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Comparative Nutritional Analysis of Black Fonio (*Digitaria iburua*) and White Fonio (*Digitaria exili)*

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Abstract

A comprehensive study was carried out to compare the nutritive value of black and white Fonio, both of which are of West African origin. Standard methods of analysis was used to analyses the proximate and some mineral composition of the both grains. The nutritive value such as crude protein, crude fat, crude fiber, carbohydrate, moisture and ash content was determined. Minerals such as sodium and potassium were determined using flame photometry; while zinc, iron and calcium were determined using atomic absorption spectrometry. The result shows that black Fonio contains 8.75% crude protein, 4.00% crude fat, 1.03% crude fiber, 76.91% carbohydrate, 2.31% ash, 7.00 % moisture, sodium (Na) 30mg/100g, potassium (K) 8.45mg/100g, calcium (Ca) 30.00mg/100g, Iron (Fe) 2.75mg/100g, Zinc (Zn) 0.75mg/100g while that of white Fonio was found to contained 7.11% crude protein, 3.00% crude fat, 0.79%crude fiber, 79.72% carbohydrate, 2.13% ash, 7.00% moisture, sodium (Na) 20.00mg/100g, Potassium (K) 5.40mg/100g, Calcium (Ca) 20.00mg/100g, Iron (Fe) 1.10mg/100g, Zinc (Zn) 0.65mg/100g. The result shows that black Fonio is more nutritive than the white Fonio.

Keywords: Proximate, minerals, nutrients, black fonio, white fonio.

Introduction

Fonio is an indigenous cereal grain native to West Africa. It has been cultivated in dry savannas of West Africa for years and it was once steadily demanded in some West African communities including Nigeria, Mali, Guinea and Burkina Faso. Farmers in the West Africa allocate about 300,000 hectares each year for Fonio production, and the crop feeds about 3-4 million people[1]. Of all the grains, Fonio is the most nutritious and a good source of cyteine and methionine, which are important to health of humans and also not found in some common cereals[1,2]. These combining properties of both nutrition and taste may probably be importance in the future. Above all, Fonio May probably provide resources to local farmers and hold the potential for reducing poverty and hungry[1]. White Fonio is the most commonly used among the two species. It is found in Senegal, Chad and Nigeria and particularly raised in plateau located in the central Nigeria popularly called "*acha*" and also in the nearby areas. The black Fonio was reported to be limited to the Bauchi and Jos of Nigeria along with other regions of the northern Benin and Togo [1]. Although Fonio was once thought to be one of the "Lost Crops of Africa" and was entirely ignored by scientists[3], the grain is how re-explored' and chosen for improvement as a species for cultivation [1-3]. Due to it high protein content (about 7% or more) that is found to be rich in leucine, valine and methionine, the grain has been regarded as best nutritious and testing of all grains[1-4]. Fonio was also reported to have high malting and brewing possibilities[2,4]. Many factors were believed to have caused the declined in the production of Fonio, the identified disadvantages of Fonio include but not limited to; the smaller size of the grain, less yield than other cereal grains shattering and lodging[2, 4]. The aim of this research is to compare the nutritive value of the two varieties of Fonio.

Material and Methods

Sample Collection: Two varieties of Fonio, black and white were purchased from Rimi market in Kano city, Nigeria. The market is located in Kano city on coordinates: 11°59'48"N and 8°31'28"E. The market is patronized by many Kano inhabitants for purchase of food stuffs.

Preparation of sample: The samples were washed with distilled water and dried. They were then grinded into finely powder using mortar and pestle. The nutritional analysis was done using the powder.

Reagent Preparation: 2% Boric acid made by dissolving 2g of boric acid in volumetric flask of 100ml and making it up to the mark. 1%HCl (v/v) made by adding 5ml of concentrated. HCl of specific gravity 1.18 to distilled water and making it up to 500ml in a volumetric flask.

1.25% H_2SO_4 working solution prepared by dissolving 100g in 125ml of stock solution to $1dm^3$.

10% NaOH made by dissolving 40g NaOH with distilled water in 1000ml volumetric flask and making it up to the mark.

0.1M HCl made by diluting 9ml of analar grade HCl and making the solution up to 1 liter with distilled water. This is then standardized by titrating against 0.1N Na_2CO_3 (anhydrous) using methyl red as indicator.

0.1M NaOH made by dissolving 4g with distilled water in 1000ml volumetric flask and making it up to ml mark.

Kjeldahl catalyst-A combination of 500g K_2SO_4 + 15g $CuSO_4$ + TiO_2 in the ratio of 100:3:3 grinded together in finely powder.

0.1N HNO_3 was prepared by diluting $63cm^3$ to 1 liter with distilled water.

Determination of Protein by Microkjeldahl Method[5]:
Principle: Protein-containing sample is digested using conc. H_2SO_4 in the presence of Kjeldahl catalyst. Standard alkali was added to digest the sample and the ammonia produced is steam distilled into a standard solution of HCl. Titration of The acid gives an indication of the amount ammonia (NH_3) distilled, and hence the nitrogen content from which crude protein is calculated.

Procedures: Each of the samples 0.20g was weight into the digestion tubes. Conc. H_2SO_4 (15ml) was added to each tubes and swirl the tubes gently until the samples and the acid were thoroughly mixed. Kjeldahl catalyst (5g) was added to each tube. The tubes were heated until the solution clears. The temperature was risen and heat to boiling for 2 hours after the solution has cleared and allows cooling. The content of each tube were transferred into 100ml volumetric flasks and diluted with distilled water where the tube is marked. 2%boric acid (10ml) and 4 drops of mixed indicator were measured into a 250ml-Erlenmeyer flask. Aliquot of the digest (10ml) was transferred into the distillation flask and the flask was attached to the distillation apparatus. Sodium hydroxide (10ml) was added into the distillation flask containing the digest. Nitrogen was distilled into boric acid/mixed indicator receiver flask until the 150 mark is reached. The condenser tip was washed with distilled water and titrated the distillate with 0.025 N H_2SO4 until pink end point was developed. The calculation of the total protein was done through the multiplication of the percentage of nitrogen with 6.25.

The percentage of nitrogen is calculated as follows:

%N = 0.014 # titre # volume # normality # 100 weight of sample # volume of aliquate % crude protein = total nitrogen # 6.25

Determination of Crude Fat by Method of AOAC [6]:
Principle: The principle is based on the fact that lipophilic (non-polar) constituent of a sample are readily extracted into organic solvent. Determination of crude fat involves the continuous removal of fat from the sample with solvent e.g. petroleum ether (B.P 40-60^{0}C) in soxholer extractor.

Procedure: Few granules that prevent bumping were added to Six (6) cleaned round flasks and Petroleum ether with B.P 40-60^{0}c of about 300mls was put into each flask and then fixed in the soxholer extraction units. The thimbles for Extraction were weight and 20 milliliters of the samples was put into the weighed thimble (W1) and the thimble put into the soxhler extraction unit including the forceps and the circulation of the cold water was turn on. The mantle for heating was turn on and the refluxing solution was set at a constant pace. The Extraction was performed for about eight hours. The thimble was taken out, dried at 70^{0}C to a constant weight and then weight (W2). The calculation of extractable fat was as follows;

% crude fible = {weight of extracted fat = weight of dried sample} # 100

Where: W1 = weight of sample, W2= weight of thimble

Crude Fiber Determination According To AOAC, AACC, ISO, AND AOCS Using the Fibrecap 2021/2023 System[7]:
Principles: Any food material submitted for analysis of crude fiber and which suspected to contain more than 1% fat is first rendered fat-free by treatment with petroleum ether (B.P 40-60^{0}C). The defatted sample is treated with boiling H_2SO_4 and later with boiling NaOH, and the residue left after the subtraction of the ash is taking as fiber.

Procedures: Pre-dried fiber capsule was weighed with lid (W1). The sample 0.5g was tare and weighed (W2). The lid was snapped and put in a tray stand. Petroleum ether (120/260ml) was added to the beaker. The tray stand was swirled with the capsule in the solvent for 0.5minutes.The process was repeated to other beakers. The capsule tray was moved to the carousel and the stopper was then put.1.25% sulphuric acid (350ml) in the extraction vessel was pre-heated on a hot plate. The carousel was inserted and condenser put on and let it boil gentle. The sulphuric acid was then discarded. The capsule was washed by swirling in a hot water for 0.5 minute. This was then repeated three times with fresh hot water.1.25% sodium hydroxide (350ml) in an extraction vessel was pre-heated on a hot plate. The carousel was inserted and the condenser put on and let it boil for 0.5 minute. Petroleum ether (120/360ml) was added to the beaker. The tray was swirled in the capsule in the solvent for 0.5 minute. The capsule in the tray was dried for 2 hours at 300C. It was then put in a desiccator and let it cool for 15minute. The capsule was weighed (W3). The capsule was place in a pre-heated ashing beaker (W4) and ashed at least 4 hours at 600^{0}C. The beaker was allowed to cool down in a desiccator and weighed (W5).

Calculations:% crude fiber = {(C-(A-F)-(E-D-G)}/B # 100.

Where: A= capsule initial weight (mg), B = weight of sample (mg), C = weight of capsule + weight of residue (mg), D = empty crucible for ashing (mg), E = total ash (mg), F = correction for solubility of capsule (mg), G = capsule ash (mg).

Determination of Ash Content by Method of AOAC[6]: **Principle:** The principle is based on the loss in weight which occurs after igniting the sample in a muffle furnace at a temperature of about 600^0C which causes the organic matter to burn completely without affecting the ash constituents.

Procedures: The ash content was determined according to the method provided by AOAC. About Six (6) crucibles were dried in an ovum and desiccator was used to cool the crucibles. The crucible with the samples were introduced into furnace and set at 600^0C and then ignited in the furnace for about 8 hours.The crucibles with the ash ware taken out and cooled in a desiccator and weight (W3). % ash content is calculated as follows;

%Ash = weight of ash/weight of sample # 100

Where: W1= empty crucible weight.W2= crucible weight + sample weight before drying.W3= weight of crucible + sample weight after drying.

Determination of Moisture Content[6]**: Principle:** The principle involved difference in weight prior to (before) and after drying carry through 100^0C constantly in 24 hours.

Procedures: Six empty dishes were heated in an ovum at a temperature of about 100^oC until a constant weight is attained (W1). About 2g of the sample was put into each of the empty dishes and weighted (W2). The dishes in which the sample is put was heated at a temperature of about 100^oc in an ovum or a day (24hours), after which it was weighed and then reweight after another 3hours to obtained a constant weight (W3).The moisture content was calculated as follows;

% moisture = {W2 – W3} / {W2 – W1} # 100

W1= empty dish weight.W2= dish weight + sample weight before drying. W3= dish weight + sample weight after drying.

Determination of Total Carbohydrate (By Difference Method): The total carbohydrate was determined by difference method in which the percentages of crude protein, crude fiber, crude fiber, ash content and moisture content were subtracted from

100 % Carbohydrate = 100% - % Protein + Fiber +% Fat + Moisture

Specific Minerals Analysis: Sample Preparation for Specific Mineral Analysis Using Dry Ashing[8]: The finely grounded sample (1g) was weight into porcelain crucible .It was ignited into murple furnace for 6-8hours at 450^0C until grayish ash was obtained. It was cool on top of asbestos sheet and 1N HNO_3 (5ml) was added and evaporated on a hot plate. It was re-ignited at 400^0C for 10-15 minutes till a perfect whitish ash was produced. After cooling it on top of asbestos sheet again, 1N HCl (10ml) was added and filtered the solution into a 50ml volumetric flask. Additional 10ml part of 0.1NHCl solution was used to wash the porcelain crucibles as well as the filter paper. The prepared sample was used for determination of Na, K, Ca, Fe, and Zinc.

Determination of Sodium and Potassium using Flame Photometry[9]**, Principle:** Flame photometry is based on the flame atomization characterized by emission of certain amount of energy. The intensity of energy is detected by photo cells at a particular wave length which is specific to the element of interest. The amount of current produced is measured through the signal display.

Procedure: The flame photometer was set for sodium by selecting the appropriate wave length 598nm and that of potassium at 768nm.The instrument was set to 100% transmittance. Standard solution of sodium of 0,2,4,6,8,10 (mg/l) and that of potassium 0, 2, 4, 6, 8, 10, (mg/l) were then aspirated into the instrument through the capillary tube and the intensity readings were recorded. A standard curve was done by plotting absorbance against concentration of sodium; the same was done to the potassium. The samples were then analyzed and the concentrations were obtained by using the following relations.

Concentration mg/l = absorbance of sample # Slope obtained from graph

Energy Calculation: The percent calories in black and white Fonio were calculated from the values of crude protein, fat and carbohydrate obtained in this experiment. First, crude protein and carbohydrate percentages were each multiply by 4 while that of crude fat was multiply by 9 and all the values obtained were added[10]. The calculation was done as follows;

Energy (Kcal/100g) =
{[% C.P # 4] + [% carbohydrate # 4] + [% C.F # 9]}

Where: C.P, Crude Protein, C.F, Crude Fat

Determination of Iron, Calcium and Zinc using Atomic Absorption Spectrophotometer[11,12] **Principle:** Atomic absorption spectroscopy is technique in which free atom(s) in a gaseous state absorbed ultraviolet (UV) radiation. The absorbance is measured at a specific wavelength as beams of radiation are passed through the atomized sample. The absorbance is normally measure at wave length that corresponds to the mineral of under question.

Procedure: The instrument was set up according to the manufactures instruction which includes section of fuel, oxidant gases, and burner fuel and wave length. Specific wave length was selected for Fe, Zn and Ca (248.3, 213.9 and 422.7nm) respectively. The sample solution was aspirated into the flame and ions absorbances were recorded for each element. Calibration curved for absorbance of standard solution for each

metal was plotted. A plot of absorbance against concentration gave linear graph. The slope of the graph was used to calculate the concentration of each metal in a given sample using absorbance values. The exact concentration of interested element was calculated by applying the following formula.

Concentration mg/l =
Absorbance of sample # Slope obtained from graph

Results and Discussion

This study was performed to compare the nutritive value of the locally available black and white Fonio. Using standard procedures, the proximate composition as well as minerals of the black and white fonio were determined and presented in table-1 to 4

Table -1
Nutrients composition of Black Fonio

Nutrients	%Composition
Protein	8.75
Fat	4.00
Fiber	1.03
Carbohydrate	76.91
Ash	2.31
Moisture	7.00
Energy	378.64 Kcal/100g

Table-2
Nutrient composition of white Fonio

Nutrients	%Composition
Protein	7.11
Fat	3.00
Fibre	0.79
Carbohydrate	79.72
Ash	2.13
Moisture	7.00
Energy	374.32 Kcal/100g

Table-3
Minerals composition of Black Fonio

Mineral	Composition (mg/100g)
Sodium	30.00
Potassium	8.45
Calcium	30.00
Iron	2.75
Zinc	0.75

The result shows that black Fonio contains 8.75% crude protein, 4.00% crude fat, 1.03% crude fiber, 76.91% carbohydrate, 2.31% ash, 7.00 % moisture, sodium (Na) 30mg/100g, potassium (K) 8.45mg/100g, calcium (Ca) 30.00mg/100g, Iron (Fe) 2.75mg/100g, Zinc (Zn) 0.75mg/100g. while that of white Fonio was found to contained 7.11% crude protein, 3.00% crude fat, 0.79% crude fiber, 79.72% carbohydrate, 2.13% ash, 7.00% moisture, sodium (Na) 20.00mg/100g, Potassium (K) 5.40mg/100g, Calcium (Ca) 20.00mg/100g, Iron (Fe) 1.10mg/100g, Zinc (Zn) 0.65mg/100g. Fonio, with 7% protein, rich in leusine , valine and methionine[4] was consider to be most excellent grain in term of nutrients and taste[3]. It has been suggested that the composition of both black and white Fonio is comparable to that of white rice but having comparatively higher cystine and methionine (sulphur amino acid) content[13,14]. Amino acids that contain sulphur are very vital for appropriate nerve transmission and proper functioning of the heart and people with low meat intake depend on cereals as source of essential amino acids[14].

Table-4
Minerals composition of white Fonio

Mineral	Composition (mg/100g)
Sodium	20.00
Potassium	5.40
Calcium	20.00
Iron	1.10
Zinc	0.65

In Nigeria Fonio products are presently recommended as preferred carbohydrate source for patient suffering from diabetes[14]. Black and white Fonio may probably be rich in nutraceuticals, for instance antioxidants containing phenols and waxes which lower cholsterol[14-16]. It has been reported that in part of the West Africa, black and white Fonio have play significant role for diabetic patients[14]. The potential of cereals in decreasing the risk of cancer as well as cholesterol lowering has been predicted and the ability of grains to bind bile acid has been evaluated physiologically invitro[14-16]. Many increasing approach has encourage the use of whole grains as they are excellent source of fiber which is important in the prevention of constipation, cardiovascular diseases and hypertension. The nutraceuticals found in the whole grain have found to be beneficial in obesity, general health maintenance and diabetes[14,16].

Due their resistance to digestion and absorption in the small intestine, resistance starch has been one of the interest sources of dietary fiber. It has been suggested that Fonio contains resistance starch which may play important role in the diseases managements as well as heath conditions[14]. Due to their resistance to digestion and absorption in the small intestine, resistance starch has been one of the rich sources of dietary fiber and it was been suggested that, Fonio contains resistance starch which may play important role in the diseases managements as well as heath conditions. Fonio is a good source of minerals required by both children and pregnant women. A study found modest zinc supplements (5.7mg/day) results in increased growth rate compared to placebo[17] indicating that grains with high zinc content might be beneficial to children under active growth. The recommended daily intakes of calcium and iron for

an adult male are 1,000 and 10 mg, respectively[18].

From the data in table-3 and 4, it can be estimate that 100 g dry weight of black and white Fonio would provide about 30 mg and 20mg of calcium that is 3% and 2% of recommended calcium daily intake respectively. Data from table-3 and 4 also shows that 100g of black Fonio can supply 27.5% of recommended daily iron intake while that of white Fonio can supply 11% of the recommended iron intake.

Carbohydrates are main components in cereals and are the main energy supply used by the human. Several industries uses carbohydrates for making food and feed and important industrial raw material which are of commercial importance such as fuels which are ethanol-based, adhesives, and plastics that are readily biodegradable[19]. The carbohydrates of Fonio grains can also have many uses in industrial sectors[20]. The low-starch gelatinization temperature and high-beta-amylase activity shows the brewing potential of both black and white Fonio in partial substitution of barley malt[2,4,14].

From this study, it is well noted that black and white Fonio can provide substantial nutrients required for proper functioning of the body. Proper attention has to be paid to this 'lost crop of Africa' due to its exceptional nutritional properties.

Conclusion

Based on the results obtained from this research, it can be concluded the black fonio is more nutritive in terms of protein, fat, fiber, ash content and calculated calories. The levels of these parameters show that these grains can provide substantial recommended daily intake of these nutrients. Proper attention has to be paid to this 'lost crop of Africa' due to its exceptional nutritional properties.

Abbreviations

AOAC, Association of Official Analytical Chemists.
AACC, America Association of Cereal Chemists.
ISO, International Organization for Standardization.
AOCS, American oil chemists society.
B.P, Boiling Point.

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