclerosis, improved endothelial health (Kumar *et al.*, 2023).

(c) Tannins

Tannins are high-molecular weights polyphenolic compounds capable of binding and precipitating proteins and other macromolecules. In wheat, they are mainly located in the outer layers of the grain where they contribute to defense against pests and oxidative damage (Ghosh *et al.*, 2023; Shahidi and Naczki, 2004). While high levels may reduce protein digestibility, moderate concentrations possess antimicrobial, antioxidant, and anti-carcinogenic properties (Kaur *et al.*, 2022; Zhou *et al.*, 2022).

(d) Alkaloids

Alkaloids are nitrogenous plant metabolites with strong biological activity. In cereals like wheat, alkaloids occur in lower concentrations compared to legumes but still contribute to defense against pathogens and pests exhibit notable **antimicrobial and antidiabetic** potential (Wang *et al.*, 2022). Some alkaloids have demonstrated antimicrobial and antidiabetic properties, though excessive amounts may be toxic emphasizing the need for balanced consumption (Kumar *et al.*, 2023; Cushnie *et al.*, 2014).

(e) Saponins

Saponins are glycosidic compounds found in wheat germ and bran (Rahman *et al.*, 2021) They possess surface-active properties and are associated with cholesterol-lowering effects, **anticancer** effects through the inhibition of cholesterol absorption and stimulation of immune responses (Sharma *et al.*, 2024). Additionally, saponins have shown anticancer and immune-modulating activities (Shi *et al.*, 2004).

1.2.3 Physicochemical Properties of Wheat

(a) Moisture Content

Moisture content is critical for grain storage stability. High moisture levels (>14%) encourage microbial growth, mold development, and insect infestation (Shahzadi et al., 2005). Optimal moisture content ensures preservation of quality during storage and determines the milling yield and baking performance of wheat (Kent & Evers, 1994).

(b) pH

The pH of wheat extracts provides information about acidity and potential microbial activity. Most cereals, including wheat, exhibit slightly acidic pH values (5.5–6.5), which affect enzymatic reactions and storage behavior (Oke *et al.*, 2015).

(c) Proximate Composition

The proximate composition of wheat typically includes:

Carbohydrates: Carbohydrates are the major macronutrient in wheat, accounting for approximately **65–75%** of the grain, primarily in the form of starch (Zhang *et al.*, 2023). These carbohydrates serve as the main source of **energy** and influence the texture, color, and sensory properties of wheat-based foods (Kumar *et al.*, 2023).

Proteins: Wheat contains about **10–15% protein**, consisting mainly of **gluten-forming proteins** (gliadin and glutenin), which are responsible for the dough's **elasticity, extensibility, and baking quality** (Shewry *et al.*, 2022). Protein quality and content vary among wheat varieties and are key indicators of processing potential and nutritional value (Li *et al.*, 2024)

Lipids: lipids constitute **1.5–2.5%** of the wheat grain, concentrated mainly in the **germ and aleurone layers** (Sharma *et al.*, 2024). Although present in small amounts, wheat lipids contribute to **flavor, aroma, and oxidative stability** in flour and baked products. They also contain essential fatty acids and vitamin E, which add to the grain's nutritional profile (Ghosh *et al.*, 2023)

Crude Fiber: Wheat is an excellent source of dietary fiber (2–3%), mainly composed of **arabinoxylans and β -glucans** located in the bran fraction (Kaur *et al.*, 2022). Fiber improves

digestive health, glycemic control, and cholesterol metabolism, thereby reducing risks of cardiovascular diseases and type 2 diabetes (Rahman *et al.*, 2021)

Ash Content: The **ash content (1–2%)** represents the total **mineral content** of wheat, which varies according to genotype and milling process (Zhou *et al.*, 2022). Major minerals include **phosphorus, potassium, magnesium, calcium, and iron**, which contribute to both nutritional value and functional properties of flour (Sharma *et al.*, 2024).

CHAPTER TWO

MATERIALS AND METHODS

This chapter is divided into sections namely; materials, which dealt with all the reagents and apparatus used in the study, and methods which dealt with the scientific techniques employed in the study.

2.1. MATERIALS:

The various reagents and apparatus used in this study include the followings;

Crucibles

Funnel

Whatman`s filter paper

Beakers

Pipette

Stirrers

Test tubes

Measuring cylinder

Soxhlet extractor

Spatula

Volumetric flask

Conical flask

EQUIPMENTS

Weighing balance

Hot air oven(serial oven 980704)

Muffle furnace(Manufacturer- BIOBASE BIOMETCH.Co, LTD model: MX6-10TP)

Desiccator

Fume Hood (JINAN BIOBASE BIOTECH Co, LTD, model -FHZ18Z1407015)

Hot Plate (Manufacturer- EUROSONIC Model-3825,1500W)

UV – Vis Spectrophotometer

Atomic Absorption Spectrometer

Heating mantle (Manufacturer- TECHMEL AND TECHMEL USA)

SAMPLES

Wheat grains

REAGENTS

Distilled water

Sodium hydroxide

Chloroform

Potassium hydroxide

Hager's reagent

Fehling's reagent

Sodium hypochlorite

Sodium potassium titrate

Alkaline sodium phenate solution

Hexane

Kjehdhal catalyst

Oxalic acid

Ascorbic acid

Potassium permanganate

Hydrochloric acid (HCl)

Sulfuric acid (H₂ SO₄)

Ferric chloride(FeCl₃)

2.2. METHODS

2.2.1 COLLECTION OF SAMPLES:

The wheat samples used in the work were obtained from open market in Warri, Delta state.

2.2.2 SAMPLES COLLECTION

The methodology for preparation of raw wheat samples for investigation of selected phytochemical and physicochemical properties generally involves the following steps:

Collection and cleaning: Wheat grains/seeds were collected and cleaned manually to remove dirt, defective grains, as well as extraneous materials.

Drying: The cleaned grains were sun-dried for several days to reduce their moisture content.

Grinding/Milling: The dried wheat grains were milled or into a fine particle sizes using a milling machine. The milled wheat was used for subsequent analysis.

Storage: The milled wheat sample was stored in airtight containers to prevent contamination and further moisture absorption before analysis.

Extraction for phytochemical analysis: phytochemical constituents of the milled wheat samples were extracted using methanol as solvent. Soxhlet extraction procedure was carried out, after 10g of milled wheat samples was measured into the thimble and the apparatus set up .The extraction lasted for a period of six hours.

flour or powdered sample was used directly or prepared under specific conditions described in standard methods.

Plate2.3: Milled wheat sample

PHYTOCHEMICAL SCREENING

The Phytochemical examinations of the plant extract were carried out using standard methods as described by Tiwari *et al.*, 2001, with little modification.

Qualitative determination of Alkaloids: This was done by first evaporating 2.0ml of the plant extract to dryness. Then the resultant residues were dissolved in 5ml of HCl (2mol/ dm^3) and filtered. The filtrate was divided into three portions and put in separate test tubes.

portion A: To the solution in the first test tube was added few drops of Mayer's reagent (made of mixture of potassium mercuric iodide salt) were added, and the formation of a yellow-coloured precipitate or reddish-brown precipitate indicated a positive test for the presence of alkaloids.

portion B: The solution in the second test tube was treated with a few drops of Wagner's reagent, the formation of brownish-red precipitate indicated alkaloids.

portion C: 2ml of picric acid was added to the solution in the third test tube yellowish precipitate showed positive test

Determination of glycoside: Keller-Jillian test (for cardiac glycosides)

Two milliliters of extract was added to 1ml of glacial acetic acid to which a trace of ferric chloride was previously added. Thereafter and carefully 1ml of concentrated H₂SO₄ was added along the side of the test tube,

A blue-green ring at the interface indicated the presence of deoxy sugars.

Determination of Tannins: To about 2ml of the extract was added 3ml of distilled water and thereafter, 2 drops of ferric chloride was added to the solution. No precipitate or colour change was observed which indicates absence of tannins.

Qualitative determination of phenols: To 1ml of the extract was added 5ml of 90% ethanol. This was followed addition of 10% FeCl₂ was solution. A pale yellow coloration is indicated of positive test

Qualitative determination of Saponins: The foam test method and froth test methods were used for the qualitative determination of saponins. In the foam test method, 0.5ml of the plant

extract was shaken with 2.0 ml of distilled water. The formation of foam which persists for 10 minutes indicated the presence of saponins.

Qualitative Determination of Flavonoids: two milliliter of the extract was boiled in 10ml of distilled water. The filtrate was divided into two diff portions A and B of 5 ml each. 1) To portion A: 5 drops lead acetate solution was added, A yellowish precipitate indicated a positive test. To portion B, 5ml of 20% NaOH and a three drops of dilute HCL were added. The formation of a colorless solution indicated positive result.

Qualitative Determination of Eugenols: 2ml of the extract was mixed with 5ml of 5% KOH solution. The aqueous layer was separated and filtered. Four drops of dilute HCl were added to the filtrate. A pale-yellow precipitate indicated positive test result.

Qualitative Determination of Steroids: 2 ml of acetic anhydride was added to 0.5ml of the extract of each of the test samples followed by the addition of 2 ml of H_2SO_4 . No colour change was observed which indicates absence of steroids.

Qualitative determination of Terpenoid: two millimeters of the extract of the plant sample was mixed with 2 ml of chloroform ($CHCl_3$) and 3ml of concentrated H_2SO_4 was carefully added. Layer formation was observed. A reddish-brown colouration in the interface indicated positive results for the presence of terpenoids.

Test for reducing sugar:

Fehling's Test: Equal volume of fehling's solution A and B were mixed together and boiled, Thereafter, 5ml of the plant extract was added and boiled for 5 mins. A bricked-red precipitate indicated a positive test.

2.2.6. PROXIMATE ANALYSIS

Ash Content

Two Grammes of the dried sample was placed in a porcelain crucible which initially was weighed and transferred into a preheated muffle furnace set at the temperature of 900⁰C. The sample was heated at the temperature for one hour after which the crucible and its content were transferred to a desiccator and allowed to cool Thereafter, the crucible and its content was re-weighed and the weight noted. The processes of heating, cooling and weighing were repeated, until constant Weight was obtained. Thereafter, the percentage ash content was calculated from the relationship:

$$\text{Ash content (\%)} = \frac{((\text{wt of crucible} + \text{ash}) - (\text{wt of crucible}))}{\text{wt of sample}} \times 100$$

Moisture Content

Two gramme of the sample was weighed and dried in an oven maintained at a temperature of 100g. The processes of drying, cooling and weighing were repeated until a constant weight was obtained. The ratio of the change in weight to the original weight expressed in percentage gave the moisture content:

$$\text{Moisture content (\%)} = \frac{W1 - W_{\text{dry}} (\%)}{W1}$$

W1= Initial weight

Wdry(%)= Final weight

Crude Fiber Determination: This was carried out in accordance with the procedure of AOAC (1980). Initially, 4 g of each moisture-free sample was weighed into a 250 mL beaker, and 100ml of 1.25% HCL was added followed by distilled water to a volume of 100ml. This was then heated to boiling and the boiling was continued for 30 min on a hot plate. After 30 minutes. The content of the beaker was washed several times with distilled water, filtered and then transferred to a funnel. The Washing was continued in the funnel until the filtrate was acid-free as tested using phenolphthalein. The acid-free residue was qualitatively transferred from the filter paper into a 250ml beaker, and the last traces of residue removed with a 1.25% NaOH solution and water to a volume of 100ml. The mixture was boiled for 30 min, Therefore the mixture was filtered and washed as earlier described until it was alkaline-free. Finally, the residue was washed with distilled water, filtered and tested to be alkaline free using methyl-orange. The Residues on the filter paper were transferred to a pre-weighed porcelain crucible. The content of the crucible was then dried in an oven maintained at 110°C to a constant weight and cooled in a desiccator. Subsequently, the content of the crucible was ignited in a muffle furnace at 550°C for 8 h, cooled, and weighed. Triplicate determination were carried out. percentage of crude fiber was therefore calculated as:

$$\text{Crude fiber}(\%) = \frac{100(y - a)}{x}$$

x = Weight of sample (g)

y = Weight of insoluble matter (g)

a = Weight of Ash (g)

Plate 2.4: washing of the sample

Crude fat determination: The method of Pearson (1973) was employed; this method was based on the principle that non-polar components of samples are easily extracted into organic solvents.

Procedure: Three grams, (Moist-free) of each sample, were placed into fat-free thimbles. These were then weighed and transferred into a filter paper, tied properly using a thread and introduced into Soxhlet extractors containing 160 mL n-hexane (b.p 60-80°C). Cleaned and dried flask was weighed and fitted to the extractors. The extraction unit was then assembled and cold water was allowed to circulate through the condenser, while the temperature of the water bath was maintained at 60°C. Extraction was carried out for 8 hours. At the end of this time, the thimble containing the sample was removed and placed in an oven at 70°C for 3 h and dried to constant weight. The weight of the Thimble and the content were then obtained using a standard analytical balance.

Calculation: The crude fat was obtained as the difference in weight before and after the exhaustive extraction.

Hence the percentage of fat was calculated as:

$$Fat(\%) = \frac{X - Y}{Z}$$

were,

x = Weight sample and thimble and oil

Y = Weight of empty thimble

Z = Weight of sample

Plate 2.5: samples in the dessicator to cool

Crude protein determination: A modified method of micro-Kjeldahl as described by AOAC (1990) was used for crude protein determination.

Procedure for digestion: Three grams of each of the defatted samples were separately weighed on into a micro-Kjeldahl digestion flask together with a few anti-bumping granules. Two grams of catalyst mixture (CuSO_4 : Na_2SO_4 : SeO_2 , 5:1:02 w/w) was added to each flask and then 10 ml nitrogen-free concentrated H_2SO_4 was also added to each flask. The flasks were placed in an inclined position on a heating mantle in a fume cupboard. Digestion was commenced at a temperature of 30°C until frothing ceased and then heating was increased to 50°C for another 30

min and finally at full heating (100°C) until a clear solution was obtained. Simmering was continued below boiling point for another 30 min to ensure complete digestion and conversion of nitrogen to ammonium sulphate. At the completion of digestion, the digest was allowed to cool and then transferred quantitatively to 100 mL volumetric flasks. Complete recovery to digest was ensured by rinsing the digestion flask, and transferring of the recovered solution to the 100ml flask. The digest was subsequently cooled to room temperature. Thereafter the volume was made up to mark with distilled water

1ml of the filtrate from the digest was transferred with the aid of a 10 ml pipette into a 10 ml standard flask after which 4ml of water was added subsequently, 2.5ml of the Alkaline Phenate was added and the solution was shaken to mix properly. Thereafter 1ml of Sodium Potassium tetrartrate was added and shaken properly followed by the addition of 2.5ml of sodium hypochlorate . Subsequently, the solution was made up to the 10ml mark with distilled water and the absorbance of the resultant solution was read at 630nm with the aid of a UV/visible spectrophotometer, . The standards were treated the same way with the sample.

CALCULATION

$$\%N = \frac{\text{Instrument. Reading. X Slope reciprocal X Color Vol. X Digest vol}}{\text{Weight of Sample X Aliquot Taken X 10000}}$$

% Crude protein = %Nitrogen x 6.25 (AOAC, 1975)

2.2.7 MINERAL ELEMENTS DETERMINATION

Wet digestion of samples

The determination of mineral elements in wheat grains was carried out using the wet digestion method, which is widely recognized as an efficient technique for preparing plant materials for

elemental analysis. This method ensures the complete breakdown of organic matter and the release of mineral elements into solution for accurate determination using atomic spectroscopic techniques (Abebe *et al.*, 2023).

Wheat grains were first cleaned to remove impurities, oven-dried at 105°C to constant weight, and then ground into a fine powder to ensure sample uniformity. About 0.5 g of the powdered sample was accurately weighed into a clean digestion flask. To this, 10 mL of concentrated nitric acid (HNO₃) was added and allowed to stand for about 20 minutes for pre-digestion to minimize excessive frothing during heating. The sample mixture was then heated gently on a hot plate at 80–90°C until the initial brown fumes subsided, indicating the oxidation of most organic components. Thereafter, 2–5 mL of hydrogen peroxide (H₂O₂) was added dropwise to enhance the oxidation process and ensure complete digestion. Heating continued at 150–180°C until the digest became clear or pale yellow, signifying the complete breakdown of organic matter (Abebe *et al.*, 2023).

After digestion, the sample was allowed to cool and was quantitatively transferred into a 50 mL volumetric flask. The digestion flask was rinsed with deionized water, and the rinses were added to the volumetric flask to ensure no loss of analytes. The final volume was made up to the mark with deionized water. The digested sample was filtered through Whatman No. 42 filter paper and stored in clean polyethylene bottles for subsequent mineral analysis.

The concentrations of zinc (Zn), iron (Fe), magnesium (Mg), sodium (Na), potassium (K), and calcium (Ca) were determined using Atomic Absorption Spectrophotometer (AAS) at their respective wavelengths. Calibration standards were prepared from certified stock solutions of each element, while reagent blanks were included to correct for background interference. The concentration of each element in the sample was calculated using the relationship:

$$\text{Element (mg/kg)} = C \times V \times 1000 / W$$

where C is the concentration obtained from the instrument (mg/L), V is the final volume of the digest (L), and W is the weight of the sample (g).

This method proved reliable and reproducible for the determination of essential mineral elements in wheat grains. According to Abebe *et al.* (2023), the wet acid digestion method is highly

suitable for cereal grains as it is cost-effective, simple, and ensures total decomposition of organic matter, allowing accurate quantitative determination of macro- and micro-elements using AAS or other spectrometer

2.2.3: Preparation of Sample for Vitamin C Determination

The preparation of the sample for vitamin C determination was carried out in accordance with the method described by Isam *et al.*, (2017) and, Aiyegoro and Oko (2010) with little modification. The samples were Sinitially washed with distilled water, and diced for easy blending. Thereafter 100g of the diced sample was weighed and transferred into the blender. Subsequently 200ml of distilled water was added and the sample blended vigorously. This was followed by the addition of 30 ml of oxalic acid (0.5% w/v) in order to prevent the oxidation of ascorbic acid (vitamin C). The mixture was thereafter filtered using whatmann filter paperin a 250 ml Erlenmeyer flask. The aliquot of each sample was transferred to a 100ml volumetric flask and then made up to the 100ml mark with an oxalic acid solution (0.5%).

etric techniques.

2.2.3.1 PREPARATION OF STOCK AND STANDARD SOLUTIONS OF ASCORBIC ACID.

Standard solution of ascorbic acid was prepared by dissolving an of 0.01g of ascorbic acid in a small amount of oxalic acid solution (0.5%.) and then made up to 100 ml with the same solution to obtain a concentration of 100 µg/ml. A series of dilutions 10, 8.0, 6.0, 4.0, and 2.0 µg/mL were prepared from the stock ascorbic acid solution.

2.2.3.2 PREPARATION OF POTASSIUM PERMANGANATE (KMNO₄) SOLUTION.

A solution of KMnO₄ of concentration of 100 µg/mL was prepared by dissolving an 0.01 g of KMnO₄ in H₂SO₄ solution, then transferred into a 100 mL volumetric flask. Thereafter, the solution was made to the 100ml mark with distilled water and thoroughly mixed.

2.2.4 Determination of Vitamin C

Ten milliliters of the sample extract were measured and transferred into a test tube. Thereafter 1.0ml of the prepared KMnO_4 (100 $\mu\text{g}/\text{ml}$) was added and content mixed thoroughly. It was then allowed to stand for 5 minutes. The standard solutions and blank were treated in the same manner. The resultant solutions were read at 530nm, using a UV/Visible Spectrophotometer against the reagent blank.

CHAPTER THREE

RESULTS AND DISCUSSION

3.1 results for phytochemical screening

Table 1: Phytochemical screening of wheat grains (*aestvitiium tricticum*)

| PHYTOCHEMICALS | TEST METHOD | INFERENCE |
|-----------------|--|-----------|
| Glycosides | glacial acetic acids 2 drops of ferric chloride Concentrated sulphuric acid(H ₂ SO ₄) | + |
| saponins | distilled water | + |
| Alkaloids | wagners reagent + extract | + |
| Phenolics | Into the extract add 90% ethanol and 1 drop of 10% ferric chloride | + |
| Tannins | ferric chloride test | – |
| Steroids | Acetic anhydride/H ₂ SO ₄ | – |
| Terpenoids | Salkowski test | + |
| flavonoids | sample + water and then boil | + |
| Reducing sugars | Fehling A Fehling B | + |

Table 1: phytochemical screening for wheat grains

The qualitative phytochemical screening of wheat grains (*Triticum aestivum*) revealed the presence of glycosides, saponins, alkaloids, phenolics, terpenoids, flavonoids, and reducing sugars, while tannins and steroids were absent. This diverse phytochemical profile reinforces the nutritional and functional value of wheat, extending its importance beyond a carbohydrate staple to a source of bioactive compounds that support human health.

The presence of glycosides is significant, as cereal-derived glycosides have been linked with antioxidant and cardioprotective properties (Li *et al.*, 2021). Saponins, which tested positive, are known to lower cholesterol absorption, enhance immunity, and exhibit antimicrobial activity. Recent studies highlight their potential role in modulating gut microbiota, thereby improving digestive health (Xie *et al.*, 2022).

The detection of alkaloids in wheat aligns with reports of their antimicrobial and anti-inflammatory effects, even in trace amounts. Alkaloids contribute to the therapeutic relevance of cereals, though their concentrations are typically lower than in medicinal plants (Rahman *et al.*, 2021). Phenolics were also strongly positive, confirming wheat's well-documented richness in ferulic acid, caffeic acid, and other phenolic acids. These compounds act as antioxidants that scavenge free radicals and reduce the risk of chronic diseases such as diabetes and cardiovascular disorders (Sharma *et al.*, 2020; Tavares *et al.*, 2022).

Interestingly, tannins were not detected in the sample. This is advantageous nutritionally, since tannins are known antinutritional factors that can reduce protein and mineral bioavailability by forming insoluble complexes. Their absence improves the digestibility and nutrient utilization of wheat. Similarly, steroids were absent, which is consistent with previous findings that wheat phytochemistry is dominated by phenolics and flavonoids rather than steroidal metabolites.

The positive test for terpenoids is important, as these compounds are recognized for their antimicrobial, antioxidant, and anticancer potentials. Recent evidence shows that cereal terpenoids may also enhance stress tolerance and improve grain storage quality (Xu *et al.*, 2021). Flavonoids, detected in this study, further support the functional food role of wheat. Flavonoids

such as apigenin and luteolin are widely reported in wheat and contribute to anti-inflammatory, antioxidant, and cardioprotective effects (Gupta *et al.*, 2023).

Finally, the detection of reducing sugars is consistent with wheat's carbohydrate profile, as the grain contains simple sugars alongside starch. These reducing sugars not only contribute to energy metabolism but also participate in Maillard reactions during processing, influencing flavor and color in wheat-based products.

Overall, the phytochemical screening suggests that wheat grains from Warri, Delta State, are nutritionally valuable and rich in bioactive compounds. The absence of antinutritional tannins enhances their digestibility, while the presence of phenolics, flavonoids, and terpenoids underscores their potential as functional foods with antioxidant and protective health benefits.

Table 2: proximate composition of wheat grains composition (%) (triticum aestivum L)

| <u>NUTRIENT</u> | <u>COMPOSITION (%)</u> |
|----------------------|------------------------|
| <u>Moisture</u> | <u>12.78%</u> |
| <u>Ash</u> | <u>2.15%</u> |
| <u>Crude fat</u> | <u>1.92%</u> |
| <u>Crude fibre</u> | <u>2.39%</u> |
| <u>Crude protein</u> | <u>10.81%</u> |
| <u>Carbohydrate</u> | <u>69.95%</u> |

3.2 Proximate Composition

The proximate analysis showed that wheat grains contained 12.78% moisture, 2.15% ash, 1.92% crude fat, 2.39% crude fibre, 10.81% crude protein, and 69.95% carbohydrate.

The moisture content (**12.78%**) is within the safe storage limit of cereals (<14%), suggesting reduced susceptibility to microbial growth and longer shelf life (FAO, 2019). The ash value (2.15%) indicates the presence of nutritionally relevant mineral elements, correlating well with the mineral analysis.

The low crude fat content (1.92%) is characteristic of cereals, reinforcing wheat’s role as a carbohydrate-rich staple rather than a fat source. This is advantageous nutritionally, as low-fat foods reduce risks associated with obesity and cardiovascular disease. Crude fibre (2.39%) was also present in appreciable amounts, contributing to bowel regulation, cholesterol reduction, and prevention of constipation-related disorders (Slavin, 2004).

The crude protein level (10.81%) confirms wheat as a significant source of plant-based protein, especially gluten proteins that are vital for the rheological properties of bread and pasta (Shewry & Hey, 2015). While lower than that of legumes, wheat protein plays a crucial role in meeting dietary amino acid requirements when consumed with complementary foods.

Finally, carbohydrate (69.95%) constituted the bulk of the composition, affirming wheat as an energy-dense cereal. This agrees with previous reports that place wheat carbohydrate content within 68–72% (Hoseney, 1994).

Table 3: Mineral analysis of wheat grains from Warri, delta state(triticum aestivum L.)

| PARAMETERS | WHEAT GRAINS |
|------------|--------------|
| | (mg/kg) |

| | |
|----------------|---------|
| Sodium(Na) | 62.86 |
| potassium (k) | 3650 |
| Magnesium (mg) | 1635.50 |
| Calcium (ca) | 272 |
| Iron(fe) | 67 |
| Zinc(zn) | 28.51 |

3.3 Mineral Analysis

The mineral profile revealed that wheat grains contained potassium (3650 mg/kg), magnesium (1635.5 mg/kg), calcium (272 mg/kg), iron (67 mg/kg), zinc (28.51 mg/kg), and sodium (62.86 mg/kg).

Potassium was the most abundant element, which is consistent with literature stating that cereals are rich in potassium, an essential electrolyte for maintaining fluid balance, nerve function, and normal blood pressure (WHO, 2012). Magnesium was also present at high levels (1635.5 mg/kg), contributing to enzymatic activity, bone mineralization, and glucose metabolism (Volpe, 2013).

Calcium (272 mg/kg) was detected in moderate amounts, which although lower than dairy sources, contributes to dietary calcium intake, particularly in populations with limited access to animal-based foods. Iron (67 mg/kg) was relatively high, making wheat an important plant-based iron source. However, the bioavailability of iron may be limited by the presence of phytates, a known antinutritional factor in cereals (Sandberg, 2002).

Zinc (28.51 mg/kg) was present in appreciable amounts, supporting its role in immune function and enzymatic processes, while the relatively low sodium content (62.86 mg/kg) is advantageous in preventing hypertension and cardiovascular complications. Collectively, these results confirm

that wheat grains are a valuable source of essential minerals required for normal physiological functions.

Table 4: vitamin C content in wheat grains from Warri, delta state

| PARAMETER | 1(mg/100g) | 2 (mg/100g) | 3 (mg/100g) | mean (mg/100g) |
|-------------|------------|-------------|-------------|----------------|
| 3rvitamin C | 0.253 | 0.271 | 0.256 | 0.260+/-0.01 |

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3.4 Vitamin C Content

The determination of vitamin C content revealed low levels in wheat grains. This outcome is expected, as wheat and other cereals are not primary sources of ascorbic acid compared to fruits and vegetables. Nonetheless, the presence of small amounts of vitamin C may synergize with phenolic compounds to enhance antioxidant activity in the grain matrix (Podsdek, 2007).

Since vitamin C is water-soluble and heat-labile, its dietary significance in wheat is more relevant in raw or minimally processed forms such as wheatgrass or sprouted wheat. For human nutrition, therefore, wheat consumption should be complemented with fruits and vegetables to ensure adequate vitamin C intake

3.6 Conclusion

This study established that wheat grains (*Triticum aestivum*) from Warri, Delta State, contain important phytochemicals such as glycosides, saponins, alkaloids, phenolics, terpenoids, flavonoids, and reducing sugars, while tannins and steroids were absent. These compounds,

together with the balanced proximate composition and rich mineral profile, demonstrate wheat's value not only as a staple carbohydrate source but also as a functional food with health-promoting properties. However, the low vitamin C content highlights the need for dietary complementation with fruits and vegetables.

3.7 Recommendations

Encourage consumption of whole wheat products rather than refined forms to maximize fibre, minerals, and phytochemicals.

Combine wheat-based diets with vitamin C-rich foods to ensure balanced nutrition.

Support breeding and processing techniques that enhance the retention of phytochemicals and minerals.

Promote public nutrition awareness on the benefits of wheat as both a staple and a functional food.

3.8 Recommendations for Further Study

Conduct quantitative analysis of individual phytochemicals in Nigerian wheat varieties.

Investigate the bioavailability of minerals and phytochemicals after processing and cooking.

Compare regional variations in wheat grown across Nigeria to assess environmental influence on nutrient composition.

Explore the role of wheat phytochemicals in preventing chronic diseases such as diabetes and hypertension.

Evaluate the potential of fortification or biofortification to improve wheat's micronutrient density.

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