

Effects of Fermentation and Germination on Raw Whole-wheat Grain of *Triticum durum* in the Evaluation of Its Proximate, Minerals and Antinutrients Composition

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Abstract:

Background: This work reports on the effects of processing on food composition of *Triticum durum* grown in Nigeria.

Methods: Standard methods were used to determine proximate, minerals and antinutrients levels in raw (RS), fermented (FS) and germinated (GS) samples of *T. durum*.

Results: Protein was enhanced in GS, crude fat in FS and GS whereas fibre was reduced in FS and GS and ash in FS. Water balance for protein metabolism were (ml): RS (579) > FS (576) < GS (630). Mineral reduction due to treatment can be seen as follows (mg/100g): RS (266.6) > GS (242.21) > FS (241.59). Major enhanced minerals during processing: Zn, Mn, and Na. Among the mineral ratios, [K/(Ca+Mg)] had values between 2.96-3.00 which were higher than the reference ideal balance of 2.20. In MSI for Na, Ca, Mg, Zn, Fe and P, only Zn had values greater than standard MSI indicating no deleterious effects in all the samples (except Zn). Processing highly reduced the antinutrients. Enhancement occurred in tannic acid, RS/FS (30.6), RS/GS (14.5), FS/GS (12.3). Significant differences (rc=0.01) existed; pairs RS/FS, RS/GS, FS/GS for proximate, mineral, antinutrient and molar ratios.

Conclusion: In the areas of food functionality, importance would be GS > FS > RS.

Key words: whole-wheat; *Triticum Durum*, raw; processing; chemical composition

1.Introduction

Wheat is a grass which is widely cultivated for its seed, a cereal grain which is a worldwide staple food [1,2,3]. There are many species of wheat and they together make up the genus *Triticum*; the most grown of them being the common wheat (*Triticum aestivum*). Botanically, wheat kernel is a type of fruit called a caryopsis. The three major types of wheat are *Triticum vulgare* (or *aestivum*), *T. durum*, and *T. compactum*.

Wheat is grown on more land area than any other food crop (220.4 million hectares or 545 million acres, 2014) [4]. World trade in wheat is greater

than for all other crops combined [5]. In 2020, world production of wheat was 761 million tonnes (1.7 trillion pounds), making it the second most produced cereal after maize [6] (Table 1). World demand for wheat has continued to increase because of its unique viscoelastic and adhesive properties of gluten proteins that facilitate the production of processed foods, whose consumption is increasing as a result of the worldwide industrialization and the westernization of the diet [7, 8].

Table 1: Top wheat producers in 2020

Country	Millions in tons
China	134.2
India	107.6
Russia	85.9
United States	49.7

Canada	35.2
France	30.1
Pakistan	25.2
Ukraine	24.9
Germany	22.2
Turkey	20.5
World	761

Source: FAOSTAT [6].

Wheat is an important source of carbohydrate [7]. It is the leading source of vegetable protein in human food globally, having protein content of about 13%, which is relatively high compared to other major cereal [9] although relatively low in protein quality for supplying essential amino acids [10,11]. As a whole grain, wheat is a source of multiple nutrients and dietary fibre [7]. Raw wheat can be ground into flour or, using hard durum wheat only, can be ground into semolina; germinated and dried creating malt; parboiled (or steamed), dried, crushed and de-branned into bulghur also called groats [12]. Wheat is a major ingredient in such foods as bread, porridge, crackers, biscuits, muesli, pancakes, pasta and noodles, pies, pastries, pizza, semolina, cakes, cookies, muffins, rolls, doughnuts, gravy, beer, vodka, boza (a fermented beverage) and breakfast cereals [13].

Major cultivated species of wheat are: Hexaploid species-Common wheat or bread wheat (*Triticum aestivum*) [14]. Tetraploid species- Durum (*Triticum durum*); a tetraploid form of wheat widely used today, and the second most widely cultivated wheat [14]. Some methods used in naming wheat which are based on special characteristics are: protein content (e.g bread wheat); the quality protein content (e.g. bread wheat); the quality of the wheat protein gluten (determines use of protein in a particular dish; e.g. strong and elastic gluten in bread wheats; strong but non-elastic gluten in durum); and grain colour (red, white or amber).

We have the scientific classification of wheat as follows;

Kingdom: Plantae; Clade: Tracheophytes; Clade: Angiosperms; Clade: Monocots; Clade: Commelinids; Order: Poales; Family: Poaceae; Subfamily: Pooideae; Supertribe: Triticeae; Tribe: Triticeae; Genus: *Triticum* L.; Type species: *Triticum durum* [15] Species are *T. aestivum*, *T. durum*, etc.

The nutritional value of foods strongly depends on their nutritional and anti-nutritional composition. The anti-nutritional factors are principally associated with substances of natural and synthetic origin, which interfere with the absorption of nutrients, act to reduce nutrient intake, digestion, utilization and may produce other adverse effects. Anti-nutrients are frequently related to plant-based, raw or vegan diets and are naturally synthesized in plants [16]. Some common symptoms exhibited by some anti-nutrients in the body are nausea, bloating, headache, rashes, nutritional deficiencies, etc. [17]. Plants primarily use antinutrients for their own defense. Also, anti-nutrients can be evidently advantageous to humankind when consumed wisely.

Antinutrients are found in their highest concentrations in grains, legumes, beans and nuts, also in leaves, roots and fruits of certain varieties of plants. Anti-nutrients mostly found from plant sources are phytates, tannins, lectins, oxalates, saponins, etc. Oxalate prevents calcium from being absorbed in the body by binding with it [18]. Consumption of excessive tannins leads to enzymes responsible for protein absorption inactivated. Phytates consumption may lead to a lower mineral absorption and lectins

are able to cause various reactions to the body [19]. Saponins have been linked to red blood cells damaging, enzyme inhibition and thyroid function intervention [20].

Fermentation is a desirable process of biochemical modification of primary food matrix brought about by microorganisms and their enzymes [21]. It is used in enhancing the bioaccessibility and bioavailability of nutrients from different crops [22]; improves organoleptic properties as well as extending the shelf life [23]. It makes food safe by inhibiting growth of pathogenic bacteria due to antimicrobial activity of lactic acid [24] and also detoxifies aflatoxin [23].

Germination is the process occurring at the beginning of the development of seeds into plants, during which they sprout [25]. It involves changes in the nutritional biochemical and sensory characteristics of the food. It is used in processing of cereal in improving the nutritional quality as it results in the reduction of anti-nutritional factors [26]. These changes are greatly associated with the activation of some endogenous enzymes making germinated food higher in nutritional quality compared to nongerminated seeds [27].

From classes used in North America for wheat grouping [28,29], Durum has been described as being very hard, translucent, light-coloured grain used to make semolina flour for pasta and bulghur; high in protein, specifically, gluten protein. A strong and elastic gluten present in bread wheats enables dough to trap carbon dioxide during leavening, but elastic gluten interferes with the rolling of pasta into thin sheets. The gluten protein in durum wheats used for pasta is strong but not elastic. The yellowing colour of durum wheat and semolina flour made from it is due to a carotenoid pigment called lutein, which can be oxidized to a colourless form by enzymes present in the grain.

Some research work had been reported on *Triticum durum*. In the year 2000, Adeyeye et al. [30] reported on the calcium, zinc and phytate interrelationships in some foods of major consumptions in Nigeria (*T. durum* was involved). The chemical composition and the effect of salts on the food properties of *T. durum* whole meal flour had been reported [31]. Young and Greaves [32] reported on the influence of variety and treatment on phytin content of wheat. The amino acids and sugar composition of *T. durum* whole meal flour had been reported [33]. The relationship in the amino acid quality between raw, steeped and germinated wheat (*Triticum durum*) grains had also been reported [34]. As a follow up to reference number 34, the present research reports on the effects of fermentation and germination on raw, whole-wheat flour of *Triticum durum* in the evaluation of proximate, minerals and anti-nutrients composition.

Hypotheses

Correlational analysis of proximate composition, mineral composition, mineral molar ratios and antinutrients values of *Triticum durum* among pairs of raw/fermented samples (A/B), raw/germinated samples (A/C) and

fermented/germinated samples (B/C) led to the generation of the following null hypotheses.

- i. There is no significant difference in the correlational analysis of the proximate composition values of *T. durum* among pairs of A/B, A/C and B/C.
- ii. There is no significant difference in the correlational analysis of the mineral composition values of *T. durum* among pairs of A/B, A/C and B/C.
- iii. There is no significant difference in the correlational analysis of the mineral molar ratios of *T. durum* among pairs of A/B, A/C and B/C.
- iv. There is no significant difference in the correlational analysis of the anti-nutrients values of *T. durum* among pairs of A/B, A/C and B/C.

The level of significance was set at $\alpha = 0.01$ at $n-2$ (df)

2. Materials and Methods

2.1. Collection of Samples

The wheat grains (*T. durum*) were collected from farms located in Zaria, Kaduna State, Nigeria. About 1.5kg of the grains was used for the experiments.

2.2. Sample treatment

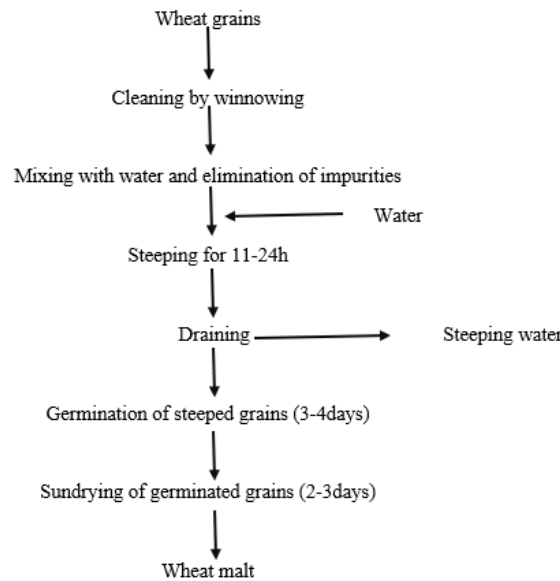


Figure 1: General flow diagram of traditional malting of wheat grains.

2.3. Sample Analysis

2.3.1. Proximate Analyses

Moisture content was determined gravimetrically using ventilated oven set at 105°C to dry the samples to constant weight [37]. Crude protein was determined by multiplying the estimated nitrogen content by a factor of

$$\text{Carbohydrate (g/100g)} = 100 - (\text{Moisture} + \text{Crude protein} + \text{Crude fat} + \text{Fibre} + \text{Ash}) \dots \dots \text{Equation (1)}$$

2.3.1.1. Total Energy

Total energy from protein, fat and carbohydrate in kJ/100g and kcal/100g was estimated using the Atwater Factors [42].

$$\text{Total energy (kJ/100g)} = (\text{fat} \times 37) + (\text{protein} \times 17) + (\text{carbohydrate} \times 17) \dots \dots \text{Equation (2)}$$

First of all, the shaft was removed by threshing, sorting of grains was done to separate bad grains, stones and other non-wheat particles. The sample was divided into three equal parts for use as raw, fermented (steeped) and germinated sample and labeled accordingly.

The portion labeled as raw (0.5kg) was not specially treated but was only dried to constant weight (8.87g/100g moisture content). The portion labeled for steeping (0.5kg) was placed into a plastic container, distilled water was added to cover the grains and left in the laboratory at ambient temperature (30.9°C) at 0.41lm²/ft light intensity for four days. After this, the grains were washed with distilled water, dried in the sun to constant weight (9.56g/100g moisture content) and stored in a covered plastic container. The portion labeled for germination (0.5kg) was treated as follows: grains were soaked in distilled water at room temperature for 24h; the grains were then spread on a damp fabric, protected from the direct sun for approximately 48h, until 5.04cm sprouts developed; germinated grains were dried in the sun for three days until constant weight of 8.94g/100g moisture content; the sprouts were manually removed and the desprouted grains were stored in a plastic container [35]. [The flow chart detailing the processes in the preparation of steeped and germinated samples had been depicted in Fig. 1.] [36]. Each sample was then homogenized, sieved using 200mm mesh size and kept in plastic bottles in the refrigerator (2.8°C), pending analysis.

6.25 [38]. Extraction of crude fat (CF) was carried out by Soxhlet extraction apparatus with chloroform/methanol (2:1 v/v) mixture [39]. Total ash was determined by igniting the samples in a muffle furnace set at 550°C [40]. Crude fibre was determined by the method of AOAC [41] and carbohydrate was estimated by difference, i.e.

Total energy (kcal/100g) = (crude fat × 9) + (crude protein × 4) + (carbohydrate × 4).....Equation (3)

Utilizable energy due to protein (UEDP%) = % protein energy in total energy × 60%Equation (4)

Energy requirement for infants per day = 740kcal/(Total energy) × 100/1 Equation (5)

Energy requirement for adult per day = 2500kcal/(Total energy) × 100/1 Equation (6)

Energy requirement for adult per day = (3000 kcal)/(Total energy) × 100/1 Equation (7)

Conversion of CF to Total Fatty Acid (TFA)

Crude fat × 0.72 = TFA [43]Equation (8)

Water Requirement for Complete Metabolism from Proximate Composition

Protein energy = P (kcal/100g)

Water for excretion = (Q) = (3P)a

Water deficit = (350/100 × P) = Tml

Water balance = (T-Q)mlEquation (9)

a = 1 Calorie of protein requires 3ml of water for by-products excretion [44].

2.3.2. Mineral Analyses

The minerals were analysed from the solution obtained by first dry ashing the samples at 550°C. The filtered solutions were used to determine: Na, K, Ca, Mg, Zn, Fe, Cu, Mn, Co by means of atomic absorption spectrophotometer (Buck Scientific Model- 200 A/210, Norwalk, Connecticut 06855) and phosphorus was determined colorimetrically by spectronic 20 (Gallenkamp, UK) using the phosphovanado molybdate [45]. All chemicals used were of analytical grade from British Drug House (BDH, London, UK). The detection limits for the metals in

aqueous solution had been previously determined using the methods of Varian Techtron [46], giving the following values in µg/ml: Fe(0.01), Cu (0.002), Na (0.002), K(0.005), Ca (0.04), Mg (0.002), Zn (0.005), Mn (0.01) and Co (0.005). The optimal analytical range was 0.1-0.5 absorbance units with coefficients of variation from 0.9% to 2.21%.

2.3.2.1. Mineral Ratios

Ratios of Ca/P, Na/K, Ca/Mg, [K/(Ca + Mg)], Ca/K and Na/Mg were all calculated [47,48,49].

2.3.2.2. Mineral Safety Index (MSI)

The mineral safety index (MSI) [47] of Na, Ca, Mg, Zn, Fe and P were calculated using the formula:

Calculated MSI = MSI/ RAI × Research data resultEquation (10)

where MSI = mineral safety index Table (standard) value.

RAI = recommended adult intake.

2.3.2.3. Mineral Molar Ratios

The [phytate]: [Zn], [Ca]: [Phytate],[Fe]: [Phytate] and [Ca] [Phytate]: [Zn] mole ratios were calculated as previously described by IZ: NCG[50] and Wyatt and Triana – Tejas [51]. Their equations:

[Phytate]: [Zn] = (Phytate (mg/100g)/660)/(Zn (mg/100g)/65.38)Equation (11)

[Ca]: [Phytate] = (Calcium(mg/100g)/40.08)/(Phytate (mg/100g)/660)Equation (12)

[Fe]: [Phytate] = (Iron (mg/100g)/55.85)/(Phytate (mg/100g)/660)Equation (13)

[Ca] [Phytate]: [Zn] = ([Calcium (mg/100g) /40.08]×[Phytate (mg/100g)/660])/(Zinc (mg/100g)/65.38)Equation (14)

2.3.2.4 Other Calculations on Mineral Data

i. Mineral percentages of each mineral in each sample.

ii. In the mineral safety index (MSI), differences (and their percentages) were calculated between standard MSI and calculated MSI.

2.3.3. Determination of Antinutrients Composition

Phytate was quantified using the method described by Harland and Oberleas [52]. The amount of phytate in the sample was calculated as hexaphosphate equivalent using the formula:

Phytate, mg/g sample = “mean K” x A x 20 / (0.282x1000)Equation (15)

Where: A = absorbance; "mean K" - std P (μg) / A/n(stds); phytate = 28.2 % P.

The phytate values were reported in mg / 100g. The determination of oxalate was described by Day and Underwood [53]. Tannin determination followed the method of Makkar and Goodchild [54]. The quantitative determination of saponins followed the descriptions of Ukpabi Chibueze et al. [55]. Determination of flavonoid content was conducted using the method presented by Jia et al. [56]. Determination of alkaloids followed the procedure of Shamsa et al. [57].

2.3.3.1. Calculations on Antinutrients Data

- Antinutrient percentages of each antinutrient in each sample.
- Differences between the antiutrient values (and the percentage differences) between the raw and processed samples.

2.4. Statistical Analyses

The statistical analyses are in two forms: descriptive and inferential statistics. For descriptive model, the data obtained were subjected to calculation of mean, standard deviation (SD) and coefficient of variation percent (CV%). For the inferential statistics, the model involved was the correlation analysis. The correlation model was subjected to statistical Table setting the critical level at $r_{xy} = 0.01$ to find out if statistical differences existed within the samples as the case may be [58]. The degree of freedom was $n-2$ where n = number of items involved in the correlational analyses. The coefficient of correlation (r_{xy}) was further expanded to variance (coefficient of determination) (r_{xy}^2), regression coefficient (Rxy). Further on this, was the calculation for coefficient of alienation (CA) and index of forecasting efficiency (IFE) [59]. The statistics were between the pairs of raw/fermented (A/B), raw/germinated (A/C) and fermented/germinated (B/C) samples in: proximate composition; mineral composition; mineral molar ratios and antinutrients constituents.

2.5. Pubchem Database

Pubchem is a database of chemical molecules and their activities against biological assays. The system is maintained by the National Centre for Biotechnology Information (NCBI), a component of the National Library of Medicine, which is part of the United States National Institute of Health (NIH). Hence we can talk of Pubchem Compound ID (CID) [60].

2.5.1. PubChem CID for Mineral Elements

Mineral elements studied in this report were: Copper/Cu (PubChem CID: 23978); Iron/Fe (PubChem CID: 23925); Zinc/Zn (PubChem CID: 23994); Magnesium/Mg (PubChem CID: 5462224); Calcium/Ca (PubChem CID: 5460341); Cobalt/Co (PubChem CID: 104730); Manganese/Mn (PubChem CID: 23930); Sodium/Na (PubChem CID: 5360545); Potassium/K (PubChem CID: 5462222); Phosphorus/P (PubChem CID 6326970).

2.5.2. PubChem CID for Some Antinutrients

Some antinutrients studied in this report were:

Tannic acid/Tannin [C76H52O46- PubChem, CID: 16129778]; Saponin [C58H94O27- PubChem, CID198016]; Oxalate [C204-2 – PubChem, CID: 71081], parent compound: CID 971 (oxalic acid).

3. Results and Discussion

3.1. Proximate Composition

Table 2 contained the macronutrient/energy and percentage composition of raw (untreated or control) *Triticum durum* whole grain grown in Nigeria. Column 2 contained the weight (g/100g) distribution of the nutrient contents (proximate) of the raw sample. Protein (19.3g/100g) was high as well as carbohydrate (61.9g/100g). Moisture was slightly high at 8.54g/100g whereas total lipid, total ash and crude fibre were all within the bracket of 3.31=3.31 [lipid=fibre] to 3.64 (ash) g/100g. The total proximate energy values had 1502.87kJ/100g (354.59kcal/100g).

Table 2: Macronutrient/energy content and percentage composition of raw (untreated) *Triticum durum* whole grain grown in Nigeria.

1 Nutrient	2 Weight(g)	3 At water(g) factor		4 Energy		5 Percentage of weight	6 Percentage of energy	
		kJ	kcal	kJ	kcal		kJ	kcal
Protein	19.3	17	4	328.1	72.2	19.3	21.83	21.77
Carbohydrate	61.9	17	4	1052.3	247.6	61.9	70.02	69.83
Lipid	3.31	37	9	122.47	29.79	3.31	8.15	8.40
Ash	3.64	0	0	0		3.64	0	0
Water	8.54	0	0	0		8.54	0	0
Fibre	3.31	0	0	0		3.31	0	0
Total	100	0	0	1502.87	354.59	100	100	100

The proximate values in fermented *T. durum* were depicted in Table 3. These values were reduced in Table 3 compared to values in Table 2: (Table 3/ Table 2, g/100g): protein, 19.2/19.3; ash, 2.70/3.64; fibre, 2.99/3.31/ whereas these values were better in Table 3 than Table 2

(although very slightly): carbohydrate, 62.2/61.9; Lipid, 3.39/3.31; moisture, 9.55/8.54; making a sharing of 3:3 (Table 2: Table 3 or vice-versa). The total energy in Table 3 was marginally higher than Table 2: 1509.23/1502.87kJ/100g (356.11/354.59kcal/100g).

Table 3: Macronutrient/energy content and percentage composition of fermented *Triticum durum* whole grain grown in Nigeria.

1 Nutrient	2 Weight(g)	3 At water(g) factor		4 Energy		5 Percentage of weight	6 Percentage of energy	
		kJ	kcal	kJ	kcal		kJ	kcal
Protein	19.2	17	4	326.4	76.8	19.19	21.63	21.57
Carbohydrate	62.2	17	4	1057.4	248.8	62.18	70.06	69.87

Lipid	3.39	37	9	125.43	30.51	3.39	8.31	8.57
Ash	2.70	0	0	0	0	2.70	0	0
Water	9.55	0	0	0	0	9.55	0	0
Fibre	2.99	0	0	0	0	2.99	0	0
Total	100.03	0	0	1509.23	356.11	100	100	100

Table 4 contained the macronutrient constituents of the proximate composition of germinated T. durum. Comparisons of the results from Table 2/3/4 (g/100g) can be seen as follows: protein 19.3/19.2/21.0; carbohydrate, 61.9/62.2/60.1; lipid 3.31/3.39/3.49; ash, 3.64/2.70/3.55; water, 8.54/9.55/8.94; fibre, 3.31/2.99/2.93; and energy,

1502.87/1509.23/1507.83kJ/100g (354.59/356.11/355.81kcal/100g). Consistently enhanced parameter was lipid and consistently reduced parameter was fibre across the board. Both parameter reduction and enhancement were due to the treatment of the raw sample along the treatment lines.

Table 4: Macronutrient/energy content and percentage composition of germinated *Triticum durum* whole grain grown in Nigeria.

1 Nutrient	2 Weight(g)	3 At water(g) factor		4 Energy		5 Percentage of weight	6 Percentage of energy	
		kJ	kcal	kJ	Kcal		KJ	Kcal
Protein	21.0	17	4	357	84.0	21.0	23.68	23.61
Carbohydrate	60.1	17	4	1021.7	240.4	60.09	67.76	67.56
Lipid	3.49	37	9	129.13	31.41	3.49	8.56	8.83
Ash	3.55	0	0	0	0	3.55	0	0
Water	8.94	0	0	0	0	8.94	0	0
Fibre	2.93	0	0	0	0	2.93	0	0
Total	100.01	0	0	1507.83	355.81	100	100	100

Table 5 exhibited the concentration differences and the percentage differences in the proximate composition between raw and fermented (A-B), between raw and germinated (A-C) and between fermented and germinated (B-C) samples.

In A-B, the followings were positive: protein, and ash; in A-C, ash and fibre were positive and in B-C, moisture, fibre and carbohydrate were positive but total was zero. Positive meant that ash and protein were A>B; in column 3, A>C in fibre and carbohydrate whereas in column 4, B>C in moisture, fibre, and carbohydrate but B=C in total. On the whole, B>A

(in 5/7 or 71.4% parameters); C>A (in 4/7 or 57.1% parameters); and C>B (in 3/6 or 50.0% parameters since in total, C = B).

From literature, it has been shown that 100g wheat provides 1,368 kilojoules (327 kilocalories) of food energy and hence, a rich source (20% or more of Daily Vaule, DV) of multiple essential nutrients, such as protein, dietary fibre, etc. Wheat is 13% water, 71% carbohydrates, 1.5% fat. Its' 13% protein content is mostly gluten (75-80% of the protein in wheat) [13]. These values are highly comparable to the present results.

Table 5: Concentration differences (proximate) in the *Triticum durum* between raw and fermented (A-B), between raw and germinated (A-C) and between fermented and germinated (B-C) samples grown in Nigeria.

1 Parameter	2		3		4	
	A Value	B (%)	A Value	C (%)	B Value	C (%)
Ash	0.94	25.8	0.09	2.47	-0.85	-31.5
Moisture	-1.01	-11.8	-0.40	-4.68	0.61	6.39
Fibre	-0.03	-1.01	0.03	1.01	0.06	2.01
Protein	0.07	0.363	-1.67	-8.65	-1.74	-9.05
Fat	-0.08	-2.42	-0.18	-5.44	-0.10	-2.95
Carbohydrate	-0.22	-0.355	1.80	2.91	2.02	3.25
Total	-5.23	-5.52	-5.23	-5.23	0.00	0.00

In column 2, negative means A<B, in column 3, negative means A<C; in column 4, negative means B<C.

The lipid analysis of the samples had been depicted in Table 6. The crude fat (CF) was converted to the corresponding total fatty acid (T-FA) by a factor. Values of the CF ranged from 3.31-3.49g/100g and corresponding T-FA as 2.38-2.51g/100g with the trend in both parameters being raw (A) < fermented (B) < germinated (C). Values of other lipids (like sterols, phospholipids, etc.) would then be (g/100g): 0.93(A), 0.95(B) and 0.98(C) following the earlier trend. The (T-FA/Lipid) % was A = 71.9 and B

was 72.0 and for other lipids, A = 28.1% and B= 28.0%. Total energy contribution from lipid ranged as 122.47-129.13kJ/100g (29.79-31.41kcal/100g) and the T-FA range was 88.06-92.87kJ/100g (21.42-22.59kcal/100g) whereas for other lipids, we have 34.41-36.26kJ/100g (8.37-8.82kcal/100g) and all followed the earlier trend. All the parameter variations (CV%) were all very low ranging from 0.058-2.67 showing the homogeneity of the results of the parameters.

Table 6: Lipid analysis of the lipid values of the T. durum samples grown in Nigeria.

1	2	3	4	5	6	7
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Parameter	Raw	Fermented	Germinated	Mean	Standard deviation (SD)	Coefficient of variation (CV%)
	(A)	(B)	(C)			
Lipid (g/100g)	3.31	3.39	3.49	3.40	0.090	2.65
Lipid × 0.72* = TFA	2.38	2.44	2.51	2.44	0.065	2.66
Difference (Lipid- TFA)	0.930	0.950	0.980	0.953	0.025	2.62
(TFA/Lipid) %	71.9	72.0	71.9	71.93	0.058	0.081
(Difference/Lipid)%	28.1	28.0	28.1	28.07	0.058	0.207
Energy: Lipid						
(kJ)	122.47	125.43	129.13	125.68	3.34	2.66
(kcal)	29.79	30.51	31.41	30.57	0.812	2.66
: TFA						
(kJ)	88.06	90.28	92.87	90.40	2.41	2.67
(kcal)	21.42	21.96	22.59	21.99	0.586	2.66
: Difference:						
(kJ)	34.41	35.15	36.26	35.27	0.931	2.64
(kcal)	8.37	8.55	8.82	8.58	0.226	2.63
Percentage energy: TFA						
(kJ)	71.9	72.0	71.92	71.93	0.042	0.058
(kcal)	71.9	72.0	71.92	71.93	0.042	0.058
: Difference						
(kJ)	28.1	28.0	28.08	28.08	0.042	0.150
(kcal)	28.1	28.0	28.08	28.08	0.042	0.150

* = Conversion factor.

The proportion of total energy due to protein (PEC%) and utilizable energy due to protein at 60% (UEDP%) utilization from the proximate values were shown in Table 7. The total energy value of the samples: 1502.87-1509.23kJ/100g [1.50-1.51MJ/100g] or 354.71-356.3kcal/100g showed the samples to be energy dense. The PEP% range was 21.6-23.7. For PEF%, values range was 8.40-8.83 and in PEC% we have 67.8-70.1. This meant that PEF% < PEP% < PEC%. Human control groups should consume diets that are similar to the average diet of population (e.g. 10-15% of energy as protein, 30-35% of energy as fat and 45-55% of energy as carbohydrate). The T. durum energy values had their energy percentages lower or higher than the stated values but this is highly comparable. However, in the case of PEF%, it is much lower than the following comparisons: the PEF% values in this study were lower than

recommended 30% of the total energy requirement [61] and 35% for total energy intake [62]. The present total energy report of 1.50-1.51MJ/100g fell within the value of 1.3-1.6MJ/100g from cereal [63]. The utilizable energy due to protein (UEDP%) for the samples (assuming 60% utilization) ranged from 13.1-14.2. An adult man who requires about 55g protein per day with 60% utilization will be satisfied highly by the UEDP% since the requirement for the group is just 8%. The UEDP% values showed that the samples have protein concentration in terms of energy that would be more than enough to prevent energy malnutrition in children and adults fed solely on the samples as a main source of protein. The PEF% low values is useful for people wishing to adopt the guidelines for a healthy diet. All the CV% values were low showing that any of the samples might be able to carry out the food properties of another sample and vice versa.

Table 7: Proportion of total energy due to protein (PEP%), fat (PEF%), carbohydrate (PEC%) and utilizable energy due to protein at 60% (UED%) from the proximate values of wheat grown in Nigeria.

1 Energy contribution	2 Raw sample	3 Fermented sample	4 Germinated sample	5 Mean	6 Standard deviation (SD)	7 Coefficient of variation (CV%)
Total energy						
kJ /100g	1502.87	1509.23	1507.83	1506.64	3.342	0.222
kcal /100g	354.71	356.3	355.81	355.61	0.814	0.229
PEP%						
kJ /100g	21.83	21.63	23.68	22.38	1.130	5.049
kcal /100g	21.76	21.57	23.61	22.31	1.127	5.052
PEF%						
kJ /100g	8.149	8.311	8.564	8.341	0.209	2.506
kcal /100g	8.398	8.567	8.828	8.598	0.217	2.524
PEC%						
kJ /100g	70.02	70.06	67.76	69.28	1.317	1.901
kcal /100g	69.84	69.94	67.56	69.11	1.346	1.948
UED%						
kJ /100g	13.098	12.978	14.208	13.428	0.678	5.049
kcal/100g	13.056	12.942	14.166	13.388	0.676	5.049

The approximate sample weight equivalent to the energy requirement of infants and adults from the proximate composition can be seen in Table 8. The daily energy requirement for an infant is 740kcal and range from 2500-3000kcal for adults depending on adults physiological state [64]. This shows that for 2500kcal model, an adult would need to consume between 701.66-704.80g and between 841.99-845.76g (for 3000kcal model) depending on the sample to cater for energy need per day. Infants would have to take between 207.69-208.62g (depending on the sample) in order to satisfy their energy needs per day. The present values for sample weight equivalent were lower than the literature reports:

Acanthurus monroviae adult: 733g and 880g (for 2500kcal model and 3000kcal model respectively), infant: 220; Lutjanus goreensis: adult : 735g and 882g respectively, infant: 221 [65]; even in the body parts of stock fish (Gardus morhua), their weight equivalent levels were higher than the present report as shown, body part/energy (kcal)/2500kcal equivalent (g)/3000kcal equivalent (g)/740kcal equivalent(g) : muscle/352/710/852/210; body/348/718/862/213; gill/349/716/860/212; bone/346/723/867/214; head/346/723/867/214; skin/362/691/829/204; eyes/352/710/ 852/210 [66].

Table 8: Approximate sample weight equivalent to the energy requirement of infants and adults from the T. durum proximate composition grown in Nigeria.

1 Sample	2 Total energy (kcal)	3 Infant energy requirement per day (740kcal) Sample equipment (g)	4 Adult energy requirement per day	
			2500kcal Sample equivalent (g)	3000kcal Sample equivalent (g)
Raw	354.71	208.62	704.80	845.76
Fermented	356.3	207.69	701.66	841.99
Germinated	355.81	207.98	702.62	843.14

The water required for excretion of urea and sulphate formed as well as water deficit as a result of metabolism in each sample is depicted in Table 9. The values of water required for complete metabolism of 100 calories of food substances are: preformed water: 0.0g (for protein, fat and starch); water gained by oxidation: 10.3 (protein), 11.9 (fat) and 13.9 (starch); water lost in excreting end products: 30 (protein) and 0.00 (for both fat and starch); water deficit: 350 (protein), 48 (fat) and 46 (starch). 1 Calorie of protein requires 3ml of water for excretion of urea and sulphate formed

from it [44]. In Table 9, the required water for excretion of urea and sulphate by-products formed (Q) ranged from 230.4-882ml. Hence, the required water balance for complete metabolism for each sample (T-Q)ml: raw (579), fermented (576), and germinated (630) all with low CV% values. Effect of the water deficit cannot be mitigated by carbohydrate and fat since they still have their own water deficit (although insignificant). However, water deficit in the samples could be mitigated by water intake.

Table 9: Water requirement for complete metabolism of the proximate composition (protein part) o the T. durum samples grown in Nigeria.

1 Parameter	2 Raw sample	3 Fermented sample	4 Germinated sample	5 Mean	6 SD	7 CV%
Protein (g/100g)	19.3	19.23	20.97	19.83	0.985	4.967
Protein energy (P) (kcal/100g)	77.2	76.8	84	79.33	4.046	5.100
Water for excretion (Q) = (3P) ^a	231.6	230.4	252	238	12.14	5.101
Water deficit (350/100×P = T) (ml)	810.6	806.4	882	833	42.49	5.101
Water balance (= T-Q) (ml)	579	576	630	595	30.35	5.101

a = 1 calorie of protein requires 3ml of water for by-products excretion.

The correlational analysis of the proximate composition values among pairs of raw/fermented (A/B), raw/germinated (A/C) and fermented/germinated (B/C) samples had been depicted in Table 10. The descriptive analysis involved were mean, standard deviation (SD) and coefficient of variation (CV%). In the inferential statistics, model used was correlation coefficient (r_{xy}) determination, variance (r_{xy}²), regression coefficient (R_{xy}) and the r_{xy} was evaluated at r_{xy} = 0.01 confidence level to see if significant differences occurred between the pairs compared setting the degree of freedom (df) at n-2. Further, the r_{xy} value was further subjected to the evaluation of coefficient of alienation (CA) and index of forecasting efficiency (IFE). Results in Table 10 showed that all the r_{xy} values were positive, high and significantly different since calculated values (0.9943-0.9990) > r_T of 0.917 at n-2 [6-2 = 4 (df)]. All the r_{xy}² were also high. The R_{xy} values showed that sample A (column 2), sample A (column 3) and sample B (column 4)

were each greater than 1.00g. R_{xy} could further be explained thus: R_x:R_y = R_x(1.00): R_y (0.9812) in samples pair A/B; hence R_{xy} = x(1.00): y(0.9812) in samples pair A/B; hence R_{xy} = x (1.00) : y(0.9812); this explanation goes for R_{xy} in A/C and B/C. First members of the pairs in columns 2,3,4 had mean values of 15.8g, 15.8g and 16.7g respectively and respective values of SD/CV%: 23.5/149,23.5/149,23.2/139 showing that the mean values were low with correspondingly high vales of SD/CV%. However, the mean, SD and CV% were close among each member of the group. In the second member of the pairs in columns 2,3,4 (B,C,C respectively), the mean values were uniform at 16.7g for B,C,C respectively whereas the respective SD/CV% values were 23.2/139, 22.4/134, 22.4/134 showing similar characteristics as earlier discussed for the columns first pair member above. The CA values were low at 0.04360-0.1063; the IFE values were correspondingly high at 0.8937-0.9564. The CA and IFE work together, when CA is high, IFE is low and when IFE is

high, CA is low since $CA + IFE = 1.00$ (fractional basis) or $CA + IFE = 100\%$ (when valued on percentage basis). CA represents index of alienation or non-relationship or error in the prediction of relationship between comparable pair; hence, high CA mean non-relationship or high error of prediction. On the other hand IFE represents reduction in the error

of prediction of relationship. In all the CA and IFE values, $CA \lll IFE$ as we have $CA (4.36-10.63\%) \lll IFE (89.37-95.64\%)$. Since CA was low and IFE was high, it followed that any member of a pair can carry out all the food functionalities of the other and vice versa.

Table 10: Correlational analysis of the proximate composition values of *Triticum durum* among pairs of raw/fermented samples (A/B), raw/germinated samples (A/C) and fermented/germinated samples (B/C) grown in Nigeria.

1 Statistics	2 A/B	3 A/C	4 B/C
Correlation coefficient (r_{xy})	0.9943*	0.9955*	0.9990*
Coefficient of determination (r_{xy}^2)	0.9887	0.9911	0.9981
Regression coefficient (Rxy)	0.9812	0.9484	0.9644
Mean ₁	15.8	15.8	16.7
Standard deviation ₁ (SD ₁)	23.5	23.5	23.2
Coefficient of variation ₁ (CV% ₁)	149	149	139
Mean ₂	16.7	16.7	16.7
SD ₂	23.2	22.4	22.4
CV% ₂	139	134	134
Coefficient of alienation (CA)	0.1063	0.0943	0.0436
Index of forecasting efficiency (IFF)	0.8937	0.9057	0.9564

Mean₁, SD₁, CV%₁ represent values due to A (column 2), A (column 3), B (column 4); Mean₂, SD₂, CV%₂ represent values due to B (column 2), C (column 3), C (column 4); * Values significantly different at $r=0.01$ at $n-2=6-2=4$ (df) at critical level of 0.917.

3.2. Mineral Composition

The mineral composition (mg/100g) of the samples are depicted in Table 11. Cu and Co were not detected in any of the samples. Minerals of relatively low values were Fe(4.49-5.07, CV% of 6.166) and Mn(1.13-1.88, CV% of 25.85, being the highest CV%). Minerals of average levels were Ca(21.78-22.54, CV%= 1.887), Mg(23.28-24.07, CV% = 1.696), and Zn(21.12-30.46, CV% = 18.70, being the second highest CV%). The highest concentrated three minerals were P(53.2-58.5, CV% = 5.347), Na(33.33-38.55, CV% = 8.158), and K(61.49-68.26, CV% = 5.706). The ratio of K:Na in the samples were, raw (2.03:1.00); fermented (2.02-1.00); and germinated (1.60:1.00). On the whole, the concentration trend at mg/100g was: Raw (266.6) > Germinated (242.21) > Fermented (241.59).

All plant ash is similar in certain respects. The main constituent is usually potassium, which often comprises nearly 50% of the total weight of ash.

Animal tissues, in general, are much less rich in K, but on the other hand, they usually contain more sodium; this is possibly related to the preferential accumulation of K in large vacuoles which are a prominent feature of many plant cells, but meristematic cells, which only have small vacuoles, show an even greater preference for potassium over Na [67]. After K, Ca is often the most abundant element in plant ash, although its concentration ranges widely from trace amounts in maize (*Zea mays*) grains to over 7% of the dry weight in mature sunflower (*Helianthus annuus*) leaves. Plant ash is also rich in Mg, which is a constituent of some organic molecules, including chlorophyll and also occurs as free ions in the cell sap. Phosphorus is present in plant ash mainly as phosphorus pentoxide produced by oxidation of organic and inorganic phosphate during burning. The ash from plant seeds is particularly rich in phosphorus, most of which is derived from phytin (calcium and magnesium myo-inositol hexaphosphate) [68].

Table 11: Mineral composition values (mg/100g) of raw, fermented and germinated samples of *Triticum durum* grown in Nigeria.

1 Mineral	2 Raw sample	3 Fermented sample	4 Germinated sample	5 Mean	6 Standard deviation	7 Coefficient of variation
Na	33.33	33.85	38.55	35.24	2.875	8.158
K	67.69	68.26	61.49	65.81	3.755	5.706
Ca	21.78	22.54	22.47	22.26	0.420	1.887
Mg	23.28	23.56	24.07	23.64	0.401	1.696
Zn	21.12	28.99	30.46	26.86	5.022	18.70
Fe	5.07	4.49	4.89	4.817	0.297	6.166
Cu	ND	ND	ND	-	-	-
Mn	1.13	1.40	1.88	1.47	0.380	25.85
P	53.2	58.5	58.4	56.7	3.032	5.347
Co	ND	ND	ND	-	-	-
Total	266.6	241.59	242.21	250.13	14.26	5.701

ND = Not detected; -= Not determined.

Range of concentration (ppm of dry matter) of various elements in plant ash goes thus K-Ca-Na-Mg-P-Fe-Mn-Zn-Sr-etc. [69]. In the present

report, percentage levels trend in the samples mineral goes thus: $K > P > Na > Zn > Mg > Ca > Fe > Mn$. However, this trend changed within the samples due to processing. The CV% values were generally low at 0.00-

23.23 showing the variation among the percentage levels to be low. The percentage levels of the minerals were shown in Table 12.

Table 12: Percentage levels of the mineral composition values of *Triticum durum* samples produced in Nigeria.

Mineral	Raw sample (Percentage value)	Fermented sample (Percentage value)	Germinated sample (Percentage value)	Mean	SD	CV%
Na	14.71	14.01	15.92	14.88	0.966	6.492
K	29.87	28.25	25.39	27.84	2.268	8.147
Ca	9.61	9.33	9.28	9.407	0.178	1.892
Mg	10.27	9.75	9.94	9.987	0.263	2.633
Zn	9.32	12.00	12.58	11.30	1.739	15.39
Fe	2.24	1.86	2.02	2.040	0.191	9.363
Cu	-	-	-	-	-	-
Mn	0.50	0.58	0.78	0.620	0.144	23.23
P	23.48	24.21	24.11	23.93	0.396	1.655
Co	-	-	-	-	-	-
Total	100	100	100	100	0.00	0.00

- = Not determined.

The mineral concentration differences (and their percentage differences) were shown in Table 13. In column 2, we have raw-fermented (A-B) samples; among the minerals with discernible levels, 8/9 (88.9%) parameters were higher in B than in A; exception being 1/9 (11.1%) in Fe. Percentage differences ranged from 0.842 (K) – 37.3 (Zn); meaning Na, K, Ca, Mg, Zn, Mn, P and total minerals were enhanced by fermentation. In fermented-germinated samples, B was more concentrated than C in 5/9 (55.6%) parameters whereas C>B in 4/9 (44.4%) parameters. For raw-germinated (A-C) samples, C>A in 7/9 (77.8%)

parameters and C<A in 2/9 (22.2%) parameters; this showed that 77.8% of the parameters were enhanced in the germination process over the raw sample. The difference between B/C was low: B(fermented) had undergone enhancement but this enhancement was further enhanced to the tune of 44.4% parameters by the germination process. There was no enhancement in the Fe by both fermentation and germination processes; this could have been to bacterial usage of the mineral since Fe was reduced from 5.07mg/100g (raw) to 4.49mg/100g (fermentation) and 5.07mg/100g (raw) to 4.89mg/100g (germination).

Table 13: Mineral concentration differences in the *Triticum durum* between raw and fermented (A-B), between raw and germinated (A-C) and between fermented and germinated (B-C) samples grown in Nigeria.

1 Mineral	2		3		4	
	A	B	B	C	A	C
	Value	(%)	Value	(%)	Value	(%)
Na	-0.52	(-1.56)	-4.70	(-13.9)	5.22	(-15.7)
K	-0.57	(-0.842)	6.77	(9.92)	6.20	(9.16)
Ca	-0.76	(-3.49)	0.07	(0.311)	-0.69	(-3.17)
Mg	-0.28	(1.20)	0.51	(2.16)	-0.79	(-3.39)
Zn	-7.87	(-37.3)	-1.47	(-5.07)	-9.34	(-44.2)
Fe	0.58	(11.4)	0.40	(-8.91)	0.18	(3.55)
Cu	-	-	-	-	-	-
Mn	-0.27	(-23.9)	-0.48	(-34.3)	-0.75	(-66.4)
P	-5.30	(-9.96)	0.10	(0.171)	-5.20	(-9.77)
Co	-	-	-	-	-	-
Total	-14.99	(-6.62)	-0.62	(-0.257)	-15.6	(-6.89)

In column 2, negative means A<B; in column 3, negative means B<C; in column 4, negative means A<C.

The mineral ratios of the samples were shown in Table 14. The Ca/P values were all lower than 0.5 which is the minimum ratio required for favorable Ca absorption in the intestine for bone formation [70]. Ca/P result values ranged from 0.385-0.409, this is within the poor class, hence one needs to be careful unless food is good for other reasons. None of the Ca/P ratios fell within the acceptable ideal range. The Ca/P ratio is reported to have some effect on Ca in the blood of many animals [71]. For the Na/K ratios all fell below both reference balance ideal and acceptable ideal range; also, none of the ratio was up to 0.60 (except germinated sample, 0.627) which is the ratio that favours none enhancement of high blood pressure disease in man [70]. To raise these ratios may not be necessary since it is always good to have high level of K than Na in any

food substance. Ca/Mg ratios were each below the reference ideal and acceptable ideal range. The Ca/Mg values ranged from 0.934-0.957 which is close to 1.00. The milliequivalent ratios of [K/(Ca+Mg)] were all greater than 2.2 as values ranged from 2.64-3.00; to avoid the promotion of hypomagnesaemia in human beings [72], more K would have to be taken with wheat. All the Ca/K ratios fell below the range of 2.2-6.2 and reference balance of 4.20. The Na/Mg ratio has the following information: ideally there should be 4:1 ratio of Na relative to Mg with a range of 2-6 being acceptable. The sample results gave ratios of 1.43-1.60 which were all below the acceptable range of 2-6. Mineral ratios analyses have been very important in analysis of hair as a biochemical marker. Most of the ratios calculated here were for the purpose of gathering analytical data.

The mineral ratios are often more important than the individual mineral levels themselves and this had been illustrated by the following statements by Vitale et al., as quoted by Watts [48]: “Determining nutritional interrelationships is much more important than knowing minerals level alone. From a global standpoint, although dietary deficiency is at the more serious end of the spectrum, the opposite end, dietary excess and aberrations contribute to the burden of disease”. “Mild and sub-chemical deficiencies of nutrients outnumber overt syndromes

ten to one”. The calculated mineral ratios revealed not only the important balance between these elements, but that also provide information regarding the many possible factors that may be represented by a disruption of their relationship such as disease states, physiological and developmental factors, the effects of diet, drugs, would also predispose a person with parasymphatetic dominance to certain health conditions of severe or chronic [73].

Table 14: Mineral ratios of *Triticum durum* samples from Nigeria.

1 Mineral ratio	2 (Reference balance ideal)	3 Acceptable ideal range	4 Calculated mineral ratio		
			Raw	Fermented	Germinated
Ca/P	2.60	1.5-3.6	0.409	0.385	0.385
Na/K	2.40	1.4-3.4	0.462	0.496	0.627
Ca/Mg	7.00	3-11	0.936	0.957	0.934
K/(Ca+Mg)	2.20	-	3.00	2.96	2.64
Ca/K	4.20	2.2-6.2	0.322	0.330	0.365
Na/Mg	4.00	2-6	1.43	1.44	1.60

*Not determined ratios were Zn/Cu, Fe/Cu and K/Co because both Cu and Co recorded ND.

The mineral safety index (MSI) values of Na, Ca, Mg, Zn and P of the samples are shown in Table 15. The RAI (recommended adult intake), the standard MSI were included in the Table 15. Also, the calculated MSI (CV) values, the difference (D) between MSI(T) and MSI(C) and the percentage difference (%D) were all calculated for the minerals involved in the various samples. Differences (and percentage differences) between MSI(T) - MSI(C) were positive in all the samples for Na, Ca, Mg, Fe and P whereas Zn was negative. For Na, the %D trend was 93.3 (raw) (column 4), 93.2 (fermented) (column 5) and 92.3 (germinated) (column 6). For Ca, %D range was 98.1-98.2; Mg %D range was 94.0-94.2; Fe varied much differently, %D was 66.2-70.1 and P, %D range was 95.1-95.6. This meant that Na, Ca, Mg, Fe and P cannot be deleterious to the samples

consumers since MSI(T) > MSI(c) for those minerals. On the other hand, Zn was higher than the standard MSI in all the samples, hence the D of MSI(T) and MSI(c) would result into negative values. Hence %D values in Zn were -40.8 (raw, column 4); -93.3 (fermented, column 5); and -103 (germinated, column 6). The meaning of this is that raw Zn would be deleterious to its consumers to the level of 40.8%, fermented Zn would be deleterious to the level of 93.3% whereas germinated Zn would be deleterious to the level of 103%. However, highly deficient consumers of Zn deficient diets would have good Zn supplements by consuming the wheat samples in particular the processed samples. Earlier, negative D had been reported for MSI in Fe and Zn in four fast foods consumed in Nigeria [71].

Table 15: Mineral safety index (MSI) of Na, Ca, Mg, Zn and P of *T. durum* (raw, fermented and germinated) samples from Nigeria.

1 Mineral	2 RAI (mg)	3 TV of MSI	4 Raw			5 Fermented			6 Germinated		
			CV	D	%D	CV	D	%D	CV	D	%D
Na	500	4.80	0.320	4.48	93.3	0.325	4.48	93.2	0.370	4.43	92.3
Ca	1200	10.0	0.182	9.82	98.2	0.188	9.81	98.1	0.187	9.81	98.1
Mg	400	15.0	0.873	14.1	94.2	0.884	14.1	94.1	0.903	14.1	94.0
Zn	15	33.0	46.5	-13.5	-40.8	63.8	-30.8	-93.3	67.0	-34.0	-103
Fe	15	6.70	2.26	4.34	66.2	2.01	4.69	70.1	2.18	4.52	67.4
P	1200	10.0	0.443	9.56	95.6	0.488	9.51	95.1	0.487	9.51	95.1

CV = Calculated MSI; TV = Table MSI; D = Difference; RAI = Recommended Adult Intake; No MSI for K, Mn and Cu; Cu only being due to ND.

The Table 16 contained the statistical analysis result of the mineral composition data depicted in Table 11. The rxy values of samples A/B, A/C and B/C were high, positive and significantly different at rxy = 0.01 and n-2 = 8-2 = 6 (df) at 0.834. The rxy² values were high. The Rxy values were 1.00:1.03(A/B); 1.00:0.9580 (A/C); and 1.00:0.9295 (B/C); the Rxy value in A/B showed that B>A. All the mean values were moderately high

(23.3-30.3mg/100g); both the SD and CV% values were high as shown: range of SD was 22.0-23.5 and CV% range was 72.6—80.2. All the CA values were lower than all the IFE values: CA (0.1233-0.2049) <<< IFE (0.7951-0.8767) making prediction of relationship between paired samples simple and reliable and carry all the positive attributes of low CA values.

Table 16: Statistical analysis result of the mineral composition data depicted in Table 11.

1 Statistics	2 Raw/Fermented		3 Raw/Germinated		4 Fermented/Germinated	
	A	B	A	C	B	C
r _{xy}		0.9921		0.9788		0.9924
r _{xy} ²		0.9842		0.9580		0.9848

Rxy		1.028			0.9498			0.9295	
Mean	28.3		30.2	28.3		30.3	30.2		30.3
SD	22.7		23.5	22.7		22.0	23.5		22.0
CV%	80.2		77.8	80.2		72..6	77.8		72.6
CA		0.1257			0.2049			0.1233	
IFE		0.8743			0.7951			0.8767	
Remark		*			*			*	

*Values were significantly different at $r=0.01$, at $n-2= 8-2= 6$ (df) and critical level of 0.834.

3.2.1. Mineral Molar Ratios

Table 17 showed the mineral molar ratios of the samples. In a general term, bioavailability is a term that refer to how well a nutrient can be absorbed and used by the body. Bioavailability can be affected by many factors like the presence of antinutrients such as phytates, oxalates, tannins and polyphenols in foods, a person’s need, fibre, competition with other nutrients and acidity of intestinal environment [74]. Minerals normally classified as micronutrients are needed by our body in small amounts. Deficiency in minerals, however, can have a major impact on health such as anaemia and osteoporosis that commonly occur in both developed and developing countries. The study under discussion focuses only on Fe, Zn and Ca. Literature shows that in Malaysia, the incidence of anaemia due to deficiency of Fe is nearly one million cases (969, 645), osteoporosis due to Ca deficiency is 2,421,432 cases [75]. The cause of mineral deficiency is commonly due to its low bioavailability in the diet. One of the factors is the presence of phytate. Phytate, which is also known as inositol hexakisphosphate, is a phosphorus containing compound that binds with mineral and inhibits mineral absorption. The presence of phytate in foods has been associated with reduced mineral absorption due to the structure of phytate which has high density of negatively phosphate groups which form very stable complexes with mineral ions causing non-availability for intestinal absorption [76]. Phytates are generally found in food high in fibre especially in wheat bran, whole grains and legumes [77].

Many techniques have been used to determine the bioavailability of minerals in the human body. One of the methods is by measuring the molar ratio of phytate/minerals in the food and diet [78]. The proportion of samples with ratios above suggested critical values has been calculated; phytate: calcium > 0.24[79], phytate: iron > 1.00 [80], phytate: zinc > 15 [81,82,78], calcium: zinc > [83,84]. The Phy: Zn, Ca: Phy, Ca:Zn, Fe: Phy and [Ca] [Phy]: [Zn] levels of the samples were depicted in Table17. A

high incidence of suboptimal Zn status may exist among rural populations of low-income countries consuming cereal-based diets, low in animal products [85]. Indeed, the first cases of severe Zn deficiency in humans were reported among rural populations in Egypt and Iran [86,97, 88]. The high phytic acid level of cereal in these diets was probably a significant etiological factor in the development of Zinc deficiency [89]. Oberleas and Hardland [90] showed that foods with a molar ratio of Phy: Zn > 10 showed adequate bioavailability of Zn but problems were encountered when the value was > 15. The Phy: Zn molar ratio has been variously reported as an index of Zn bioavailability [91] and its range of 5-15 had been described by WHO [92] as being equivalent to moderate Zn bioavailability. All the Phy: Zn values were < 5 (0.0479-0.0842) which is equivalent to high Zn bioavailability [92]. Calcium has a sparing effect on Zn and Wise [93] suggested that the solubility of the phytates and the proportion of Zn bound in a mineral complex in the intestines depend on the levels of Ca. In this model phytate precipitation is not complete until dietary Ca: Phy molar ratios attain a value of approximately 6:1; that is critical Ca : Phy molar ratio is > 6:1; here phytate is completely precipitated from the solution. Thus, both the solubility of phytate and availability of Zn in the intestine are dependent on Ca level [95]. All the presently reported Ca: Phy had values > 6:1, it meant that the Zn would be bioavailable. Ferguson et al [96] showed that the molar ratio varies with different foods and recommended that this value be used in conjunction with other data to explain the availability of Zn using the Ca: Phy ratio. The present results for [Ca] [Phy]/[Zn] that is [Ca × Phy : Zn] were also shown in Table 17. Ellis et al [97] and Davies and Warrington [98] indicated that the ratio of Ca × Phy : Zn is a better predictor of Zn bioavailability and said that if the value were greater than 0.50mol/kg, there would be interference with the availability of Zn. The Cax Phy: Zn values in the samples were each lower than the critical value of 0.50mol/kg (being 0.00024-0.00051) thereby making the Zn very bioavailable from the samples. Ca:Zn values were all < critical level of 200, also Fe: Phy values of 3.338-3.928 were each > 1.00.

Table 17: Phy: Zn, Ca: Phy, Fe: Phy and [Ca] [Phy]/[Zn] molar ratios of the raw, fermented and germinated samples of *Triticum durum* from Nigeria.

1	2	3	4	5	6	7
Concentration ratio	Raw	Fermented	Germinated	Mean	SD	CV%
Ca: Phy ^a	19.98	24.03	25.1	23.0	2.70	11.7
Phy: Zn ^b	0.0842	0.0528	0.0479	0.0616	0.0197	32.0
Fe: Phy ^c	3.338	3.436	3.928	3.57	0.3162	8.86
[Ca][Phy]/Zn ^d	0.00051	0.00025	0.00024	0.00033	0.00002	6.06
Ca:Zn	1.682	1.268	1.203	1.38	0.2598	18.8

amg of Ca/AW (atomic weight) of Ca:mg of Phy/AW of Phy; bmg of Phy/AW of Phy:mg of Zn/AW of Zn; cmg of Fe/AW of Fe: mg of Phy/AW of Phy; d(mol/kgCa) (mol/kg Phy)/(mol/kg Zn).

The statistical analysis result of the data on mineral ratios was depicted in Table 18. The rxy values for all sample pairs were positive, high and significantly different. Corresponding rxy2 values were also high. Mean values were low: 5.757-6.056; SD values were higher than the mean

values: 8.475-10.76. CV% values were all high: 168.9-179.1. CA values were less than IFE values. CA (0.0173-0.0346) < IFE (0.9694-0.9827), hence prediction of relationship among sample pair groups would be easy, simple and reliable.

Table 18: Statistical analysis result of the data on mineral molar ratios depicted in Table 16.

1 Statistics	2 Raw/Fermented		3 Raw/Germinated			4 Fermented/Germinated			
	A		B	A		C	B		C
r_{xy}		0.9994			0.9994			0.9999	
r_{xy}^2		0.9989			0.9988			0.9997	
R_{xy}		1.216			1.269			1.044	
Mean	5.017		5.757	5.017		6.056	5.757		6.056
SD	8.475		10.31	8.475		10.76	10.31		10.76
CV%	168.9		179.1	168.9		177.7	179.1		177.7
CA		0.0332			0.0346			0.0173	
IFE		0.9668			0.9654			0.9827	
Remark		*			*			*	

*Values were significantly different at $r=0.01$ at $n-2=5-2=3$ (df) and critical level of 0.959.

3.3. Antinutrient Constituents

Table 19 contained the antinutrient constituents. They were tannic acid, phytic acid, oxalate, saponin, alkaloids and flavonoid. The total antinutrient constituents ranged between 65.21 and 73.36mg/100g. It should be noted that there was consistent reduction from raw to germinated samples as follows (mg/100g) 73.36 (raw) > 67.81 (fermented) > 65.21 (germinated) with grand mean value of 68.8 ± 4.16 mg/100g and CV% of 6.05. The total value range exhibited the effect of processing on the samples.

3.3.1. Phytic Acid

Phytic acid levels in the samples were (mg/100g): 17.93 (raw) > 15.45 (fermented) > 14.71 (germinated). These values were relatively low. These values were also highly comparable to the literature values obtained in pearl millet grains [36]; follow the comparisons, wheat/millet (mg/100g): raw (17.93/15.7), fermented (15.45/18.1), germinated (14.71/10.7). Some studies had shown that the Asian diet contains very high amounts of phytate compared with western diets. For example, a study in India showed that phytate content in their foods ranged from 480 to 520 mg/100g [99]. The phytate content of Korean foods ranged between 191.7 to 973.3mg/100g [100], whilst a study in Indonesia showed that phytate content ranged between 8 to 319mg/100g for cereals and 24 to 108mg/100g for legumes [101]. Results of 13 species found in Nigeria had their phytate levels ranging between 390 to 6210mg/100g [102]. In the samples of Bambara groundnut, phytic acid values (mg/100g) were 29.2 (testa), 17.5 (dehulled) and 14.4 (whole seed) [103], values being comparable to the present results. Also, seven varieties of Nigeria garden egg fruits had phytate levels of 507-2788mg/100g [104]. In Adeyeye et al [30], various food phytate values were reported: legumes (14-344mg/100g) and cereals (112-287mg/100g).

Values reported for *Canavalia ensiformis* ranged from 5.1-18.5mg/100g; 6.0-15.3mg/100g for *Mucuna pruriens* seed flours [105] and 33.4-37.8mg/100g for groundnut seed samples [106].

Phytates and phenolics are known antioxidants present in the bran layers of cereal grains. Phytic acid forms chelation complexes with various divalent minerals (e.g. Fe), suppressing the iron-mediated free-radical oxidant damage created by the colonic bacteria [107]. Phytates are also inhibitors (antinutrients) and they have been shown to have some beneficial effects also. Phytate has been reported to reduce the risk of colon and breast cancer in animals, lowers plasma glucose, insulin and /

or improve blood lipid profile in humans [108]. Shamsuddin [109] has shown that only phytate in the form of inositol triphosphate (IP3) can inhibit the absorption of minerals.

3.3.2. Tannic Acid

Tannins values were lower than the phytic acid values, tannic acid values ranged from 6.20-8.10mg/100g. Enhancement occurred in fermented than in the germinated samples; mean was 7.13 ± 0.950 and CV% of 13.3. Tannic acid was one of the antinutrients that did not undergo reduction in the processed samples. Tannin values were also low in pearl millet with values of fermented = germinated = 0.68g/100g and raw = 0.50 [36] and was enhanced as in wheat samples during fermentation and germination processes. During fermentation, roasting and alkalization mono and oligomeric – catechins may be partially polymerized into tannins; could this have resulted into higher levels of tannin in both pearl millet and whole wheat on fermentation? Tannin is known to possess antioxidative properties in vitro as well as certain potential preventive effect against a number of chronic conditions including cancer and cardiovascular disease [110]. In natural cocoa cake, cocoa liquor and alkalized cocoa powder sourced in Nigeria, tannin contents ranged from 4.72-8.72g/100g [110]. Other literature values of tannin were: 0.09-0.84mg/100g in Bambara groundnut seed parts [103]; 0.35-0.85mg/100g reported for groundnut samples [106]; 0.3-0.9g/100g for *C. ensiformis* and 0.8-7.8g/100g for *M. pruriens* [105]. Tannins have been reported to bring about their antinutritional influences (especially in monogastric animals) largely by precipitating dietary proteins and digestive enzymes to form complexes which are not readily digestible [111].

3.3.3. Oxalate

Oxalate values in the samples ranged from 1.07-1.54mg/100g having a mean value of 1.29 ± 0.236 mg/100g and CV% of 18.3 (largest CV% in the antinutrients) with consistent reduction from raw fermentation germination. The present level of oxalate were lower to 2.88-4.86 in millet [36]; lower than 5.02-8.59mg/100g in Bambara [103]; 4.08-6.42mg/100g reported for groundnut seed flours [106]; 2.46-6.03mg/100g reported for natural cocoa cake, cocoa liquor and alkalized cocoa [36]. Oxalate presence has an unerirable effects on calcium absorption and utilization. Oxalate combines with Ca to form a compound known as calcium oxalate that passes through the intestine without being absorbed. Calcium oxalate is responsible for most of the kidney stone formation. About half of all the kidney stones are calcium phosphate, magnesium ammonium phosphate and calcium carbonate. The amount of oxalate formed

normally depends on the amount of oxalic acid in the food [112]. Formation of these stones frequently reflects chronic alkalinity of bladder and renal pelvic urine caused by infection with bacteria that hydrolyze urea, releasing ammonia [113].

3.3.4. Saponin

Saponins are naturally occurring substances with various biological effects. Some saponins (steroid or triterpene glycoside compounds) can be used for food while others are toxic. Saponin parameter values ranged from 12.4-13.7mg/100g with trend of (mg/100g): 13.7(raw) > 13.3 (germinated) > 12.4 (fermented) showing reduction more in fermented than in germinated samples. The variation was however low at 5.07%. Saponins with a bitter taste are toxic in high concentrations and can affect nutrient absorption by inhibiting enzymes (metabolic and digestive) as well as by binding with nutrients such as zinc. In the presence of cholesterol, saponins exhibit strong hypocholesterolemic effect [114]. They can also lead to hypoglycemia [115] or impair the protein digestion, uptake of vitamins and minerals in the gut, as well as lead to the development of a leaky gut [116].

3.3.5. Alkaloids

Alkaloids constitute a class of diverse allelochemicals, some of which have great dietary importance that often goes unnoticed [111]. There have been reports that if ingested by ewes between (usually) days 8 and 17 of gestation teratogenic alkaloids can alter normal fetal development resulting in fetal malformation [117]. Forage alkaloids were implicated for the near epidemic increase in the birth of monstrous lambs with single mid-facial eyes in the Rocky Mountain region of the United States in the 1950's [111]. Apart from forage alkaloids, the need to develop rapid technique to control the quality and evaluate the safety of alkaloid-containing foods has been stressed [118]. Examples of such food alkaloids are the steroidal glycoalkaloids present in potato and potato products, which include α -solanine and α -chaconine. Solanine and chaconine are hemolytically active and toxic to fungi and humans. Some of the toxicological manifestations of potato glycoalkaloids involve

gastrointestinal upsets and neurological disorders especially in doses in excess of 20mg/100g of sample. Values of alkaloids in the *Triticum durum* wheat samples ranged as follows (mg/100g): 25.7 (raw) > 23.9 (fermented) > 23.3 (germinated) showing marginal processing effects. The CV% was low at 5.14.

3.3.6. Flavonoid

Flavonoids are structurally diverse secondary metabolites in plants, with a multitude of functions. These span from functions in regulating plant development, pigmentation, and UV protection, to an array of roles in defence and signaling between plants and microorganisms. The pigments that colour most flowers, fruits and seeds are flavonoids. Flavonoids are classified in six major subgroups: chalcones, flavones, flavonols, flavandriols, anthocyanins and proanthocyanidins or condensed tannins and a seventh group is found in some species, the aurones [119,120]. More than 6000 different flavonoids have been identified [121]. The biological functions of flavonoids are linked to their potential cytotoxicity and their capacity to interact with enzymes through protein complexation. Some flavonoids provide stress protection, e.g., acting as scavengers of free radicals such as reactive oxygen species (ROS), as well as chelating metals that generate ROS via the Fenton reaction [122]. Flavonoids are also involved in the resistance to aluminium toxicity in maize [123]. The different flavonoids have diverse biological functions, they include; protection against ultraviolet (UV) radiation and phyto pathogens, signaling during modulation, male fertility, auxin transport, as well as the colouration of flowers as a visual signal that attracts pollinators [124,125,126]. Flavonoids are also responsible for the display of fall colour in many plants, which may protect leaf cells from photo oxidative damage, enhancing the efficiency of nutrient retrieval during senescence [127]. Flavonoid levels in the samples were low at (mg/100g): 8.70 (raw) > 7.10 (fermented) > 6.10 (germinated) with highest value of CV% (17.9). Evidence of beneficial functions of flavonoids in human health and the use of natural compounds for prevention and treatment of different pathologies will continue to elucidate interest in the study of flavonoids.

Table 19: Some antinutrients content (mg/100g) of raw and processed *Triticum durum* samples from Nigeria.

1 Parameter	2 Raw	3 Fermented	4 Germinated	5 Mean	6 SD	7 CV%
Tannic acid	6.20	8.10	7.10	7.13	0.950	13.3
Phytic acid	17.93	15.45	14.71	16.03	1.69	10.5
Oxalate	1.13	0.860	0.700	0.897	0.217	24.2
Saponin	13.7	12.4	13.3	13.13	0.666	5.07
Alkaloids	25.7	23.9	23.3	24.3	1.25	5.14
Flavonoid	8.70	7.10	6.10	7.30	1.31	17.9
Total	73.36	67.81	65.21	68.8	4.16	6.05

The percentage distribution of the antinutrient values over total values per sample were shown in Table 20. The highest percentage concentration among all samples was alkaloids whose percentage range was 35.0-35.7, followed by phytic acid (22.8-24.4), third position was saponin (18.3-

20.4), next was tannic acid (8.45-10.9), closely followed by flavonoid (9.35-11.9) and least percentage was in oxalate (1.07-1.54). The CV% values were generally low at 1.02-18.3.

Table 20: Percentage level of each antinutrient in each sample total antinutrient value of *Triticum durum* from Nigeria.

1 Antinutrient	2 Percentage Values			3 Mean	4 SD	5 CV%
	Raw	Fermented	Germinated			
Tannic acid	8.45	11.9	10.9	10.4	1.78	17.1
Phytic acid	24.4	22.8	22.6	23.3	0.987	4.24

Oxalate	1.54	1.27	1.07	1.29	0.236	18.3
Saponin	18.7	18.3	20.4	19.1	1.12	5.86
Alkaloids	35.0	35.2	35.7	35.3	0.361	1.02
Flavonoid	11.9	10.5	9.35	10.6	1.28	12.1
Total	100	100	100	100	0.00	0.00

The antinutrient differences (and their percentage differences) between raw-fermented, raw-germinated and fermented-germinated were shown in Table 21. Only tannic acid showed negative values across the board and saponin only in fermented-germinated. The differences observed were due majorly to the fermentation and germination processes on the

samples. In column 2, tannic acid (-30.6%) and oxalate (23.9%) exhibited the highest difference; they were oxalate (38.1%) and flavonoid (29.9%) in column 3; whereas highest percentage difference values in column 4 were oxalate (18.6%) and flavonoid (14.1%).

Table 21: Differences between the antinutrient values between the raw and processed samples of *Triticum durum* produced in Nigeria.

1 Parameter	2 Raw-Fermented		3 Raw-Germinated		4 Fermented-Germinated	
	Value	%	Value	%	Value	%
Tannic acid	-1.90	-30.6	-0.90	-14.5	1.00	12.3
Phytic acid	2.48	13.8	3.22	18.0	0.74	4.79
Oxalate	0.27	23.9	0.43	38.1	0.16	18.6
Saponin	1.30	9.49	0.40	2.92	-0.90	-7.26
Alkaloids	1.80	7.00	2.40	9.34	0.60	2.51
Flavonoid	1.60	18.4	2.60	29.9	1.00	14.1
Total	5.55	7.57	8.15	11.1	2.60	3.83

The statistical analysis of the data from Table 19 on antinutrients was shown in Table 22. All the rxy values were positive, high and significantly different with range values of 0.9868-0.9958 and the rxy² values were also high at a range of 0.9738-0.9917. The mean values were low at 10.9-12.2mg/100g with lower values of SD (7.93-8.81) but high levels of CV%

(70.2-72.8). All CA values were much lower than IFE: CA (0.0911-0.1619) <<< IFE (0.8381-0.9089), hence low level of error of prediction of relationship. Therefore, functionality interchange between members of each pair would be expected and highly possible and reliable. The critical rxy was 0.01 at n-2 [6-2=4 (df)] and critical value of 0.917.

Table 22: Statistical analysis of the data from Table 19 on antinutrients of raw and processed *Triticum durum* produced in Nigeria

1 Statistics	2 Raw/Fermented		3 Raw/Germinated			4 Fermented/Germinated		
	A	B	A	C	B	C		
r_{xy}	0.9882		0.9868		0.9958			
r_{xy}²	0.9764		0.9738		0.9917			
R_{xy}	0.8889		0.8898		0.9982			
Mean	12.2	11.3	12.2	10.9	11.3	10.9		
SD	8.81	7.93	8.81	7.94	7.93	7.94		
CV%	72.2	70.2	72.2	72.8	70.2	72.8		
CA	0.1536		0.1619		0.0911			
IFE	0.8464		0.8381		0.9089			
Remark	*		*		*			

All rxy values were significant when rxy was r = 0.01 at n-2=6-2=4 (df) at critical level of 0.917.

3.4. Effect of Fermentation on Nutrients

Removing undesirable food components is essential to their quality improvement. Different techniques such as, soaking, cooking, fermentation, radiation, germination, chemical treatment or a combination of several of these techniques may come as handy instruments for antinutritional disabling [128].

3.4.1. Carbohydrates

The major carbohydrate in cereals and legumes is starch which provides the most calories in developing countries [23]. Fermentation activates starch-hydrolyzing enzymes such as α-amylase and maltase which degrade starch into malto-dextrins and simple sugars [129] respectively.

3.4.2. Protein

The effect of fermentation on proteins has yielded inconsistent results due to various reasons ranging from sample amino acid profile, different experimental designs and study duration. Some studies had reported increase [130,131,132] while others observed decrease [129,130] in protein and /or some amino acids upon fermentation. It will appear that most of these effects may not reflect actual changes but relative changes due to loss of dry matter as a result of microorganisms hydrolyzing and metabolizing carbohydrates and fats as a source of energy [134]. It is also reported that fermenting microorganisms also uses amino acid which could lower the protein content and quality of some fermented food [129,133].

3.4.3. Minerals

Cereals and legumes are the major source of minerals in developing countries where they are widely consumed. Minerals from plant sources have very low bioavailability because they are found complexed with nondigestible materials such as cell wall polysaccharides [135] as well as phytate. The complex matrices in which these minerals are entrapped and bonded are largely responsible for their low bioavailability. Fermentation is one of the processing methods that are applied to free these complexed minerals and make them readily bioavailable [136,133]. The effect of fermentation depends on food composition and that other food components such as dietary fibres may also slow down the accessibility of some minerals. To offset these challenges, germination or incubation of foods with polyphenol oxidase (PPO) or phytase during fermentation may help reduce the tannins or phytates, respectively and thus make minerals bioaccessible [137].

3.4.4. Phytochemicals

Phytochemicals are important plant secondary metabolic products produced in phenylpropanoid biosynthesis and shikimate pathways during the growth of plant [27]. During growth, L-phenylalanine, under the effect of phenylalanine ammonia lyase (PAL) catalyzation, changes into cinnamic acid. From then on, many phenolic components such as caffeic acid, ferulic among others are synthesized [134]. These can later be converted into tannins, flavonoids, lignins and other compounds. Advances in research have revealed importance of these phytonutrients to human health by virtue of their antioxidant properties [27], cholesterol-lowering effect [138] and reduction in the production of pro-inflammatory cytokines and immunosuppressive cells [139]. Fermentation has significant effect on phytochemicals that are both beneficial and adverse. The ability of fermentation to increase antioxidant properties of foods can be explored as a cost-effective way to reduce oxidative stress within the body after consuming such foods. Fermentation increased the tannic acid of the sample by 30.6%.

3.5. Effect of Germination on Nutrients

Germination is the process that occurs at the beginning of the development of seeds into plants, during which they sprout [25]. It involves changes in the nutritional, biochemical and sensory characteristics of the food. It is used in processing of cereals to improve nutritional quality as it results in reduction of anti-nutritional factors [140,26,141]. These changes are greatly associated with the activation of some endogenous enzymes making germinated foods higher in nutritional quality compared to non-germinated seeds [27].

3.5.1. Carbohydrates

Germination facilitates the enzymatic breakdown of carbohydrates into simple sugars through activation of endogenous enzymes such as α -amylase thereby improving digestibility [26] as a result of degradation of starch to provide energy for the seed development [27]. Germinating white sorghum for 24 and 36 h resulted into a decrease in carbohydrates and increase in simple sugars [142]. Germination increased the digestibility of starch, making it a good method in the preparation of complementary and infant foods [144,145].

3.5.2. Proteins

The actual protein content will be determined by net effect of synthesis and breakdown. Overall, it seems the net protein synthesis outweighs breakdown due to critical need for synthesis of nucleic acids required for growth, which can influence a net increase in proteins [146]. After germination of buckwheat for 72h, protein content increased significantly [27] probably due to higher rate of protein synthesis compared to proteolysis.

3.5.3. Minerals

It has been hypothesized that the remarkable increase in phytase activity during germination helps reduce phytic acids, which bind minerals subsequently leading to increased minerals availability [147]. A study carried out on buckwheat [27] showed that phytic acid in buckwheat decreased with increase in the germination time due to activation of phytase which hydrolyzes phytic acid into phosphoric acid and myoinositol thereby making minerals more bioavailable [148,149].

3.5.4. Phytochemicals

Germination of buckwheat increases total phenolics, flavonoid and undensed tannin contents [27]. PAL, the enzyme that catalyzes the pathway responsible for biosynthesis of the different phytochemicals, is responsible for limiting the rate of biosynthesis of phenolic acids and flavonoids. Tang and Zhao [150] concluded that PAL activity is enhanced during the process of germination. This may however not hold for all samples.

3.6. Hypotheses

The results of the null hypotheses are as shown below

3.6.1. Proximate Composition

The statistical analysis showed that the pairs of raw/fermented (A/B), raw/germinated (A/C) and fermented/germinated (B/C) were significantly different at $\alpha = 0.01$; hence the null hypotheses was rejected.

3.6.2. Mineral Composition

Here, A/B, A/C and B/C had significant differences since $\alpha(C) > \alpha(T)$ in each pair thereby rejecting the null hypothesis; $\alpha = 0.01$.

3.6.3. Mineral Molar Ratios

Under this observation, A/B, A/C and B/C had significant differences within each pair of samples; $\alpha(C)$ being greater than $\alpha(T)$ at $\alpha = 0.01$ and $n-2(df)$. Null hypothesis was rejected.

3.6.4. Antinutrients Composition

Correlational values showed that significant differences occurred with the pairs of A/B, A/C and B/C at $\alpha = 0.01$ and $n-2(df)$; null hypothesis was rejected.

Conclusions

For ease of reference, raw fermented, germinated samples would mostly be represented as A, B, C respectively. In the proximate composition values, C (21.0g/100g) > A(19.3g/100g) in protein; in the carbohydrate, B (62.2g/100g) > A (61.9g/100g); in moisture content, A (8.54g/100g) > C (8.94g/100g) < B (9.55g/100g) whereas in the lipid, C (3.49g/100g) > B (3.39g/100g) > A (3.31g/100g) and in energy (kcal/100g), values were

B(356.11) > C (355.81) > A (354.59). On the whole for the proximate composition, the followings were observed: B>A (5/7 or 71.4% parameters); C > A (4/7 or 57.1% parameters); C > B (3/6 or 50.0% parameters since total parameters of C=B). Between the total lipid (crude fat CF) and the total was true fatty acid (T-TFA), the observation was A<B<C whereas other lipids followed a similar trend. The UEDP% values of 13.1-14.2 would be more than enough to prevent protein energy malnutrition in children and adult fed solely on the samples as a main source of protein. The PEF% low values is good for a healthy diet. In the minerals, the concentration trend at mg/100g was: A (266.6) > C (242.21) > B (241.59) showing evidence of microbial usage of the minerals. In minerals concentration differences and their percentages, 88% parameters in B>A, due to enhancement of Na, K, Ca, Mg, Zn, P; total mineral differences/percentages in B>C (55.6%), C>B (44.4%), C>A (77.8%); Fe (5.07, A) > 4.49 (B) < 4.89 (C), Fe was not enhanced but reduced probably due to bacterial Fe utilization. In all the mineral ratios, no value was in the reference ideal range. From the MSI values, Na, Ca, Mg, Fe and P would not be deleterious to the samples consumers-since MSI(T) < MSI(C) for those minerals. Zn might be deleterious because MSI(T) > MSI(C) but this can be mitigated by using the samples to supplement Zn deficient diets. For the mineral molar ratio techniques used, Zn will be highly bioavailable. The antinutrient values were low and positive nutritionally with the exception of alkaloids. For the choice of treatment to enhance the nutritional quality of *Triticum durum*, both fermentation and germination processes are recommended and the one to pick eventually will depend on the user or experimenter. In the various correlational, CA and IFE calculations, the followings were observed:

Proximate: A/B, A/C, B/C – each pair was significantly different at $r_{xy} = 0.01$ and $n-2$ (df).

Minerals: A/B, A/C, B/C- each pair was significantly different at $r_{xy} = 0.01$ and $n-2$ (df).

Minerals Molar Ratios: A/B, A/C, B/C- each pair was significantly different at $r_{xy} = 0.01$ and $n-2$ (df).

Antinutrients: A/B, A/C, B/C- each pair was significantly different at $r_{xy} = 0.01$ and $n-2$ (df).

CA values – all values were low and far less than IFE values, hence, low error of prediction of relationship between A/B, A/C, B/C.

IFE values- all values were high and far higher than CA values, hence, high reduction in the error of prediction of relationship between A/B, A/C, B/C. This meant that food functionality in the samples would be like this: A B; A C; B C.

Supplementary Materials

No supplementary material was attached.

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Data Availability statement

The data and materials supporting the conclusions of this study are included within the article.

Conflicts of Interest

The author declares no conflict of interest, financial or otherwise.

Consent for Publication

Not applicable.

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