

Nutritional Evaluation and Aflatoxin Levels in Selected Leguminous Grains Retailed in Wukari, Taraba State, Nigeria

Anih David Chinonso¹, Arowora Kayode Adebisi¹, Imo Chinedu¹, Moses Adondua Abah¹,
Ekele Jiata Ugwah², Eunice Ibukunoluwa Olobatoke³, Asare Bernard Kwame⁴,
Atunwa Bushirah Omolara⁵, Farayola Deborah Taiwo⁶, Sojay Tryphosa Tibile⁷,
Oghenetejiri C. Ovwigho-Ugbede⁸, Anifowose Isaiah Olumide⁹ and Ibejo Blessing Ugoojo¹⁰

¹Department of Biochemistry, Faculty of Biosciences, Federal University Wukari, Taraba State, Nigeria

²Biological and Environmental Sciences, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF United Kingdom

³Ministry of Agriculture and Food Security, Ekiti State, Nigeria

⁴Department of Nutritional, Food and Consumer Sciences, Fulda University of Applied Sciences, Germany

⁵Global Health and Infectious Disease Control Institute- Nasarawa State University, Keffi, Nigeria

⁶Department of Nutrition and Dietetics, Faculty of Public Health, University of Ibadan, Oyo state, Nigeria

⁷Department of Food Nutrition and Home Sciences, Faculty of Agriculture, Prince Abubakar Audu University, Anyigba, Kogi State, Nigeria

⁸Department of Medical Laboratory Science, School of Basic Medical Sciences, University of Benin, Benin city, Nigeria

⁹Department of Food Technology, Faculty of Technology, University of Ibadan, Oyo State, Nigeria

¹⁰Department of Biotechnology, I.M. Sechenov First Moscow State Medical University (Sechenov University)

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Corresponding Author: **Moses Adondua Abah** | E-Mail: m.abah@fuwukari.edu.ng

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ABSTRACT

In Nigeria, and specifically in Taraba State, legumes such as cowpeas, groundnuts, and soybeans form a crucial part of the local diet and agricultural economy. Their high protein content, fiber, essential vitamins, and minerals make them an indispensable part of nutrition, especially in populations that rely heavily on plant-based diets. While the nutritional contributions of leguminous grains are widely recognised, concerns persist regarding their contamination with aflatoxins—naturally occurring mycotoxins produced by certain species of *Aspergillus*, particularly *A. flavus* and *A. parasiticus*. This study was conducted to determine the proximate composition, amino acid content and aflatoxin levels of selected leguminous grains retailed in Wukari, Taraba State. A total of 36 samples of various agricultural commodities, including shelled groundnut, soy beans, sesame seed, shelled melon, were procured from grain vendors operating in the markets of Wukari metropolis. These markets are namely Wukari New Market, Wukari Old Market and Dorowa Market which has distance of above 40km from Wukari city. The collection of samples took place during the period spanning from April to May of the year 2023. The sample size was determined using the composite sampling technique. Experimental procedures for proximate composition were carried out using the standard methods of Association of Official Analytical Chemistry, amino acid analysis was carried out using acid hydrolysis on grain samples employing the amino acid analyser while aflatoxin levels in samples were determined using the Enzyme Enzyme-linked immunosorbent assay (ELISA) method. The results of proximate composition of legumes ranged from 3.62-9.12% ash content, 4.25-13.45% crude fibre, 18.06-42.22% crude protein, 30.51-57.11% ether extract, 5.13-10.44% nitrogen free extract and 4.53-11.10 moisture. The amino acid results of legumes ranged from 1.59-2.54% histidine, 2.58-4.72% isoleucine, 2.87-7.6% leucine, 2.08-6.2% lysine, 0.77-1.70% methionine, 2.81-5.71% phenylalanine, 1.13-3.73% threonine, 0.01-1.51% tryptophan, 2.82-4.79% valine, 5.85-8.87% arginine, 0.5%-16.04% aspartic acid, 2.3%-8.42% Serine, 11.87%-17.54% glutamic acid, 1.63%-6.49% proline, 2.14%-12.96% glycine, 3.10%-9.64% alanine, 1.26%-5.01% cysteine and 2.21%-7.33% tyrosine. There were significant differences ($p < 0.05$) in the crude protein and moisture content of the samples among the three markets for shelled groundnut. There were no significant differences in the histidine and isoleucine residues of the essential amino acids of sesame seeds, but there was a recorded significant difference in the proline and glycine residues of the non-essential amino acids of the soya bean samples. There were no significant differences in the aflatoxin levels of shelled melon seeds, while there was a significant difference in shelled groundnut, and soybeans samples purchased from all the markets. Aflatoxin levels in legumes retailed in Wukari, Taraba State ranged from 0.57-1.17 μ g/kg in shelled groundnut samples, 0.47-2.27 μ g/kg in shelled melon samples, 1.53-3.17 μ g/kg in sesame seed samples, 0.10-0.20 μ g/kg in soybean samples, and 3.11-13.10 μ g/kg in These aflatoxin levels were within the permissible limits for total aflatoxins recommended by FDA and NAFDAC for all products intended for food, hence these legumes analysed in this study are safe for human consumption. The findings revealed that the proximate and amino acid composition were present at appreciable levels in the samples analysed.

Keywords: Leguminous grain, Aflatoxin, Proximate composition, Nutrition, Agriculture.

Introduction

Leguminous grains are a fundamental component of the human diet across many regions of the world, particularly in sub-Saharan Africa [1]. Their high protein content, fiber, essential vitamins, and minerals make them an indispensable part of nutrition, especially in populations that rely heavily on plant-based diets [2]. In Nigeria, and specifically in Taraba State, legumes such as cowpeas, groundnuts, and soybeans form a crucial part of the local diet and agricultural economy. Wukari, a town in southern Taraba, is a significant hub for the production and retail of various leguminous grains, serving not only local consumers but also neighbouring regions [3]. Given the increasing reliance on these grains for nutritional and economic sustenance, it becomes imperative to assess both their nutritional quality and safety for consumption [4]. While the nutritional contributions of leguminous grains are widely recognized, concerns persist regarding their contamination with aflatoxins, naturally occurring mycotoxins produced by certain species of *Aspergillus*, particularly *A. flavus* and *A. parasiticus* [5]. Aflatoxins are toxic and carcinogenic compounds that pose significant public health challenges globally, with the highest burden in developing countries where agricultural and storage practices may be substandard. Aflatoxin contamination typically occurs under warm and humid conditions that favor fungal growth, particularly during pre-harvest, harvest, drying, and storage phases [6]. These conditions are prevalent in many parts of Nigeria, including Wukari, making aflatoxin contamination a pressing concern for food safety in the region.

The consumption of aflatoxin-contaminated food is associated with a spectrum of health effects, ranging from acute aflatoxicosis to chronic conditions such as liver cancer, immune suppression, and stunted growth in children [7]. Of particular concern is the synergistic effect between aflatoxin exposure and hepatitis B virus infection, which significantly increases the risk of hepatocellular carcinoma. Given the high prevalence of hepatitis B in many African countries, including Nigeria, the public health implications of dietary aflatoxin exposure are profound. In the context of food safety and public health, evaluating the aflatoxin levels in leguminous grains becomes a critical step toward mitigating risks and informing stakeholders, including consumers, policymakers, and agricultural practitioners [8]. Moreover, nutritional evaluation of these grains is equally essential to ensure that dietary recommendations and food security policies are based on accurate and up-to-date data regarding the macro- and micronutrient content of widely consumed food items [9].

Previous studies in other regions of Nigeria have reported varying levels of aflatoxin contamination in legumes and other staple crops, often exceeding the permissible limits set by regulatory bodies such as the World Health Organization (WHO) and the Nigerian National Agency for Food and Drug Administration and Control (NAFDAC) [10]. However, there is a dearth of comprehensive data specific to Wukari and its environs, despite its significance as a legume retail center. Without localized data, efforts to implement effective food safety interventions may be undermined by knowledge gaps and unverified assumptions [11].

This study, therefore, aims to bridge this gap by conducting a detailed nutritional evaluation and aflatoxin analysis of selected leguminous grains retailed in Wukari, Taraba State.

The objectives include determining the proximate composition (moisture, ash, crude protein, crude fat, crude fiber, and carbohydrate content) of the selected legumes and quantifying the levels of aflatoxins (particularly aflatoxin B₁, which is the most toxic and prevalent) using reliable analytical methods. The outcomes of this research will contribute to the body of knowledge necessary for improving food safety standards, enhancing public awareness, and guiding agricultural practices to reduce contamination risks. This research is timely and significant, as it seeks to provide an evidence-based assessment of both the nutritional value and aflatoxin burden of legumes in Wukari, thereby informing strategies for safer and more nutritious food systems in the region.

Materials and Method

Study Area

Wukari represents a distinct administrative division within Taraba State, Nigeria. The organization's main office is located in Wukari, a town situated along the A4 motorway. The Donga River traverses the region, while the Benue River demarcates the boundary between Nasarawa State and the northwest region. The region under consideration encompasses a total land area measuring 4,308 square kilometres and was inhabited by a population of 241,546 individuals as recorded at the 2006 census [12].

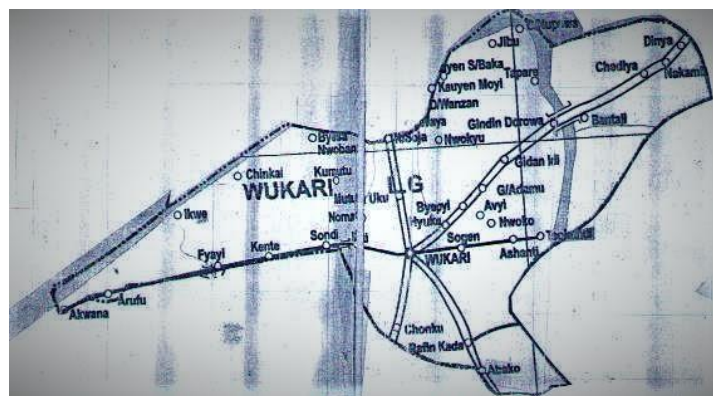


Figure 1. Wukari Local Government Map
Source: www.google.com

The rainy season in the region is typified by oppressive and overcast conditions, whereas the dry season is characterized by high humidity and partial cloud cover. Moreover, the area maintains consistently high temperatures year-round. Temperature variations occur throughout the year, with fluctuations typically ranging from 62°F to 93°F. It is infrequently observed to fall below 55°F or surpass 98°F. According to the beach/pool score, the optimal period to visit Wukari for engaging in hot-weather activities spans from early November to late February. According to data from Weatherspark.com, the duration of the hot season spans around 2.3 months, commencing on February 5 and concluding on April 15. During this period, the average daily high temperature exceeds 91°F. March is widely acknowledged as the warmest month of the year, with an average high temperature of 93°F and a corresponding low temperature of 73°F. The cool season lasts approximately 3.8 months, beginning on June 25th and ending on October 17th. Throughout this period, the average daily high temperature stays below 84°F. According to weather data from Weatherspark.com, December is identified as the month with the lowest temperatures, characterised by an average minimum of 63°F and an average maximum of 86°F.

The town of Wukari exhibits notable seasonal fluctuations in the average cloud cover percentage of the sky throughout the year. The period of improved clarity typically begins around November 13th and lasts for approximately 3.7 months, ending around March 3rd. December is notably recognized as the month with the highest level of atmospheric clarity. On average, the sky is observed to be clear, mostly clear, or partly cloudy almost 48% of the time during this period. According to the data provided by weatherspark.com, the period characterised by cloudier weather commences approximately on March 3rd and spans a duration of 8.3 months, concluding around November 13th. May is the month characterised by the highest cloud cover throughout the year, with an average of 83% of the sky being overcast or largely cloudy.

A wet day is defined as a day that receives at least 0.04 inches of precipitation, either in the form of liquid or its equivalent. Precipitation frequency varies significantly throughout the year. The rainy season lasts for approximately 6.4 months, starting on April 13th and ending on October 25th. During this period, there is a probability of over 44% for any given day to have precipitation. September stands out with the highest frequency of rainy days, averaging 25.7 days with precipitation of at least 0.04 inches. Conversely, the drier season lasts for about 5.6 months, from October 25th to April 13th. December experiences the fewest wet days, averaging only 0.3 days with the minimum threshold of 0.04 inches of precipitation. According to the provided categorization, rain is identified as the prevailing kind of precipitation throughout the year, with the highest likelihood of occurrence at 87% on September 14 (weatherspark.com).

According to data from weatherspark.com, the region within a 2-mile radius around Wukari is predominantly characterised by cropland (49%), followed by shrubs (18%), grassland (17%), and trees (16%). Expanding the scope to a 10-mile radius, the dominant land cover types are cropland (47%) and shrubs (42%). Further extending the analysis to a 50-mile radius, the primary land cover types remain cropland (42%) and shrubs (41%).

Collection of Selected Leguminous Grains

A total of 36 samples of various agricultural commodities, including shelled groundnut, soy beans, sesame seed, and shelled melon were procured from grain vendors operating in the markets of Wukari metropolis. These markets are namely Wukari New Market, Wukari Old Market and Dorowa Market, which has distance of above 40km from Wukari city. The collection of samples took place during the period spanning from April to May of the year 2023. Three sellers were picked in a random manner at distinct points within each market, and a total of three samples (leguminous grains: shelled groundnut, soy beans, sesame seed, shelled melon) were procured from each of these vendors. The study involved the collection of three samples each of maize, rice, and millet. Samples weighing approximately 100 grammes were procured from each vendor and thereafter placed in individual clean containers. These samples were promptly brought to the Laboratory for analysis. The samples were separated into two equal parts, with one-half allocated for proximate analysis and amino acid analysis, and the other half designated for the estimation of Aflatoxins.

Glasswares Used in this Study

Some of the glasswares employed in the analysis includes: beakers, volumetric flasks, viable tubes, dispersive tubes,

pipettes, round bottom flask, 300 millilitres Kjeldahl flask and conical flask.

Equipment/facilities Used in this Study

Total aflatoxin Standard, Acetic acid, centrifuge, weighing balance, amino acid analyser, sulphuric acid, soxhlet extraction apparatus, petroleum ether, dessicator, Kjeldahl distillation equipment, condenser, muffle furnace, filter paper, sodium hydroxide, hydrochloric acid, conical flask, mixed indicator, boric acid, sodium chloride, methanol, glass fibre filter, micro pipette, ELISA reader, amino acid analyser, ion exchange chromatography, flame initiation detector and whatman filter paper

Proximate Analysis of Selected Leguminous Grains

The proximate composition of the selected cereal samples was determined according to [13]

Determination of Moisture Content in Selected Leguminous Grains

A crucible that had been cleaned was dried in an air oven at a temperature of 105 degrees Celsius until it reached a consistent weight. Subsequently, it was cooled in a desiccator and the weight was measured, denoted as W_1 . A quantity of two grammes from the sample was measured and put into the crucible, which had been previously labelled. The crucible was then reweighed, resulting in a measurement denoted as W_2 . The crucible and sample were subjected to oven drying until a consistent weight (W_3) was achieved. The moisture content percentage was determined in using the relation:

$$\% \text{ Moisture content} = \frac{W_2 - W_1}{W_3 - W_1} \times 100$$

Determination of Ash Content in Selected Leguminous Grains

The porcelain crucible was dried in an oven set at 100 °C for 10 minutes. Subsequently, it was allowed to cool within a desiccator and its weight was measured, denoted as W_1 . Two grammes of the sample were carefully deposited into the porcelain crucible, which had been pre-weighed, and subsequently measured for its weight (W_2). The specimen was ignited and afterwards put into a furnace, where it was heated to a temperature of 550 degrees Celsius. The specimen was subjected to a duration of eight hours within the furnace to guarantee adequate ashing. Subsequently, the crucible, which held the ash, was extracted and subjected to a cooling process within the desiccator. The crucible was then weighed and denoted as W_3 . The ash was determined through calculation.

$$\% \text{ Ash content} = \frac{W_3 - W_1}{W_2 - W_1} \times 100$$

Determination of Crude Lipid in Selected Leguminous Grains

A 500ml round bottom flask, which was clean and dry, was weighed (W_1). The flask was then fitted with a soxhlet extraction device, and 300ml of petroleum ether (40-60°C) was added to the flask for the purpose of extraction. The flask included just a small number of anti-bumping granules. The thimble carrying a quantity of twenty grammes of the sample was securely placed within the soxhlet extraction apparatus. The round-bottom flask and condenser were interconnected with the soxhlet Soxhlet extractor, and a cold-water circulation system was activated. The heating mantle was activated and the heating rate was modified until the solvent reached a state of constant reflux. The extraction process was conducted for a duration of six hours.

The solvent was subsequently retrieved, and the oil was subjected to a drying process in an oven set at a temperature of 70°C for a duration of one hour. The round-bottom flask, which held the oil, was subjected to cooling within the desiccator before being weighed as W_2 . The lipid content was determined using the relation:

$$\% \text{ Crude Lipid} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100$$

Determination of Crude Fibre in Selected Leguminous Grains

A quantity of two grammes of the selected sample was measured and placed into a round bottom flask. A volume of 100 millilitres of a 0.25 molar solution of sulphuric acid was introduced into the mixture, which was subsequently subjected to reflux for a duration of 30 minutes. The heated solution was rapidly filtered using suction. The insoluble residue was subjected to multiple hot water washes to remove any remaining traces of acid. The substance was quantitatively placed into the flask, followed by the addition of 100 mL of hot sodium hydroxide solution with a concentration of 0.31 M. The resulting mixture was then refluxed for 30 minutes and thereafter filtered rapidly under suction. The insoluble residue underwent a series of washes with hot water until it was completely free of any residual base. The sample was dried and placed in an oven at 100°C until a consistent weight was gotten. Subsequently, it was cooled in a dessicator, measured and was denoted as C_1 . afterwards, the specimen was subjected to incineration within a muffle furnace, maintained at a temperature of 550 degrees Celsius, for a duration of 2 hours. Following this process, the specimen was allowed to cool within a dessicator and afterwards reweighed, denoted as C_2 . The calculation of crude fibre was performed in the following manner:

$$\text{The loss of weight on incineration} = \frac{C_1 - C_2}{\text{Weight of original sample}} \times 100$$

Determination of Nitrogen Content and Crude Protein in Selected Leguminous Grains

Approximately 1.5 grammes of the defatted sample was placed on an ashless filter paper and thereafter introduced into a 300 millilitre Kjeldahl flask for protein digestion. A total volume of 25 millilitres of H_2SO_4 and a mass of 3 grammes of a mixed catalyst was separately measured and added to the Kjeldahl flask, with the catalyst being weighed on an ashless filter paper. Subsequently, the flask was moved to the Kjeldahl digesting device. The material underwent digestion until a distinct green hue was achieved. The digest underwent a cooling process and was afterwards diluted to a final volume of 100ml using distilled water. A volume of 20 millilitres of the diluted digest was carefully transferred into a Kjeldahl flask with a capacity of 500 millilitres. The flask was equipped with anti-bumping chips, and subsequently, 40 millilitres of a 40% sodium hydroxide (NaOH) solution was added gradually along the side of the flask. A conical flask with a volume of 250ml was utilised to hold a mixture consisting of 50ml of a 2% solution of Boric acid and 4 drops of a mixed indicator. This mixture was employed to capture the ammonia that was released. Subsequently, the conical flask and the Kjeldahl flask were positioned onto the Kjeldahl distillation equipment, whereby the tubes were put into the conical flask and the Kjeldahl flask. The flask was subjected to heat to facilitate the distillation process and separate the evolved NH_3 . The distillate was gathered and added to the solution containing boric acid. Following the transformation of boric acid into a green colour, a duration of 10 minutes was allocated to ensure the thorough distillation of the ammonia contained within the mixture.

The distillate underwent titration using a solution of 0.1M hydrochloric acid. The nitrogen concentration and crude protein were subsequently determined through calculation. The percentage of nitrogen can be calculated by multiplying the values of 14, M, Vt, Tv, and 100, and then dividing the result by the weight of the sample in milligrams multiplied by Va. The percentage of crude protein can be determined by multiplying the percentage of nitrogen (N_2) by 6.25. Let M represent the true molarity of the acid. The symbol "Tv" represents the titre volume of hydrochloric acid (HCl) utilised, while "Vt" denotes the total volume of the diluted digest. The variable Va represents the volume of the aliquot that has been distilled.

Determination of Carbohydrate Content in Selected Leguminous Grains

The total percentage of moisture, ash, crude fat, crude protein, and crude fibre was deducted from 100% as depicted in the following manner: the equation for calculating the total carbohydrate content in a food product is derived as follows: the total carbohydrate content is equal to 100 minus the sum of the percentages of moisture, ash, fat, protein, and fibre present in the food sample.

Quantification of Aflatoxins Levels in Selected Leguminous Grains by Elisa Method: Sample Preparation and Extraction

The selected Cereal samples were pulverised to a particle size where 75% of the material passed through a mesh sieve. A total of 50 grammes of the pulverised samples was gathered and placed into a conical flask, followed by the addition of 5.0 grammes of NaCl. The samples were subsequently combined with 100 mL of methanol solution containing 80% methanol and subjected to high-speed blending for a duration of 3 minutes. The samples were let to undergo sedimentation and afterwards passed through filter paper to collect the filtrate. A total of 5ml of the filtrate was thoroughly added to 20ml of distilled water and then filtered using a glass fibre filter [13].

Assay Procedure

A total of twenty-one wells were allocated within a micro well strip holder, with each well designated for a certain sample or standard. Next, a volume of 50 microliters of enzyme conjugate was accurately measured from the bottle with a green cap and dispensed into each of the designated test wells. Using a micro pipette, 50 microliters of each sample and standard were extracted and added to the respective test wells containing the enzyme conjugate. Subsequently, 50 microliters of antibody were dispensed into each test well. The plate was gently shaken to ensure thorough mixing of the contents, and then incubated at room temperature for 10 minutes. After incubation, the contents of the wells were discarded, and the wells were cleansed by repeatedly filling them with distilled water and carefully draining and discarding it five times. This washing procedure was conducted with the intention of avoiding any disruption to the wells from their holder. After the completion of the previous washing step, the absorbent paper towel was positioned on the level surface of the test wells and gently tapped in order to eliminate any remaining remnants of the wash solution. A volume of 100 μ L of the substrate from the blue-capped vial was measured and dispensed into each of the test wells. The plate was then gently shaken and incubated at room temperature (37°C) for duration of 10 minutes. A volume of one hundred microlitre of stop solution was measured and dispensed from a bottle with a red cap into each test well.

The plate rack was then gently shaken to ensure proper mixing. The observed phenomenon involves a transition in coloration from blue to yellow. Subsequently, the test wells are subjected to analysis using a micro well ELISA reader, namely at a wavelength of 450 nm and with the implementation of a differential filter set at 630 nm. The optical density (OD) measurements were collected from each micro well, and the corresponding concentrations were determined using a graph curve derived from the OD values and the known concentrations of the standards [13].

Determination of Amino Acids in Selected Leguminous Grains

The hydrolysis of the samples was conducted by subjecting them to 6M hydrochloric acid (HCl) at a temperature of 100 degrees Celsius for an extended period of time, specifically overnight. This process was performed in an environment devoid of air, to cleave the peptide bonds present in a protein. The methodology yields favourable outcomes for the acid-stable amino acids, namely those that are widely found in dietary proteins, except for cysteine, methionine, and tryptophan. These three amino acids are susceptible to degradation under acid hydrolysis conditions and necessitate distinct analytical techniques for their determination. The amino acids cysteine and methionine are initially subjected to controlled oxidation using performic acid. This process converts them into cysteic acid and methionine-sulphone residues, respectively. The acid-stable amino acids are subsequently released from the protein through hydrolysis using hydrochloric acid. According to [14], the hydrolysis of the sample using barium hydroxide in a solution without the presence of air results in the liberation of tryptophan along with breakdown.

The hydrolysed sample was subjected to chromatographic examination using an automated amino acid analyser. The underlying idea involved the separation of amino acids through fractionation using ion-exchange resins columns, achieved by eluting them with a distinct buffer solution or carrier gas. The eluate was combined with the ninhydrin reagent, and afterwards, the resulting mixture was introduced into the reaction vessel placed in a water bath set at boiling temperature. After duration of 15 minutes, the colour reaction had undergone development. Subsequently, the resulting stream was directed via the colourimeter, where the absorbance is measured at wavelengths of 570 nm and 440 nm. A carrier gas was employed. The eluate was introduced into a detector, such as flame ionisation detectors or thermal detectors, where the resulting response was observed [14].

Statistical Analysis

The aflatoxin levels, proximate and amino acid composition of the food commodities were assessed by Analysis of Variance (ANOVA) using SPSS Version 23. A significant level of $P < 0.05$ was employed to determine statistical significance.

Results

Proximate Composition of Shelled Groundnut (*Arachis hypogea*) Samples Purchased from Three Markets in Wukari

The proximate composition of shelled groundnut samples from the three-market studied had the following ranges: Ash content: 7.36-9.12%, Crude fibre: 4.25-5.79%, Crude protein: 25.43-28.15%, Crude fat: 45.58-50.15%, NFE: 5.65-6.75%, Moisture content: 3.14-8.17%. From the results recorded in Table 1

below, it can be seen that the shelled groundnut samples had their highest Ash, Crude fibre and Moisture content values in Dorowa Market (M_3), with the following values: $9.12 \pm 2.35\%$, $5.79 \pm 1.56\%$ and $8.17 \pm 0.08\%$ respectively and their highest crude protein, fat and carbohydrate content values in New Market Wukari (M_1) for Protein, Fat and Carbohydrate contents with the following values $28.15 \pm 0.0\%$, $50.15 \pm 3.45\%$ and 6.75 ± 0.00 respectively. Also, the lowest values were recorded in Dorowa Markets (M_3) for crude protein, ether extract, and nitrogen free extract contents with the following values $25.43 \pm 0.00\%$, $45.58 \pm 0.01\%$ and $5.65 \pm 0.50\%$ respectively.

Table 1. Proximate composition of shelled groundnut samples (*Arachis hypogea*) purchased from three markets in Wukari

Parameters (%)	M_1	M_2	M_3
Ash content	7.57 ± 1.12^{ab}	7.36 ± 0.00^a	9.12 ± 2.35^c
Crude fibre	4.25 ± 0.00^a	5.12 ± 0.50^{bc}	5.79 ± 1.56^c
Crude protein	28.15 ± 0.05^c	27.35 ± 1.23^b	25.43 ± 0.00^a
Ether extract	50.15 ± 3.45^c	48.24 ± 1.52^b	45.58 ± 0.01^a
Nitrogen free extract (NFE)	6.75 ± 0.00^{ab}	6.55 ± 0.09^{ab}	5.65 ± 0.50^a
Moisture Content	3.44 ± 0.50^a	5.56 ± 0.00^b	8.17 ± 0.08^c

*Results presented as mean $\pm$ standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate level of significance ($p < 0.05$). $n=3$.

Proximate Composition of Melon Seed (*Cucumeropsis mannii*) Samples Purchased from Three Markets in Wukari

The proximate composition of Melon samples from the three markets studied, had the following ranges: Ash Contents: 3.62-4.61%, Crude fibre: 12.20- 13.45%, Crude Protein: 22.12-23.21%, Crude fat: 42.63-44.83%, Carbohydrate: 8.21-10.44%, Moisture Contents: 4.53-7.35%. From the results obtained in Table 2 below, it can be depicted that the Melon samples had their highest Ash, Crude fibre and Moisture contents at Old Market Wukari (M_2) with values $4.61 \pm 0.35\%$, $13.45 \pm 0.50\%$ and $7.35 \pm 0.00\%$ respectively. Crude protein, Ether extract and Nitrogen free extract (NFE) had their highest values in Dorowa market (M_3) with values $23.21 \pm 0.01\%$, $44.83 \pm 1.13\%$ and $10.44 \pm 0.45\%$ respectively. Ash, crude fibre and moisture contents had their lowest values in Dorowa Market (M_3), while nitrogen-free extract and ether extracts recorded the lowest in Old Market Wukari (M_2).

Table 2. Proximate composition of shelled melon seeds (*Cucumeropsis mannii*) samples purchased from three markets in Wukari

Parameters (%)	M_1	M_2	M_3
Ash content	4.23 ± 0.00^{ab}	4.61 ± 0.35^b	3.62 ± 0.07^a
crude fibre	12.91 ± 0.00^{ab}	13.45 ± 0.50^b	12.20 ± 0.20^a
Crude protein	22.65 ± 1.05^{ab}	22.12 ± 0.00^a	23.21 ± 0.01^b
Ether extract	43.15 ± 0.50^b	42.63 ± 0.10^a	44.83 ± 1.13^c
Nitrogen free extract (NFE)	8.72 ± 0.09^b	8.21 ± 0.53^a	10.44 ± 0.45^c
Moisture Content	6.94 ± 0.22^b	7.35 ± 0.00^c	4.53 ± 0.09^a

*Results presented as mean $\pm$ standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate level of significance ($p < 0.05$). $n=3$.

Proximate Composition of Sesame Seed (*Sesame Indicum L.*) Samples Purchased from Three Markets in Wukari

The proximate composition of Sesame seed samples from the three markets studied had the following ranges: Ash content: 5.23-5.65%, Crude fibre: 5.95-6.72%, Crude protein 18.86-19.42%, Crude fat: 53.65-57.11%, Carbohydrate: 7.25-7.75%, Moisture 8.12-8.62% The results obtained in Table 3 below depicts that the Sesame seed samples recorded their highest Ash, crude fibre and moisture content values at Dorowa Market (M_3) with values: $5.65 \pm 0.00\%$, $6.72 \pm 0.00\%$ and $8.62 \pm 0.05\%$ respectively. Ether and NFE extract recorded their highest value at Old Market Wukari (M_2) with values: $57.11 \pm 0.00\%$ and $7.75 \pm 0.00\%$ respectively.

Ash content, crude fibre and moisture contents had their lowest values at Old market Wukari (M_2) with values $5.23 \pm 0.00\%$, $5.92 \pm 0.23\%$ and $8.12 \pm 0.05\%$ respectively.

Table 3. Proximate Composition of Sesame Seed (*Sesame Indicum L.*) Samples Purchased from Three Markets in Wukari

Parameters (%)	M_1	M_2	M_3
Ash content	5.42 ± 0.00^a	5.23 ± 0.00^a	5.65 ± 0.00^b
crude fibre	6.35 ± 0.01^{ab}	5.92 ± 0.23^a	6.72 ± 0.00^b
Crude protein	19.42 ± 0.00^{ab}	19.12 ± 0.00^{ab}	18.86 ± 0.50^a
Ether extract	54.73 ± 0.07^a	57.11 ± 0.01^b	53.65 ± 0.02^a
Nitrogen free extract (NFE)	7.25 ± 0.06^a	7.75 ± 0.00^b	7.57 ± 0.01^b
Moisture Content	8.32 ± 0.01^b	8.12 ± 0.05^a	8.62 ± 0.05^c

*Results presented as mean $\pm$ standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate levels of significances ($p < 0.05$). $n=3$.

Proximate Composition of Soybeans (*Glycine max*) Samples Purchased From Three Markets in Wukari

The proximate composition of Soybeans samples from the three Markets studied had the following ranges: Ash contents: 4.61-6.13%, crude fibre: 6.81-7.82%, crude protein: 40.23-42.22%, ether extract: 30.51-32.55%, nitrogen free extract: 3.92-5.23% moisture contents: 8.42-11.10%. From the Results recorded in Table 4 below, it can be seen that the Soybean samples recorded their highest ash, crude and moisture contents in old market Wukari (M_3) with values: $6.13 \pm 0.32\%$, $7.82 \pm 0.00\%$ and $11.1 \pm 0.10\%$ respectively. Crude protein and ether extract had their highest values at New Market (M_1) with values $42.22 \pm 0.01\%$ and $32.85 \pm 0.58\%$ respectively, while crude protein and nitrogen free extract had their lowest values at Old Market (M_2) with values $40.23 \pm 2.34\%$ and $3.93 \pm 0.50\%$ respectively.

Table 4. Proximate composition of dried soybeans (*Glycine max*) samples purchased from three markets in Wukari

Parameters (%)	M_1	M_2	M_3
Ash content	4.62 ± 0.00^a	6.13 ± 0.32^b	4.61 ± 0.35^a
Crude fibre	6.81 ± 0.26^a	7.82 ± 0.00^b	6.82 ± 0.42^a
Crude protein	42.22 ± 0.01^b	40.23 ± 2.34^a	41.93 ± 0.00^b
Ether extract	32.85 ± 0.58^b	30.51 ± 1.52^a	32.55 ± 0.55^b
Nitrogen free extract (NFE)	5.13 ± 0.10^b	3.92 ± 0.50^a	5.23 ± 0.28^b
Moisture Content	8.42 ± 0.03^a	11.10 ± 0.10^b	8.55 ± 0.01^a

*Results presented as mean $\pm$ standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate level of significance ($p < 0.05$). $n=3$.

Essential Amino Acid levels in Shelled Groundnut (*Arachis hypogaea*) Samples Purchased From Three Markets in Wukari

The amino acid analysed for Shelled Groundnut Samples from the three markets studied had the following ranges: His. 1.73-2.31%, Ile 2.74-3.13%, Leu 4.61-6.04%, Lys 2.40-3.21%, Met. 1.21-1.70%, Phe 2.81-3.95%, Thr 1.92-2.52%, Trp 0.85-1.23%, Val 2.82-3.41%, Arg 5.90-7.81%. The results from Table 5 below revealed that the highest levels of all the essential amino in the sample were observed in New Market Wukari (M_1), while the lowest values on the samples were seen in Old Market Wukari (M_2). Arginine had their highest value in M_1 with value $7.81 \pm 0.01\%$, while tryptophan had its lowest values in M_2 with a value $0.85 \pm 0.02\%$.

Table 5. Essential amino acid levels in shelled groundnut samples purchased from three markets in Wukari

Essential Amino Acid (%)	M_1	M_2	M_3
Histidine (His)	1.80 ± 0.01^{ab}	1.59 ± 0.04^a	2.54 ± 0.02^b
Isoleucine (Ile)	3.74 ± 0.01^b	3.52 ± 0.01^a	4.25 ± 0.02^c
Leucine (Leu)	3.02 ± 0.01^b	2.87 ± 0.02^a	4.88 ± 0.02^c
Lysine (Lys)	3.04 ± 0.02^b	2.92 ± 0.02^{ab}	2.08 ± 0.01^a
Methionine (Met)	1.20 ± 0.02^b	1.05 ± 0.05^{ab}	0.96 ± 0.04^a
Phenylalanine (Phe)	4.87 ± 0.02^b	4.25 ± 0.05^a	3.86 ± 0.01^a
Threonine (Thr)	1.30 ± 0.00^a	1.13 ± 0.03^a	2.21 ± 0.02^b
Tryptophan (Trp)	0.01 ± 0.00^a	ND	0.41 ± 0.03^b
Valine (Val)	4.79 ± 0.04^c	4.23 ± 0.02^b	2.92 ± 0.01^a
Arginine (Arg)	8.87 ± 0.02^b	8.52 ± 0.02^b	6.91 ± 0.03^a

*Results presented as mean $\pm$ standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate significant difference ($p < 0.05$). $n=3$.

Essential Amino Acid Levels in Shelled Melon seeds (*Cucumeropsis mannii*) purchased from three Markets in Wukari

The amino acid analysed for Shelled Melon seeds from the three markets studied had the following ranges: His 1.59-2.54%, Ile 3.52-4.25%, Leu 2.87-4.88%, Lys 2.08-3.04%, Met 0.96-1.20%, Phe 3.86-4.25%, Thr 1.13-2.21%, Trp 0.01- 0.41%, Val 2.92-4.79%, Arg 6.91-8.87%. The result below shows that His, Ile, Leu, Thr, have their highest values in Dorowa market (M_3) with values $2.54 \pm 0.02\%$, $4.25 \pm 0.02\%$, $4.88 \pm 0.02\%$ and $2.21 \pm 0.02\%$ respectively, while Ile, Leu and Thr recorded their lowest values in Old Market Wukari (M_2) with values $3.52 \pm 0.01\%$, $2.87 \pm 0.02\%$ and $1.13 \pm 0.03\%$ respectively. Trp was not detected in Old Market Wukari (M_2).

Table 6. Essential amino acid levels in shelled melon (*Cucumeropsis mannii*) samples purchased from three markets in Wukari

Essential Amino Acid (%)	M_1	M_2	M_3
Histidine (His)	2.31 ± 0.00^b	1.73 ± 0.00^a	2.15 ± 0.0^b
Isoleucine (Ile)	3.13 ± 0.03^b	2.74 ± 0.03^a	3.10 ± 0.01^{ab}
Leucine (Leu)	6.04 ± 0.05^c	4.61 ± 0.00^a	5.35 ± 0.02^b
Lysine (Lys)	3.21 ± 0.01^b	2.40 ± 0.01^a	3.15 ± 0.02^{ab}
Methionine (Met)	1.70 ± 0.01^c	1.21 ± 0.01^a	1.54 ± 0.01^b
Phenylalanine (Phe)	3.95 ± 0.05^c	2.81 ± 0.01^a	3.71 ± 0.01^b
Threonine (Thr)	2.52 ± 0.02^{ab}	1.92 ± 0.02^a	2.48 ± 0.02^b
Tryptophan (Trp)	1.23 ± 0.02^c	0.85 ± 0.02^a	0.94 ± 0.01^b
Valine (Val)	3.41 ± 0.01^c	2.82 ± 0.02^a	3.24 ± 0.01^b
Arginine (Arg)	7.81 ± 0.01^c	5.90 ± 0.00^a	7.62 ± 0.00^b

*Results presented as mean $\pm$ standard deviation. Results within the same row with the same superscript indicate no significant differences ($p > 0.05$), while results with the different superscripts within a row indicate significant differences ($p < 0.05$). ND = not detected. $n=3$.

Essential Amino Acid Levels in Sesame Seeds (*Sesamum indicum L.*) Purchased From Three Markets in Wukari

The amino acids analysed for Sesame seeds from the three markets studied had the following ranges: His 2.07-2.12%, Ile 2.58-2.65%, Leu 4.82-4.93%, Lys 2.08-2.12%, Met 0.94-0.97%, Phe 3.78-3.86%, Thr 2.21-2.29%, Trp 0.41-0.44%, Val 2.86-2.95%, Arg 6.91-7.17%. From the results shown in Table 7 below, His, Ile, Lys, Meth, Thr, and Val recorded their highest value at New Market Wukari (M_1) with values $2.12 \pm 0.05\%$, $2.65 \pm 0.03\%$, $2.12 \pm 0.03\%$, $0.97 \pm 0.04\%$, $2.24 \pm 0.03\%$ and $2.95 \pm 0.02\%$ respectively. It was also observed from the results that His, Ile, Met, Phe and Val had their lowest values at Old Market Wukari (M_2) with values $2.07 \pm 0.02\%$, $2.58 \pm 0.01\%$, $0.94 \pm 0.03\%$, $3.78 \pm 0.01\%$ and $2.86 \pm 0.02\%$ respectively.

Table 7. Essential amino acid levels in sesame seeds (*Sesame Indicum L.*) purchased from three markets in Wukari

Essential Amino Acid (%)	M ₁	M ₂	M ₃
Histidine (His)	2.12±0.05 ^b	2.07±0.02 ^a	2.11±0.01 ^b
Isoleucine (Ile)	2.65±0.03 ^a	2.58±0.01 ^a	2.61±0.03 ^a
Leucine (Leu)	4.82±0.0 ^a	4.93±0.02 ^b	4.88±0.02 ^{ab}
Lysine (Lys)	2.12±0.0 ^b	2.09±0.05 ^a	2.08±0.01 ^a
Methionine (Met)	0.97±0.04 ^a	0.94±0.03 ^a	0.96±0.04 ^b
Phenylalanine (Phe)	3.81±0.04 ^a	3.78±0.01 ^a	3.86±0.01 ^a
Threonine (Thr)	2.24±0.03 ^a	2.29±0.01 ^{ab}	2.21±0.02 ^a
Tryptophan (Trp)	0.42±0.03 ^a	0.44±0.02 ^{ab}	0.41±0.03 ^a
Valine (Val)	2.95±0.02 ^a	2.86±0.02 ^a	2.92±0.01 ^a
Arginine (Arg)	6.93±0.01 ^a	7.17±0.02 ^b	6.91±0.03 ^a

*Results presented as mean ± standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate significant differences ($p < 0.05$). $n = 3$.

Essential Amino Acid Levels in Soybeans (*Glycine max*) Purchased From Three Markets in Wukari

The amino acid analysed for Soybeans from the three-markets studied had the following ranges: His 2.78-3.12 %, Ile 3.24-4.72%, Leu 5.45-7.63%, Lys 4.88-6.21%, Met 0.77-1.32%, Phe 4.67-5.71, Thr 2.58-3.73%, Trp 1.47-1.51%, Val 3.66-4.71%, Arg 5.85-7.31%. From the results in Table 8 below, it is clearly seen that His, Leu, Val, and Arg had their highest values at New Market Wukari (M₁) with values 3.12±0.01%, 7.63±0.01%, 3.73±0.02%, 7.31±0.01% and 7.31±0.01% respectively. It also was deduced from the table that all the essential amino acids had their lowest values recorded at Old Market Wukari (M₂).

Table 8. Essential amino acid levels in soybeans (*Glycine max*) purchased from three markets in Wukari

Essential Amino Acid (%)	M ₁	M ₂	M ₃
Histidine (His)	3.12±0.01 ^b	2.78±0.01 ^a	3.10±0.01 ^b
Isoleucine (Ile)	4.55±0.00 ^b	3.24±0.03 ^a	4.72±0.02 ^c
Leucine (Leu)	7.63±0.01 ^b	5.45±0.02 ^a	7.47±0.02 ^b
Lysine (Lys)	6.21±0.01 ^b	4.88±0.06 ^a	6.15±0.02 ^b
Methionine (Met)	1.24±0.01 ^b	0.77±0.02 ^a	1.32±0.02 ^b
Phenylalanine (Phe)	5.52±0.02 ^b	4.67±0.07 ^a	5.71±0.01 ^c
Threonine (Thr)	3.73±0.02 ^c	2.58±0.03 ^a	3.53±0.01 ^b
Tryptophan (Trp)	1.47±0.02 ^b	1.15±0.02 ^a	1.51±0.01 ^b
Valine (Val)	4.71±0.01 ^c	3.66±0.03 ^a	4.56±0.00 ^b
Arginine (Arg)	7.31±0.01 ^b	5.85±0.01 ^a	7.26±0.05 ^b

*Results presented as mean ± standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate significant difference ($p < 0.05$). $n = 3$.

Non-Essential Amino Acid Levels in Shelled Groundnut (*Arachis hypogaea*) Samples Purchased From three Markets in Wukari

The amino acid analysed for Shelled Groundnut Samples from the three markets studied had the following ranges Aspartic acid (Asp) 7.86-8.14%, Serine (Ser) 5.68-5.77%, Glutamic acid (Glu) 11.87-13.54%, Proline (pro) 6.18-6.49, Glycine (Gly) 11.45-12.96%, Alanine (Ala) 8.25-9.64%, Cysteine (Cys) 3.88-5.01%, Tyrosine (Tyr) 6.76-7.33%. The results from Table 9 below revealed that Gly and Cys had their highest value at Dorowa Market (M₃) with value 12.96±0.02% and 5.01±0.04, respectively. Pro and Ala had their highest values in Old Market Wukari with values 6.49± 0.02% and 9.64±0.03% respectively, while Serine, proline, glycine, alanine, and tyrosine recorded their lowest values at New Market Wukari, with values 5.77±0.01%, 6.186±0.02%, 11.45±0.01%, 8.25±0.01% and 6.76±0.01% respectively.

Table 9. Non-essential amino acid levels in shelled groundnut samples purchased from three markets in Wukari

Non-Essential Amino Acid (%)	M ₁	M ₂	M ₃
Aspartic acid (Asp)	8.14±0.01 ^a	7.86±0.01 ^a	8.01±0.01 ^a
Serine (Ser)	5.77±0.03 ^a	6.2±0.01 ^b	5.68±0.01 ^a
Glutamic acid (Glu)	11.87±0.01 ^a	13.29±0.01 ^b	13.54±0.01 ^b
Proline (Pro)	6.186±0.02 ^a	6.49±0.02 ^a	6.25±0.03 ^a
Glycine (Gly)	11.45±0.01 ^a	12.79±0.04 ^b	12.96±0.02 ^b
Alanine (Ala)	8.25±0.01 ^a	9.64±0.03 ^b	8.54±0.00 ^a
Cysteine (Cys)	4.65±0.06 ^b	3.88±0.02 ^a	5.01±0.04 ^b
Tyrosine (Tyr)	6.76±0.01 ^a	7.33±0.03 ^b	7.15±0.04 ^b

*Results presented as mean ± standard deviation. Results within the same row with the same superscript indicate no significant differences ($p > 0.05$), while results with the different superscripts within a row indicate significant differences ($p < 0.05$). $n = 3$.

Non-Essential Amino Acid Levels in Shelled Melon Seeds (*Cucumeropsis mannii*) Purchased From Three Markets in Wukari

The amino acid analysed for Shelled Melon Samples from the three markets studied had the following ranges Aspartic acid (Asp) 15.32-16.04%, Serine (Ser) 2.3-3.02%, Glutamic acid (Glu) 15.96-16.84%, Proline (pro) 3.16-3.76%, Glycine (Gly) 2.14-2.52%, Alanine (Ala) 4.84-6.23%, Cysteine (Cys) 1.26-1.61%, Tyrosine (Tyr) 2.21-2.84%. The result below in Table 10 reveals that proline and tyrosine had their highest value at Old Market Wukari (M₂) with values 3.76±0.04% and 2.84±0.06% respectively. Glutamic acid recorded its highest value at New Market Wukari with value 16.84±0.06%, while aspartic acid and alanine had their highest value at Dorowa Market (M₃) with values 16.04±0.01% and 6.23±0.04% respectively.

Table 10. Non-essential amino acid levels in shelled melon (*Cucumeropsis mannii*) samples purchased from three markets in Wukari

Non-Essential Amino Acid (%)	M ₁	M ₂	M ₃
Aspartic acid (Asp)	15.32±0.03 ^a	15.80±0.06 ^{ab}	16.04±0.01 ^b
Serine (Ser)	2.3±0.01 ^a	3.02±0.02 ^b	2.68±0.01 ^a
Glutamic acid (Glu)	16.84±0.06 ^b	15.96±0.03 ^a	16.4±0.06 ^{ab}
Proline (Pro)	3.16±0.03 ^a	3.76±0.04 ^b	3.34±0.06 ^{ab}
Glycine (Gly)	2.23±0.01 ^a	2.14±0.00 ^a	2.52±0.00 ^b
Alanine (Ala)	5.72±0.01 ^b	4.86±0.02 ^a	6.23±0.04 ^c
Cysteine (Cys)	1.61±0.05 ^b	1.26±0.04 ^a	1.43±0.05 ^b
Tyrosine (Tyr)	2.48±0.02 ^{ab}	2.84±0.06 ^c	2.21±0.01 ^a

*Results presented as mean ± standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate significant differences ($p < 0.05$). $n = 3$.

Non-Essential Amino Acid Levels in Sesame Seeds (*Sesamum indicum L.*) Purchased From Three Markets in Wukari

The amino acid analysed for Sesame seed samples from the three markets studied had the following ranges Aspartic acid (Asp) 8.34-9.04% Serine (Ser) 2.66-3.48% Glutamic acid (Glu) 16.67-17.54% Proline (pro) 1.63-1.84% Glycine (Gly) 3.46-5.43% Alanine (Ala) 3.10-4.66% Cysteine (Cys) 1.49-1.85% Tyrosine (Tyr) 3.66-4.21% Looking at the results recorded in Table 11, it can be seen that glutamic acid, proline and cysteine had the highest values at Dorowa Market (M₃) with values 17.54±0.06%, 1.84±0.00% and 1.85±0.01% respectively, while glutamic acid, cysteine and tyrosine recorded the lowest values at New Market Wukari (M₁) with values 16.67±0.03%, 1.49±0.00%, 3.66±0.00% respectively.

Table 11. Non-essential amino acid levels in sesame seeds (*Sesamum indicum* L.) samples purchased from three markets in Wukari

Non-Essential Amino Acid (%)	M ₁	M ₂	M ₃
Aspartic acid (Asp)	8.34±0.03 ^a	9.04±0.04 ^b	8.74±0.03 ^a
Serine (Ser)	3.48±0.01 ^b	3.27±0.00 ^b	2.66±0.01 ^a
Glutamic acid (Glu)	16.67±0.03 ^a	16.91±0.06 ^a	17.54±0.06 ^b
Proline (Pro)	1.79±0.01 ^a	1.63±0.00 ^a	1.84±0.00 ^b
Glycine (Gly)	3.83±0.02 ^a	5.43±0.06 ^b	3.46±0.04 ^a
Alanine (Ala)	4.66±0.04 ^b	3.46±0.06 ^a	3.10±0.01 ^a
Cysteine (Cys)	1.49±0.00 ^a	1.61±0.01 ^a	1.85±0.01 ^b
Tyrosine (Tyr)	3.66±0.00 ^a	5.08±0.03 ^c	4.21±0.01 ^b

*Results presented as mean ± standard deviation. Results within the same row with the same superscript indicate no significant differences ($p>0.05$), while results with the different superscripts within a row indicate significant difference ($p<0.05$). $n=3$.

4.1.18 Non-Essential Amino Acid Levels in Soybeans (*Glycine max*) purchased from three Markets in Wukari.

The amino acid analysed for Soybeans samples from the three markets studied had the following ranges Aspartic acid (Asp) 0.56- 1.32%, Serine (Ser) 6.17-6.61%, Glutamic acid (Glu) 12.45-14.63%, Proline (pro) 3.12-5.45%, Glycine (Gly) 2.31-4.81%, Alanine (Ala) 3.86-4.10%, Cysteine (Cys) 1.90-2.71%, Tyrosine (Tyr) 2.87-5.02%. The results recorded in Table 12 below clearly depicts that aspartic acid, glycine and tyrosine recorded the highest value at Dorowa Market (M₂) with values 1.32±0.04%, 4.81±0.06% and 5.02±0.03% respectively, while serine, glutamic acid, glycine and alanine had their lowest value at New Market Wukari (M₁) with values 6.17±0.00%, 12.45±0.01%, 2.31±0.04 and 3.86±0.02%. Aspartic acid was not detected in samples purchased from New Market Wukari.

Table 12. Non-essential amino acid levels in soybeans (*Glycine max*) samples purchased from three markets in Wukari

Non-Essential Amino Acid (%)	M ₁	M ₂	M ₃
Aspartic acid (Asp)	ND	0.56±0.01 ^a	1.32±0.04 ^b
Serine (Ser)	6.17±0.00 ^a	8.42±0.02 ^b	6.61±0.01 ^a
Glutamic acid (Glu)	12.45±0.01 ^a	14.63±0.06 ^b	12.89±0.03 ^a
Proline (Pro)	5.45±0.01 ^c	3.12±0.00 ^a	3.96±0.01 ^b
Glycine (Gly)	2.31±0.04 ^a	4.61±0.03 ^b	4.81±0.06 ^b
Alanine (Ala)	3.86±0.02 ^a	4.10±0.00 ^b	4.07±0.00 ^b
Cysteine (Cys)	2.71±0.03 ^b	2.45±0.05 ^b	1.90±0.01 ^a
Tyrosine (Tyr)	4.89±0.04 ^b	2.87±0.00 ^a	5.02±0.03 ^b

*Results presented as mean ± standard deviation. Results within the same row with the same superscript indicate no significant differences, while results with the different superscripts within a row indicate significant differences ($p<0.05$). ND means not detected. $n=3$.

Aflatoxin Levels of Food Samples Purchased From Three Markets in Wukari

The Aflatoxin levels of food samples purchased from the three markets studied had the following ranges: Shelled Groundnut samples: 0.5-1.17 µg/kg, Shelled melon samples: 0.47-3.27µg/kg, Sesame seeds: 1.53-3.17µg/kg, Soy beans: 0.10-0.2µg/kg, Maize: 3.11-13.10µg/kg, Millet: 6.13-15.43 µg/kg, Parboiled rice: 0.43-1.00µg/kg. From the results shown below in Table 13, it can be seen that Sesame seeds and Millet samples had their highest Aflatoxin levels in M₃ with values: 3.17±0.25 and 15.43±0.15 respectively. Maize samples purchased from M₂ (Old Market) showed a significant decrease in their Aflatoxin level with value: 3.11±2.59 compared the ones purchased from M₁ (New market) and M₃ (Old Market) with values: 13.10±0.30 and 10.97±0.25 respectively. However, samples purchased from M₁ and M₃ have the same Aflatoxin levels with values 0.1±0.00 and 0.1±0.00 respectively, While Soybean sample purchased from M₂ showed a slightly higher value of 0.2±0.00.

Table 13. Aflatoxin levels of food samples purchased from three markets in Wukari

Food Samples	M ₁ (µg/kg)	M ₂ (µg/kg)	M ₃ (µg/kg)
Shelled groundnut	0.57±0.06 ^a	1.17±0.12 ^c	0.83±0.06 ^b
Shelled melon seeds	3.27±4.10 ^a	1.07±0.06 ^a	0.47±0.06 ^a
Sesame seeds	2.07±0.15 ^b	1.53±0.02 ^a	3.17±0.25 ^c
Soy beans	0.10±0.00 ^a	0.20±0.00 ^a	0.10±0.00 ^a
Maize	13.10±0.30 ^c	3.11±2.59 ^a	10.97±0.25 ^b
Millet	6.13±0.25 ^a	12.07±0.15 ^b	15.43±0.15 ^c
Parboiled rice	1.00±0.12 ^b	0.47±0.12 ^a	0.63±0.12 ^a

*Results presented as mean ± standard deviation. Results within the same row with the same superscript indicate no significant differences ($p>0.05$), while results with the different superscripts within a row indicate significant differences ($p<0.05$). $n=3$.

Discussion

Determination of Ash Contents in Selected Legumes

Ash Content in Groundnut Samples: The proximate composition of shelled groundnut samples recorded in Table 1 revealed that groundnut samples procured from Dorowa market (M₃) recorded the highest value 9.12±2.35% while the least value were recorded at Old Market Wukari 7.36±0.00%. These values were consistent with the findings of [15] who reported 1.90±0.01% for the ash content of groundnut samples analysed in Wukari Taraba State.

Ash Content in Shelled Melon Seeds: The proximate composition of shelled melon seeds recorded in table Table 2 revealed that melon seeds procured from Old Market Wukari had the highest ash content value 4.61±0.35% while seeds procured from Dorowa Market Wukari recorded the least ash content values 3.6 ±0.07%. These values were consistent with the report of [16], who recorded 3.7±0.1% ash content in melon seed samples they analysed in their research.

Ash Content in Sesame Seeds: The proximate composition of sesame seeds recorded in Table 3, revealed that seeds procured from Dorowa Market Wukari had the highest ash content value with 5.65±0.00%, while the seeds procured from Old Market Wukari had the least value 5.23±0.00%. These results were similar to the reports of [17], who reported 1.44-5.93% ash content in sesame seed samples analysed.

Ash Content in Soybean Seeds: The proximate composition of soybean samples recorded in Table 4 showed that soybean samples procured from Old Market Wukari had the highest ash content value 6.13±0.32%, while the seeds procured from Dorowa Market Wukari had the least value 4.6±0.35%. These results were similar to the report of [18], who recorded 4.29% for the ash content in soya bean samples analysed in their study.

Determination of Crude Fibre Contents in Selected Legumes

Crude Fibre Contents in Shelled Groundnut Seeds: The proximate composition of shelled groundnut samples recorded in Table 1 above revealed that the crude fibre contents of groundnut procured from the three markets recorded the highest value in Dorowa Market Wukari (M₃) 5.79±1.56 and the least value in New Market Wukari (M₁), 4.25±0.00%. The results in this study were similar to [19], who reported (3.7%) crude fibre in shelled groundnut samples analysed in their findings.

Crude Fibre Contents in Shelled Melon Seeds: The proximate composition of shelled melon samples recorded in Table 2 above revealed that the crude fibre contents of melon seeds procured from the three markets recorded the highest value in Old Market Wukari (M₂) 13.45±0.50% and the lowest value in Dorowa

Market Wukari (M_3) $12.20 \pm 0.020\%$. These values were similar to the reports of [20], who recorded $12 \pm 0.1\%$ in the crude fibre content of shelled melon analysed in their study.

Crude Fibre Contents in Sesame Seeds: The proximate composition of sesame seeds recorded in Table 3 above showed that the crude fibre contents of the seeds procured from the three markets recorded the highest value in Dorowa Market Wukari (M_3) $6.7 \pm 0.00\%$ and the least value in Old Market (M_2) $5.92 \pm 0.23\%$. These results were similar to the findings of [21], who reported $4.6 \pm 0.03\%$ for whole sesame seed samples analysed in Ibadan, Nigeria.

Crude Fibre Content in Soyabean: The proximate composition of sesame seeds recorded in Table 4 above revealed that the crude fibre contents of the seeds procured from the three markets recorded the highest value in New Market Wukari (M_1) 7.82 ± 0.00 and the least value in Old Market (M_2) $6.81 \pm 0.26\%$. These values were closely related to the reports of [14], who recorded 6.12% as the crude fibre content of soyabean samples investigated.

Determination of Crude Protein Contents in Selected Legumes

Crude Protein Contents in Shelled Groundnut Seeds: The proximate composition of shelled groundnut samples recorded in Table 1 above clearly showed that the crude protein contents of groundnut seeds procured from the three markets recorded the highest value in New Market Wukari (M_1) $28.15 \pm 0.05\%$ and the lowest value in Dorowa Market Wukari (M_3) with $25.4 \pm 0.00\%$. These results were in agreement with the reports of [15], who recorded 22.02 ± 0.23 - $28.99 \pm 65\%$ in shelled groundnut samples analysed in their study.

Crude Protein Contents in Shelled Melon Seeds: The proximate composition of shelled melon seed samples recorded in Table 2 above showed that the crude protein contents of the seeds procured from the three markets recorded the highest value in Dorowa Market Wukari (M_3) $23.21 \pm 0.01\%$ and the lowest value in Old Market Wukari (M_2) $22.12 \pm 0.00\%$. These results were consistent with [16], who recorded $23.4 \pm 0.02\%$ in shelled melon samples analysed in their findings.

Crude Protein Contents in Sesame Seeds: The proximate composition of shelled melon seed samples recorded in Table 3 above, disclosed the crude protein contents of the seeds procured from the three markets recorded the highest value in New Market Wukari (M_1) 19.42 ± 0.00 and the lowest in Dorowa Market Wukari (M_3) 18.86 ± 0.50 . These results were similar to the reports of [17], who reported 17.01% for the crude protein values of sesame seed samples analysed in their research work.

Crude Protein Contents in Soybean Seeds: The proximate composition of soybean seed samples recorded in Table 4 above revealed that the crude protein contents of the seeds procured from the three markets recorded the highest value in New Market Wukari (M_1) $42.22 \pm 0.01\%$ and the least value in Old Market Wukari (M_2) $40.23 \pm 0.00\%$. These results were similar to the reports of [18], who reported 40% crude protein value in soybean seed analysed in their study.

Determination of Ether Extract Content in Selected Legumes

Ether Extract in Shelled Groundnut Samples: The proximate composition of shelled groundnut samples recorded in Table 1 showed that the ether extract of shelled groundnut samples procured from the three markets recorded the highest value in New Market Wukari (M_1) with $50.15 \pm 3.45\%$ and least value in Dorowa Market (M_3) $45.58 \pm 0.01\%$. These results were in agreement to the reports of [19], who reported 43.30 ± 0.27 - $48.33 \pm 0.14\%$ in shelled groundnut investigated.

Ether Extract in Shelled Melon Samples: The proximate composition of shelled melon samples recorded in Table 2 showed that the ether extract of shelled melon procured from the three markets recorded the highest value in Dorowa market Wukari (M_3) $44.83 \pm 1.13\%$ and the lowest value in old market with (M_2) $42.63 \pm 0.01\%$. These values were in conformity with the reports of [20], who recorded $45.7 \pm 0.1\%$ as the ether extract value in melon seed samples assessed.

Ether Extract in Sesame Samples: The proximate composition of sesame samples recorded in Table 3 elicited that the ether extract of sesame seeds procured from the three markets recorded the highest value in Old Market Wukari (M_2) $57.11 \pm 0.01\%$ and least value was recorded in Dorowa market (M_2) $53.65 \pm 0.02\%$. These results fall within the ranges reported by [21], who recorded 52 - 63% on the ether extract values of sesame seed samples analysed.

Ether Extract in Soybean Samples: The proximate composition of sesame samples recorded in Table 4 showed that the ether extract of soybean seeds procured from the three markets recorded the highest value in New Market Wukari. (M_1) $32.85 \pm 0.58\%$ and lowest value was recorded in Dorowa Market (M_2) $30.51 \pm 1.52\%$ These results were consistent with the reports of [11], who recorded 30.31% as the ether extract (crude lipid) values in soybean samples studied.

Determination of Nitrogen Free Extract Content in Selected Legumes

Nitrogen Free Extract Contents in shelled Groundnut Samples: The proximate composition of shelled groundnut seeds in this study Table 1 showed that the nitrogen free extract in shelled groundnut seeds procured from the three markets recorded the highest value in New Market Wukari (M_1) $6.75 \pm 0.00\%$ while the lowest value was recorded in Dorowa Market Wukari (M_3) $5.65 \pm 0.00\%$. These results were in agreement with [12], who reported 6.63 - $12.37 \pm 0.44\%$ in the shelled groundnut samples analysed in their study.

Nitrogen Free Extract Contents in Shelled Melon Seeds: The proximate composition of shelled melon samples recorded in Table 2 showed that the nitrogen free extract in melon seeds procured from the three markets recorded the highest value in Dorowa Market Wukari. (M_3) $10.44 \pm 0.45\%$, the lowest value was recorded in Old Market Wukari (M_2) $8.21 \pm 0.53\%$. These values were consistent with results obtained by [11], who reported 7.08 - 14.15% in the various melon samples analysed in their research work.

Nitrogen Free Extract Contents in Sesame Seeds: The proximate composition of sesame seeds samples recorded in Table 3 revealed that the nitrogen free extract of sesame seeds procured from the three markets recorded the highest value

7.25±0.00% in Old Market Wukari (M₁) and least value 7.25±0.06% in New Market Wukari (M₁). These results were similar to 8.34-8.80% reported by [12] for the values of the sesame seed samples analysed in their research.

Nitrogen Free Extract Contents in Soy Bean Seeds: The proximate composition of sesame seeds samples in Table 4 revealed that the nitrogen free extract of sesame seeds procured from the three markets recorded the highest value 5.23±0.28% in Dorowa Market Wukari (M₃), and lowest value 3.92±0.5% in Old Market Wukari (M₂). These results were closely related to [13], who recorded 5.08% in the nitrogen free extract values of soybean samples analysed in Kano State.

Determination of Moisture Contents in Selected Legumes

Moisture Contents in Shelled Groundnut Samples: The proximate composition of shelled groundnut seeds samples recorded in Table 1 revealed that the moisture contents of groundnut seeds procured from the three markets recorded the highest value 8.17±0.08% in Dorowa Market Wukari (M₃), and least value 3.44±0.00% in New Market Wukari (M₁). These results were similar to the values obtained by [14], who reported 9.75±0.01% for the moisture contents of groundnut samples evaluated.

Moisture Contents in Shelled Melon: The proximate composition of shelled melon seeds recorded in Table 2 above revealed that melon seeds procured from the three markets, recorded the highest value from Old Market Wukari (M₂) with value 7.35±0.00% and least values were recorded from Dorowa Market Wukari 4.53±0.09%. These results were similar to the reports of [15], who recorded 7.14% in the moisture content of melon seed assessed.

Moisture Contents in Sesame Seeds: The proximate composition of Sesame Seeds seeds recorded in Table 3 above showed that the sesame seeds procured from the three markets, recorded the highest value from Dorowa Market Wukari (M₃) with a value of 8.62±0.50% and lowest values were recorded from Old Market Wukari 8.13±0.05%. These values were similar to the reports of [16], who recorded 7.37% as the moisture content values for sesame seed samples analysed in Abakiliki, Ebonyi State Nigeria.

Moisture contents in Soy Bean Seeds: The proximate composition of shelled melon seeds recorded in Table 4 above revealed that the moisture contents of soybean seeds procured from the three markets, recorded the highest value 11.10±0.10% from Old Market Wukari (M₂), while the lowest values 8.42±0.23% were recorded from New Market Wukari (M₂). These results were consistent with the reports of [17], who recorded 8.13% as the moisture content value of soybean samples analysed in Kano State, Nigeria.

Determination of Essential amino acid in Selected legumes

The essential amino acids in legume samples collected from the three marketplaces in Wukari were gathered and arranged from lowest to highest values. Shelled groundnut contains 0.85±0.02g/100g of tryptophan in Old Market Wukari (M₂) and 7.81±0.01g/100g of arginine in New Market Wukari (M₁). Shelled melon has 0.01±0.00g/100g of tryptophan in New Market (M₁) and 8.87±0.02g/100g of arginine in New Market (M₁).

Sesame seeds contain 0.41±0.002g/100g of tryptophan in Dorowa Market (M₃) and 7.17±0.02g/100g of arginine in (M₁). Soybeans have 0.77±0.02g/100g of methionine in Old Market (M₂) and 7.63±0.01g/100g of leucine in New Market Wukari (M₁).

Determination of Non-essential Amino Acid in Selected Legumes

The non-essential amino acid in legume samples collected from the three marketplaces in Wukari were obtained and arranged from lowest to highest values. Shelled groundnut contains 3.88±0.02g/100g cysteine in Old Market Wukari (M₂) and 13.54±0.01g/100g glutamic acid in Dorowa market Wukari (M₃). Shelled melon has 1.26±0.04g/100g cysteine in Old Market Wukari (M₂) and 16.84±0.06g/100g glutamic acid in New Market Wukari (M₁). Sesame seeds contain 1.49±0.00g/100g cysteine in New Market Wukari (M₁) and 17.52±0.06g/100g glutamic acid in Old Market Wukari (M₂). Soybeans have 0.56±0.01g/100g aspartic acid in Old Market Wukari (M₂) and 14.63±0.06g/100g glutamic acid in Old Market Wukari (M₂).

Determination of Aflatoxin Levels in Selected Legumes

Aflatoxin is an important naturally occurring mycotoxin in agricultural products. They are produced by several species of *Aspergilli*. Not all strains of *Aspergillus species* produce aflatoxin [18]. In this study, the following ranges were obtained for levels of aflatoxin in food samples analysed in the three markets under study: shelled groundnut had 0.5-1.17µg/kg, shelled melon had 0.47-3.27µg/kg, sesame seed had 1.53-3.17µg/kg, and soybeans had 0.10-0.20µg/kg. The differences in contamination level might be due to the difference in environmental factors (temperature and relative humidity) that favour the growth of aflatoxigenic moulds and agricultural practices between the study areas. Soybean samples recorded the lowest aflatoxin levels in the present study. Soybean procured from New Market and Dorowa Market Wukari had the lowest aflatoxin contamination level of 0.10µg/kg, this is indicative of the quality of soybean sample analysed in this study. The findings were also consistent with [19] who reported a low aflatoxin level in soybean samples grown in Rwanda. All leguminous grains analysed in this study had aflatoxin values which did not exceed the maximum acceptable standard of total Aflatoxin limit of European Union (EU) standard adopted by Nigeria in safe-to-eat food and feeds [21].

Health Implication of the Research Findings

Even though the maximum permissible standard for safe food and feeds set by Nigeria has not been exceeded by the highest aflatoxin content in the aforementioned food samples, aflatoxin will still pass through human metabolism unaltered and eventually accumulate in tissues if exposed to food samples over time, either directly through ingestion or indirectly through the consumption of livestock previously exposed to these samples. It is now well recognised that aflatoxins induce acute and severe chronic illness in addition to cancer. At first, aflatoxins were shown to be carcinogenic and linked to the liver, which metabolises them first and creates reactive intermediate metabolites. However, subsequent research conducted on various populations and animals revealed that these toxins can also induce cancer in other organs, such as the kidney, pancreas, bladder, bones, viscera, and central nervous system. Research suggests that oxidative stress induced by AFB1 is equally, if not

more, responsible for the genotoxic effects caused by aflatoxin. Immunotoxicity is likely the second most extensively studied toxicological effect of aflatoxin. In addition to the aforementioned effects, continuous exposure to these food samples by humans, either directly or indirectly, may lead to malnutrition diseases, impaired child growth, delayed physical and mental maturation, reproductive issues, and disorders of the nervous system.

Conclusion

The study has revealed variations in the nutritional composition of the various selected grains retailed in three markets in Wukari. These differences could be due to genetic, environmental, climatic and storage conditions in the study area. The aflatoxin content in the assessed leguminous grains in this study did not exceed the maximum acceptable standard of total aflatoxin limit of the European Union (EU) adopted by Nigeria in safe-to-eat food and feeds, hence the grains analysed are safe for human consumption.

Recommendations

- i. Stringent policies and legislation should be implemented to regulate aflatoxin contamination levels in food commodities is essential. These regulations should align with the acceptable limits set by organizations such as the National Agency for Food and Drug Administration and Control (NAFDAC).
- ii. Food vendors and farmers should be educated about the importance of properly drying grains before storage. Proper drying techniques can help minimize the risk of fungal growth and aflatoxin contamination.
- iii. Consideration should be given to using non-toxic antifungal chemicals as part of storage strategies to prevent fungal growth in stored grains and reduce toxin production. These strategies can help mitigate the risk of aflatoxin contamination in food commodities.

Conflicts of Interest

All authors declare that they have no conflict of interest associated with this research article.

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