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# ASSESSMENT OF NUTRITIONAL QUALITY OF GINGER (*Zingiber officinale*) AND GARLIC (*Allium sativum*) FLOUR CULTIVATED IN KADUNA STATE, NIGERIA

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## ABSTRACT
Ginger (*Zingiber officinale*) and garlic (*Allium sativum*) are important spices widely consumed for their culinary and medicinal values. Despite their widespread availability and use, comprehensive data on the varieties grown in northern Nigeria are scarce. This study, therefore, examined the proximate, phytochemical, and amino acid profiles of ginger and garlic flour cultivated in Kaduna State using Standard Analytical Methods with three replicates per sample. Statistical analyses, such as mean, standard deviation, coefficient of variation, and Student's t-test at 5 % significance level, were performed. The proximate composition values (%) of ginger and garlic were as follows: crude protein (15.21 and 11.16), crude fat (4.03 and 2.65), ash (5.90 and 7.12), crude fiber (5.15 and 20.22), moisture (6.42 and 5.52), and carbohydrates (63.29 and 53.33). The calculated metabolizable energy was 1483.61 and 1194.38 kJ/100 g for ginger and garlic, respectively. Phytochemical analysis revealed high tannin levels in both samples (ginger, 160.38 mg/100 g; garlic, 170.33 mg/100 g), with garlic showing higher oxalate (7.64 %), alkaloid (10.43 %), and phenol (1.43 %) contents, whereas ginger had greater flavonoid (9.39 %) concentration. Garlic showed adequacy in isoleucine, leucine and phenylalanine + tyrosine, but was limited in lysine, methionine + cystine and tryptophan. In contrast, ginger was limited in all essential amino acids. These findings indicate that ginger and garlic flour from Kaduna State are nutritionally valuable spices that support their potential for application in food fortification and health-promoting applications.

**Keywords:** Amino acids, Phytochemicals, Proximate composition, Garlic, Ginger

## INTRODUCTION
Ginger (*Zingiber officinale*) and garlic (*Allium sativum*) are globally recognized for their nutritional and medicinal properties. Originating from regions with rich herbal traditions, spices have transcended cultural boundaries and become indispensable in both culinary and medicinal contexts (Adewale *et al*., 2021). The cultivation and utilization of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) have long been embedded in the cultural and medicinal practices of many societies (Chen *et al*., 2019). Nutritional profiling of ginger and garlic has provided insights into their health benefits, which are primarily attributed to their bioactive compounds. Ginger and garlic contain vital macronutrients and micronutrients, including proteins, carbohydrates, vitamins, and minerals, which contribute to their role as functional foods (Banerjee *et al.*, 2017).
Garlic, a member of the macrobiotic allium family, is characterized by its strong odor and distinctive flavor, largely due to sulfur-containing compounds such as allicin, which is released when the garlic bulb is crushed or chopped. Its nutritional profile includes significant amounts of selenium, manganese, and vitamin C. (Ried *et al.*, 2016). Ginger, on the other hand, contains gingerol, a potent antioxidant with anti-inflammatory properties (Gatenby, 2021). While praised for their health benefits, the nutritional value of ginger and garlic depends on agronomic variables, including soil quality and climatic conditions prevalent in their cultivation areas (Bouis *et al.*, 2019). These factors invoke considerations regarding the quality of ginger and garlic flour produced within the state (Filip *et al.*, 2018). Kaduna State, where the current samples were obtained, presents a unique agricultural environment that is both opportune and challenging for the cultivation of these crops. The region's humid, tropical climate and fertile soils favor the growth of spices (Rivlin, 2018).
Several studies have documented the nutritional composition of ginger and garlic. Gandhi and Saravanan (2018) showed that ginger has protein levels of 16.27 % in wild ginger, Onyema *et al*. (2024) documented essential values for ginger and turmeric from Port Harcourt, Musa *et al*. (2021) compared nutritional compositions of dried ginger and garlic flour and Banerjee *et al*. (2017) reviewed the nutritional compositions of garlic in relation with health outcomes. Despite these contributions, several gaps remain in literature. Most of the existing studies in Nigeria were conducted in the southern part of Nigeria, whereas

differences in soil minerals, climate, and agronomic practices in the northern part of the country may affect the nutritional composition of the spices. Second, most existing studies are descriptive and lack inferential statistics that show statistical comparisons between samples. Lastly, the amino acid scoring and protein quality parameters of Northern Nigerian spices against the FAO/WHO reference standards have not been investigated in existing studies. The current study addressed these gaps by examining the statistically validated proximate, phytochemical, and amino acid profiles of ginger and garlic flours from Kaduna State, Nigeria. The protein quality of the samples, particularly, the Predicted Protein Efficiency Ratio (P-PER), isoelectric point (pI), and amino acid scoring of the samples have been estimated. The outcomes are expected to enhance informed decisions on the incorporation of samples in food fortification strategies and dietary guidelines in northern Nigeria.

## MATERIALS AND METHODS

### Sample Collection and Preparation

Fresh ginger (*Zingiber officinale*) and garlic (*Allium sativum*) were collected from a farm in Rigasa, Kaduna State, Nigeria. The samples were identified and authenticated at the Department of Plant Science and Biotechnology, Federal University of Lafia, Nigeria. They were washed, peeled, sliced into uniform pieces (3 mm), and air-dried at room temperature (28 ± 2 °C) until completely dried. The dried samples were separately milled into flour using a laboratory mortar and pestle and stored in airtight containers for further analysis. All analyses were performed in triplicate.

### Proximate Analysis

The proximate composition (moisture, crude protein, crude fat, crude fiber, and carbohydrate content) was determined using standard AOAC procedures (AOAC, 2010). The moisture content was determined gravimetrically by oven-drying 2 g of the samples at 105 °C to a constant weight. The ash content was determined by incineration in a muffle furnace at 550 °C for 5 h. Crude protein was determined using the micro-Kjeldahl method, and nitrogen was determined by titration and converted to protein using a factor of 6.25. Crude fat was extracted using the Soxhlet method using petroleum ether (boiling range 40-60 °C). Crude fiber was determined after sequential digestion with dilute acid and alkali. The carbohydrate content was estimated using Difference Method, shown in equation 1;

Carbohydrate (%) = 100 - (Moisture + Ash+ Crude Protein+ Crude Fat+Crude Fibre) (1)

The fatty acid content was estimated by multiplying the crude fat content by a factor of 0.8. Metabolizable energy was calculated using the formular in equation (2);

Energy (kJ/100 g) = (Carbohydrate × 17) + (Crude Protein × 17) + (Crude Fat × 37) (2)

### Phytochemical Analysis

Alkaloid content was determined using a modified gravimetric method. Five grams of the samples were soaked in 10 % acetic acid in ethanol for 45 h and filtered. The filtrate was concentrated and treated with ammonium hydroxide until complete precipitation occurred. The precipitate was washed, oven-dried, and weighed. Alkaloid content was expressed as a percentage of the dry sample. The phytate content was determined using the ferric chloride titration technique described by Latta and Eskin (1980). A 25 mL aliquot of the extract was treated with ammonium thiocyanate indicator and treated with standard $FeCl_3$ solution until a persistent yellow-brown color appeared. The phytate concentration was calculated using a conversion factor of 1.95 and expressed as mg/100 g. Oxalate was quantified using permanganate titration. One gram of the samples was digested with 0.5 N $H_2SO_4$, and the extract was heated to 60 °C. A 10 mL aliquot was treated with standardized 0.05 N $KMnO_4$ until a faint pink endpoint persisted for ≥ 30 s. The oxalate content was expressed using the factor (1 mL $KMnO_4$ = 2.24 mg oxalate).

The tannin content was determined volumetrically. Two grams of sample were boiled in distilled water, filtered, and made up to 500 mL. A 25 mL aliquot was titrated with 0.1N $KMnO_4$ until a stable colour change was observed. The results are expressed as mg/100 g. The total saponin content (expressed as percent yield) of the ginger and garlic flour samples was determined using the gravimetric method. One gram (1 g) of each sample was subjected to methanolic extraction (Harborne, 1998). The extracts were then macerated for 24 h. Following maceration, the extracts were partitioned by vigorous shaking with water and n-butanol (1:1 ratio) in a separation funnel and left to settle for 2 h. The upper n-butanol layer containing saponin was carefully separated. The solvent was then evaporated using a rotary evaporator to obtain a crude saponin extract. The crude saponin extract was then dried to a constant weight, and its weight was used to calculate the percentage yield of saponins (Brunner, 1984). Flavonoids were extracted using 80 % methanol. The combined extract was then filtered and evaporated to dryness. The residue obtained after drying at 60 °C was weighed, and the flavonoid concentration was calculated relative to the initial sample weight.

### Amino Acid Analysis

The amino acid composition was determined according to Moore *et al.* (1958). Samples (50-100 mg) were hydrolyzed with 6 M HCl containing 0.1 % phenol under nitrogen at 110 °C for 24 h. The hydrolysates were evaporated to dryness and reconstituted in citrate buffer. Sulphur containing amino acids (methionine and cysteine) were analyzed after performic acid oxidation, while tryptophan was determined separately using alkaline hydrolysis with NaOH. All amino acids were derivatized using PHTC and quantified by HPLC.

**Protein Quality Indices**

The predicted isoelectric point was calculated using the method described by Olaofe and Akintayo (2000) presented in equation (3);

$$pIm=\sum_{i=1}^{n=1} pIiXi \quad (3)$$

Where: pIm = isoelectric point of the amino acid mixture, pI*i* = isoelectric point of the $i^{th}$ amino acid in the mixture, Xi = mass or mole fraction of the amino acids in the mixture.

The amino acid score (AAS) was estimated using the FAO/WHO (1991) formula *in* equation (4);

$$AAS = \frac{\text{mg of amino acid in 1 g of test protein}}{\text{mg of amino acid in 1 g reference protein}} \times 100 \quad (4)$$

The Predicted Protein Efficiency Ratio (P–PER) of the samples was calculated from their amino acid composition based on Alsmeyer *et al*. (1974), stated in equation (5);

P–PER=–0.468+0.454 (Leucine) – 0.105 (Tyrosine) (5)

**Statistical Analysis**

All analyses were conducted in triplicate. The results are presented as mean ± standard deviation (SD). The coefficient of variation (CV%) was computed as (SD/mean) × 100.Differences between ginger and garlic were assessed using an independent samples Student's t-test at a significance level of 5%. Statistical operations were performed using Microsoft Excel 2019. Values of the samples that are statistically different ($p<0.05$) are indicated by superscript letter a, while those that are not statistically different ($p \geq 0.05$) are indicated by superscript letter b.

**RESULTS AND DISCUSSION**

The proximate compositions of the samples are shown in Table 1. All parameters differed significantly between ginger and garlic ($p<0.05$), reflecting the biochemical and anatomical differences between the two samples. The Table also shows that ginger flour had higher crude protein (15.21 %), crude fat (4.03 %), carbohydrate (63.29 %), and higher moisture (6.42 %) contents than garlic flour, while garlic is richer in ash (5.90 %) and crude fiber (20.22 %) than ginger. Carbohydrates are important components of metabolism, supplying the energy needed for respiration and other important processes in the body (Bligh & Dyer, 1959). In this study, ginger had carbohydrates as the most abundant macronutrient, which makes it a better source of energy than garlic. The calculated metabolizable energy further supports this, with ginger recording 1483.61 KJ/100 g compared to 1194.38 KJ/100 g for garlic. The protein content of both is relatively high, indicating that ginger and garlic can contribute to dietary protein intake. The values obtained in this study for ginger (15.21 %) and garlic (11.16 %) are higher than 8.17 % in ginger by Onyema *et al*. (2024) but conform well with 16.27 % reported by Gandhi and Saravanan (2018). The crude fat content is higher in ginger (4.03 %) than garlic (2.65 %) and this agrees with 4.98 % by Onyema *et al*. (2024).

Crude fiber in the diet is necessary for digestion and effective elimination of metabolic waste. It can lower serum cholesterol, the risk of coronary heart disease, hypertension, constipation, varicose veins, diabetes, phlebitis, obesity, breast cancer, rectal cancer, colon cancer, and even the threat of gastrointestinal disorders (Tosh & Yada, 2010). The fiber content is higher in garlic (20.22 %) than ginger (5.15 %) and greater than values obtained in the kernel (4.73 %) and pulp (6.57 %) of *I. gabonesis* (Alabi *et al*., 2024) and 1.62 % reported by Onyema *et al*. (2024). The higher crude fiber content measured in this study makes the spices a good source of dietary fiber. The moisture content was relatively low in both samples (ginger: 6.42 %; garlic: 5.52 %), which is desirable for flour stability and shelf life. The value in this study is within the range of 5.49 % (ginger) and 5.92 % (turmeric) as reported by Onyema *et al*. (2024), but lower than 8.4 % in the pulp of *I. gabonensis* reported by Akubor (2017). Low moisture content tends to make them less susceptible to microbial contamination. The ash content of 7.12% (garlic) and 5.90 % (ginger) values reported in this study agree with the 7.95 % reported for turmeric (Onyema *et al*., 2024). Ash content reflects the total amount of inorganic materials, such as minerals, in food. The results of this study showed a higher ash content in garlic than in ginger. Therefore, garlic is a good source of minerals needed to meet daily mineral requirements. Similarly, Musa *et al*. (2021) reported that garlic flour is a better source of dietary fiber and minerals, whereas ginger flour is superior in energy-yielding nutrients.

**Table 1: Proximate composition of ginger (*Zingiber officinale*) and garlic (*Allium sativum*)**

| Parameter % | Ginger | Garlic | Mean | SD | CV% |
|---|---|---|---|---|---|
| Crude protein | 15.21±0.13[a] | 11.16±0.28[a] | 13.18 | 2.86 | 21.71 |
| Crude fat | 4.03±0.04[a] | 2.65±0.02[a] | 3.34 | 0.98 | 29.22 |
| Ash | 5.90±0.06[a] | 7.12±0.07[a] | 6.51 | 0.86 | 13.25 |
| Crude fiber | 5.15±0.07[a] | 20.22±0.15[a] | 12.69 | 10.66 | 84.02 |
| Moisture | 6.42±0.13[a] | 5.52±0.06[a] | 5.97 | 0.64 | 10.66 |
| Carbohydrate | 63.29±0.15[a] | 53.33±0.31[a] | 58.31 | 7.04 | 12.08 |
| Fatty acid | 3.22±0.04[a] | 2.12±0.02[a] | 2.67 | 0.78 | 29.13 |
| Metabolizable energy (KJ/100 g) | 1483.61 | 1194.38 | 1338.99 | 204.52 | 15.27 |

Carbohydrate (%) = 100–(Moisture+Ash+Crude Fat+Crude Fiber); Calculated fatty acids=crude fat × 0.8; Metabolizable energy (kJ/100 g) = (Carbohydratex17)+(Fatx37); SD=Standard deviation; CV=Coefficient of Variation; n=3, a =significant difference between ginger and garlic ($p<0.05$); b = non-significant difference between the two samples ($p \geq 0.05$)

**Table 2: Phytochemical composition of ginger (*Zingiber officinale*) and garlic (*Allium sativum*)**

| Parameter | Ginger | Garlic | Mean | SD | CV% |
|---|---|---|---|---|---|
| Oxalate (%) | 5.06±0.07[a] | 7.64±0.04[a] | 6.35 | 1.82 | 28.73 |
| Saponins (%) | 0.44±0.02[a] | 0.12±0.03[a] | 0.28 | 0.23 | 80.81 |
| Alkaloids (%) | 7.45±0.00[a] | 10.43±0.17[a] | 8.94 | 2.11 | 23.57 |
| Flavonoids (%) | 9.39±0.03[b] | 8.62±0.42[b] | 9.01 | 0.54 | 6.05 |
| Tannis (mg/100g) | 160.38±0.04[a] | 170.33±0.75[a] | 165.36 | 7.04 | 4.25 |
| Cyanide (mg/100g) | 0.15±0.01[a] | 0.35±0.04[a] | 0.25 | 0.14 | 56.57 |
| Phytate (mg/100g) | 71.28±1.17[a] | 80.78±0.59[a] | 76.03 | 6.72 | 8.84 |
| Total phenol (%) | 0.85±0.03[a] | 1.43±0.01[a] | 1.14 | 0.41 | 45.96 |

SD = Standard Deviation; CV = Coefficient of Variation; n=3; a = significant difference between ginger and garlic ($p<0.05$); b= not significant difference between ginger and garlic ($p \geq 0.05$)

Table 2 presents the phytochemical compositions of the sample. Seven parameters differed significantly between the two samples, whereas flavonoid content showed no significant difference. As shown in Table 2, garlic had higher levels of oxalate, alkaloids, tannins, phytate, phenol, and cyanide, whereas ginger had higher levels of flavonoids and saponins. The oxalate content of 7.64 % (garlic) and 5.06 % (ginger) obtained in this study was higher than 2.03 and 0.59 % in the peel and pulp of *I. gabonesis, respectively*, as reported by Adeseko *et al*. (2022). Oxalate is known to interfere with calcium absorption and may contribute to kidney stone formation when consumed in high amounts. However, the levels recorded in both samples were within the range reported for edible plants (Alabi *et al*., 2024). The phytate levels of 71.28 and 80.78 mg/100 g in ginger and garlic, respectively, were lower than the 4.12 and 6.59 % in the peel and pulp of *I. gabonensis* reported by Adeseko *et al*. (2022). The lower phytate level in this study is desirable, as phytates reduce the bioavailability of minerals such as zinc, iron, copper, and manganese. However, they can suppress colon cancer, control dental cavities, and lower blood glucose levels at low concentrations (Effiong & Udo, 2010).

The tannin levels in ginger and garlic were 160.38 and 170.33 mg/100 g, respectively. The values in the current study were higher than the 149.6 mg/100 g reported for bush mango (Alabi *et al*., 2024) but lower than the 619 mg/100 g and 616 mg/100 g reported for the peel and pulp of *I. gabonesis* by Adeseko *et al*. (2022). Flavonoid levels of 9.39 and 8.62 % were present in ginger and garlic samples, respectively. The flavonoid contents in this study were higher than 0.373 and 0.433 % of the leaves and fruits of *N. latifolia* (Eze & Obinwa, 2014) and 3.15 % of the pulp of *I. gabonesis* (Adeseko *et al*., 2022). Flavonoids are super antioxidants and free radical scavengers that prevent oxidative cell damage caused by free radicals. The high flavonoid levels observed in this study imply that both ginger and garlic are good sources of dietary antioxidants. The alkaloid contents of 7.45 and 10.43 % for ginger and garlic, respectively, agree with 11.03 % reported in pineapple (Aremu *et al*., 2025). Alkaloids seem to be the most significant and efficient phytochemicals in terms of therapeutic use (Effiong & Udo, 2010). The two samples contained appreciable amounts of phenols (0.85 and 1.43 %) and very low levels of cyanide (0.15 and 0.35 mg/100 g), which makes them safe for human consumption.

The amino acid composition of the samples is shown in Table 3. From the Table, garlic shows a richer amino acid profile than ginger in this study. In Table 3, glutamic acid (Glu) was found to be the most highly concentrated non-essential amino acid in garlic (9.60 g/100 g cp) while aspartic acid is the most concentrated non-essential amino acid in ginger (2.55 g/100 g cp). Glutamic acid acts as fuel for the brain and helps to recover the body's physiological imbalances. It is also a good neurotransmitter and may help lower blood pressure levels (Omoyeni *et al*., 2015). The current study finds that glutamic and aspartic acids are the most abundant non-essential amino acids in the samples, which are in accordance with the observations of some researchers (Aremu *et al*., 2019; Aremu *et al*., 2024). Leucine constituted the highest single essential amino acid (EAA) in ginger (1.33 g/100 g cp) and garlic (8.39 g/100 g cp). The value in garlic is higher than the reported values of 4. 61, 5.02 and 5.60 g/100g cp inmango, pawpaw and pineapple fruit samples (Aremu *et al*., 2025). Leucine, with isoleucine and valine, plays very important roles in promoting muscle function, bones, and skin (Adeyeye & Afolabi, 2004).

Tryptophan is the least concentrated essential amino acid (EAA) in garlic (0.66 g/100 g cp) while valine (0.01 g/100 g cp) and methionine (0.01 g/100 g cp) are the least concentrated EAA in ginger (Table 3). The values in this study are close to those reported in mango (0.84 g/100 g cp) and pawpaw (0.92 g/100 g cp) by Aremu *et al*. (2025), while cysteine is the least concentrated non-essential amino acid in the ginger (0.05 g/100 g cp) and garlic (1.09 g/100 g cp) samples, respectively. Tryptophan helps maintain nitrogen stability and regulates appetite, sleep and mood, while cystine is used for the synthesis of protein and is also a precursor of pyruvate and taurine (Omoyeni *et al*., 2015). The calculated isoelectric points (pI) for ginger and garlic are 5.52 and 5.60, respectively. This is useful in predicting the pI for a protein to enhance the quick precipitation of protein isolates from biological samples (Bouba *et al*., 2016). The isoelectric points from the current study are lower than 6.09 and 6.83 in some fruits as reported by Aremu *et al.* (2025) but higher than 3.52 in *M. charania* fruits and 4.05 in pulp of *D. mespiliformis* (Aremu *et al*., 2019).

The predicted protein efficiency ratio (P–PER) is one of the quality parameters used for protein evaluation (FAO/WHO, 1991). The P–PER values are 0.44 and 2.96 for ginger and garlic, respectively. The P–PER value of garlic in this study is greater than 1.83 (mango), 1.67 (pawpaw) and 1.80 (pineapple) reported by Aremu *et al*. (2025). The Leu/Ile ratios in this study are 44.33 and 2.04 in ginger and garlic, respectively. These values are greater than those reported by some authors (Aremu *et al*., 2025; Alabi *et al*., 2024). The Leu/Ile ratio is exceptionally higher in ginger than garlic which implies that there is leucine dominance in the former which may interfere with the utilization of isoleucine and thus, reduce the overall protein quality of the sample.

**Table 3: Amino acid composition (g/100g crude protein) of ginger (*Zingiber officinale*) and garlic (*Allium sativum*)**

| Parameter | Ginger | Garlic | Mean | SD | CV% |
|---|---|---|---|---|---|
| Leucine (Leu)* | 1.33 | 8.39 | 4.86 | 4.99 | 102.67 |
| Lysine (Lys)* | 0.03 | 3.81 | 1.92 | 2.67 | 139.06 |
| Isoleucine (Ile)* | 0.03 | 4.12 | 2.08 | 2.89 | 138.84 |
| Phenylalanine (Phe)* | 0.24 | 3.81 | 2.01 | 2.52 | 125.37 |
| Tryptophan (Try)* | 0.03 | 0.66 | 0.35 | 0.45 | 127.29 |
| Valine (Val)* | 0.01 | 3.88 | 1.95 | 2.74 | 140.51 |
| Methionine (Met)* | 0.01 | 1.09 | 0.55 | 0.77 | 140.00 |
| Proline (Pro)* | 0.44 | 3.65 | 2.05 | 2.27 | 110.73 |
| Arginine (Arg) | 0.62 | 5.41 | 3.02 | 3.39 | 112.25 |
| Tyrosine (Tyr) | 0.17 | 3.61 | 1.89 | 2.43 | 128.57 |
| Histidine (His)* | 0.06 | 2.20 | 1.13 | 1.51 | 133.63 |
| Cystine (Cys) | 0.05 | 1.09 | 0.57 | 0.74 | 129.82 |
| Alanine (Ala) | 0.23 | 3.79 | 2.01 | 2.52 | 125.37 |
| Glutamic acid (Glu) | 1.77 | 9.60 | 5.69 | 5.54 | 97.36 |
| Glycine (Gly) | 0.08 | 3.16 | 1.62 | 2.18 | 134.57 |
| Threonine (Thr)* | 0.03 | 2.97 | 1.50 | 2.08 | 138.67 |
| Serine (Ser) | 0.05 | 3.40 | 1.73 | 2.37 | 136.99 |
| Aspartic acid (Asp) | 2.55 | 7.59 | 5.07 | 3.56 | 70.22 |
| P-PER | 0.44 | 2.96 | 1.70 | 1.78 | 104.70 |
| Leu/Ile | 44.33 | 2.04 | 23.19 | 29.90 | 128.93 |
| pI | 5.52 | 5.60 | 5.53 | 0.06 | 1.08 |

P-PER = Predicted Protein Efficiency Ratio; pI = Isoelectric Point; (*) = essential amino acid; n=3

**Table 4: Concentration of essential, non-essential, neutral, sulphur, aromatic amino acids (g/100g crude protein) of ginger (*Zingiber officinale*) and garlic (*Allium sativum*)**

| Amino Acid Description | Ginger | Garlic | Mean | SD | CV% |
|---|---|---|---|---|---|
| TAA | 7.73 | 72.23 | 39.98 | 45.61 | 114.08 |
| TNEAA | 5.52 | 37.65 | 21.59 | 22.72 | 105.26 |
| % TNEAA | 71.41 | 52.13 | 61.77 | 13.63 | 22.07 |
| TEAA with histidine | 2.21 | 34.58 | 18.40 | 22.89 | 124.43 |
| TEAA without histidine | 2.15 | 28.73 | 15.44 | 18.79 | 121.73 |
| % TEAA with histidine | 28.59 | 47.87 | 38.23 | 13.63 | 35.66 |
| % TEAA without histidine | 27.81 | 39.78 | 33.80 | 8.46 | 25.05 |
| EAAA | 1.37 | 19.36 | 10.37 | 12.72 | 122.73 |
| EArAA | 0.27 | 6.67 | 3.47 | 4.53 | 130.42 |
| TNAA | 2.70 | 43.62 | 23.16 | 28.93 | 124.93 |
| % TNAA | 34.93 | 60.39 | 47.66 | 18.00 | 37.77 |
| TAAA | 4.32 | 17.19 | 10.76 | 9.10 | 84.62 |
| % TAAA | 55.89 | 23.80 | 39.85 | 22.69 | 56.95 |
| TBAA | 0.71 | 11.42 | 6.07 | 7.57 | 124.87 |
| % Basic (TBAA) | 9.18 | 15.81 | 12.50 | 4.69 | 37.52 |
| TSAA | 0.06 | 2.18 | 1.12 | 1.50 | 133.85 |
| % cystine in TSAA | 83.33 | 50.00 | 66.67 | 23.57 | 35.35 |

SD = Standard Deviation; CV = Coefficient of Variation; TAA = Total Amino Acid; TNEAA = Total Non-Essential Amino Acid; TEAA = Total Essential Amino Acid; EAAA = Essential Aliphatic Amino Acid; EArAA = Essential Aromatic Amino Acid; TNAA = Total Neutral Amino Acid; TAAA = Total Acidic Amino Acid; TBAA = Total Basic Amino Acid; TSAA = Total Sulphur Amino Acid

The concentration of essential, non-essential, neutral, sulphur, aromatic amino acids (g/100 g Crude Protein) of ginger and garlic flour are shown in Table 4.The Table reveals a higher level of total amino acid (TAA) of 72.23 g/100 g cp in garlic than ginger (7.73 g/100 g cp). The percentage TEAA contents with His were 28.59 and 47.87 g/100 g cp for ginger and garlic, respectively. The value in garlic is greater than the 39 % considered to be adequate for ideal protein food for infants, 26 % for children and 11% for adults (FAO/WHO/UNU, 1985) but lower than the reported value of 50 % in egg (FAO/WHO, 1991). Histidine is important for the synthesis of red and white blood cells. It is a precursor for histamine, which is good for sexual arousal and improved blood flow (Kubmarawa e*t al*., 2009). The concentrations of total sulphur amino acids (TSAA) were 0.06 (ginger) and 2.18 (garlic) g/100 g cp, respectively. The value in garlic is close to the values of 3.82, 3.15, and 2.17 g/100 g cp in mango, pawpaw and pineapple, respectively (Aremu *et al*., 2025) but are lower than the 5.8 g/100 g cp recommended for infants (FAO/WHO/UNU, 1985). The % cystine in TSAA is 83.33and 50.00 % for ginger and garlic, respectively. The values in this study are greater than 17.14 and 21.19 % reported for pawpaw and pineapple (Aremu *et al*., 2025). The essential aromatic acids (EArAA) values of 0.27 (ginger) and 6.67 (garlic) g/100 g cp are lower than the ideal range suggested for infant protein (6.8 – 11.8 g/100 g cp) (FAO/WHO/UNU, 1985). The observed values of essential aliphatic amino acid (EAAA) in the ginger and garlic constitute 1.39 and 19. 36 g/100 g cp, respectively. The total acidic amino acids (TAAAs) of 4.32 and 17.17 g/100 g cp in ginger and garlic, respectively, are greater than the total basic amino acids (TBAAs) of 0.71 (ginger) and 11.42 (garlic) g/100 g cp, indicating that these spices are probably acidic (Aremu *et al*., 2025). This study reveals that the samples contained appreciable amounts of essential as well as non-essential amino acids needed in the diet. However, the concentrations are higher in garlic than in ginger.

**Table 5: Amino acid scores of ginger (*Zingiber officinale*) and garlic (*Allium sativum*)**

| EAA | PAAESP (g/100 Protein) | Ginger | | Garlic | |
|---|---|---|---|---|---|
| | | EAAC | AAS | EAAC | AAS |
| Ile | 4.0 | 0.03 | 0.008 | 4.12 | 1.03 |
| Leu | 7.0 | 1.33 | 0.01 | 8.39 | 1.20 |
| Lys | 5.5 | 0.03 | 0.01 | 3.91 | 0.69 |
| Met + Cys | 3.5 | 0.06 | 0.02 | 2.18 | 0.62 |
| Phe + Tyr | 6.0 | 0.41 | 0.07 | 7.42 | 1.24 |
| Thr | 4.0 | 0.03 | 0.01 | 2.97 | 0.74 |
| Try | 1.0 | 0.03 | 0.03 | 0.66 | 0.66 |
| Val | 5.0 | 0.01 | 0.002 | 3.88 | 0.78 |
| Total | 36 | 1.93 | 0.16 | 33.43 | 6.96 |

**Source:** FAO/WHO (1991)

EAA = Essential Amino Acids; PAAESP = Provisional Amino Acids Scoring Pattern (egg); EAAC = Essential Amino Acid Composition; AAS = Amino Acids Score

Results of EAA based on the provisional amino acid scoring pattern standard (FAO/WHO, 1991) are shown in Table 5. As seen in the table, all the amino acid scores for ginger are less than 1. Thus, the dietary formula based on ginger should be fortified with essential amino acids. Garlic on the other hand, had values greater than 1 for Ile (1.03), Leu (1.20) and Phe+Tyr (1.24) while other EAA had values less than 1 and may require supplementation based on the provisional amino acid scoring pattern. It has been reported that some amino acids including Met (and Cys), Lys, and Try are considered as limiting amino acids, so that they are in the shortest supply among the others in the ingested protein (FAO/WHO/UNU, 1985). In this study, Met+Cys (0.62) was the limiting source in garlic, while val (0.002) was the limiting amino acid in ginger.

## CONCLUSION

The study examines statistically validated characterization of the proximate, phytochemical and amino acid composition of ginger and garlic flour sourced from Kaduna Sate, Nigeria. All proximate parameters and majority of phytochemicals constituents differed statistically between the two species ($p < 0.05$), reflecting the compositional and anatomical distinctiveness of the two spices. The higher carbohydrates composition of ginger shows its superior energy boosting capacity while garlic has higher crude fiber and mineral (ash) contents, showing its superior role as a prebiotic and mineral-rich condiment. The phytochemical profiles of the two spices suggest significant antioxidants and functional food potential of the two spices. Garlic has higher amino acid composition than ginger. These findings underscore the unique nutritional profiles of ginger and garlic flour, highlighting ginger's potential as an energy-rich food source and garlic's richness in essential amino acids. The study recommends incorporation of spices from Kaduna state into food fortification programmes for boosting fibre, mineral and amino acid intake in semi-arid communities.

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