

## Nutritional and Antinutritional Properties of Raw, Fermented, and Germinated Yellow Maize (*Zea mays* L.)

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### Abstract

This study evaluated nutritional and anti-nutritional qualities of raw (RM), fermented (FM), and germinated (GM) yellow maize (*Zea mays* L.) using traditional home methods. All analyses were performed according to standard procedures. Proximate analysis revealed that germination increased the fiber (10.19 g/100 g) and fat contents, whereas fermentation increased the crude protein (13.56 g/100 g) and carbohydrate (74.03 g/100 g) contents. Antinutrients varied with processing: total phenols decreased from 0.50 % in raw maize (RM) to 0.05 % in germinated maize (GM); phytate ranged from 289.87 to 450.56 mg/100 g; alkaloids ranged from 7.28 to 12.48 %; and tannins ranged from 5.39 to 9.17 mg/100 g. The total amino acid content was 82.18 (RM), 79.79 (FM), and 82.33 (GM) g/100 g of crude protein, with valine being the first-limiting amino acid. Germination improved protein quality, whereas fermentation reduced the presence of certain anti-nutrients and protein content. These findings demonstrate that both methods can enhance the nutritional value of maize, thereby supporting the development of an improved maize-based diet.

**Keywords:** Amino acid profile, Anti-nutritional factors, Fermentation, Germination, Yellow maize

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### Introduction

Maize (*Zea mays* L.) is one of the most widely grown grains in Nigeria, serving as an important source of starch, and is cultivated extensively worldwide. It accounts for about 40 % of the total cereals produced across sub-Saharan Africa, Asia, and Latin America [1, 2]. Approximately 9,000 years ago, maize was first cultivated by indigenous people of southern Mexico, who gradually domesticated it from a wild grass called teosinte and began growing it as a reliable food crop that later spread to many regions around the world [3, 4]. Following European contact with the Americas in the 15<sup>th</sup> and 16<sup>th</sup> centuries, maize spread quickly worldwide and was introduced to Europe, Asia, and Africa [5, 6].

Maize plays a vital role in the production of bioethanol, pharmaceuticals, and animal feed [7]. It can be prepared as roasted maize, flour-based dishes, or fermented products. Dent, Flint, sweet corn, and popcorn are the major commercially important maize varieties [8]. Kernels contain various phytochemicals as part of their

nutritional profile, including phytosterols, carotenoids, and phenolic compounds [9]. It is rich in carbohydrates, fibers, and micronutrients such as B vitamins and carotenoids [10]. Fig. 1 shows a yellow maize plant with its different parts clearly labeled, including the roots, stem, leaves, tassel, silks, and ear, illustrating how each part contributes to the plant's growth and reproduction. Every part of the maize plant holds significant value and can be used to produce a wide variety of food and non-food products [11]. It also contains essential minerals like copper, phosphorus, zinc, and magnesium. Potassium, the most abundant mineral in maize, is important in the human diet [12].

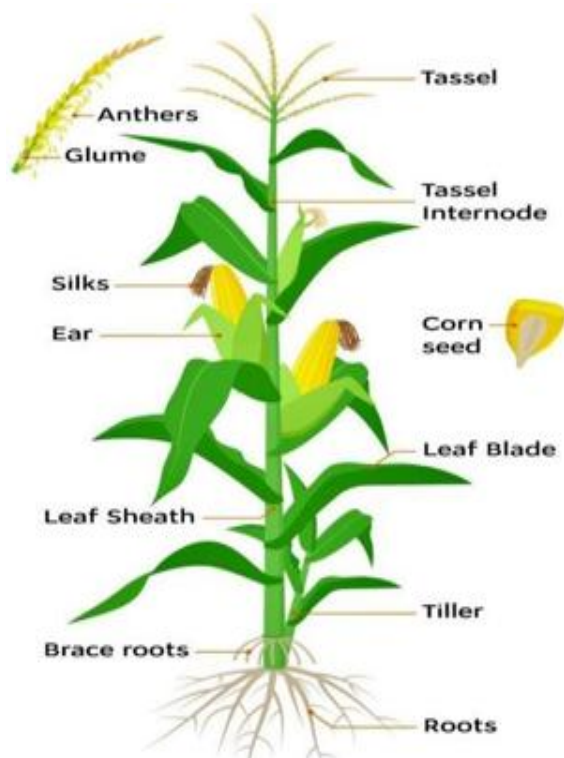


Figure 1: Image of a yellow maize (*Zea mays* L.)

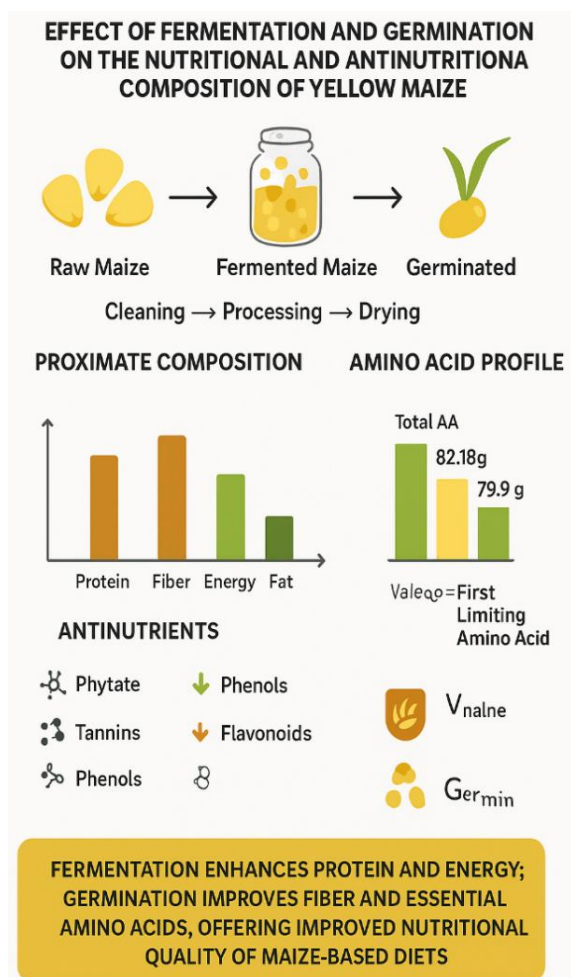


Figure 2: Image of the processing effects

Figure 2 shows how processing yellow maize through fermentation and germination improves its nutritional quality by increasing protein, energy, fiber, and essential amino acids, while reducing harmful antinutrients. Like many other cereals, maize contains antinutrients: oxalates, phytic acid, trypsin inhibitors,  $\alpha$ -amylase inhibitors, and saponins, which reduce its nutritional value, the bioavailability of minerals, and digestibility [13]. This hampers nutrient absorption and utilization [9, 14]. Excessive intake of raw or inadequately processed maize-based diets can lead to malnutrition and health-related issues, such as anemia and weakened immunity [15]. Germination and fermentation are conventional processing methods frequently used to overcome the nutritional limitations of grains intended for human consumption [16]. Processing agricultural products remains the most vital aspect of food and nutrition security in the modern world. It helps degrade complex compounds, reduce antinutrient content, and enhance the bioavailability of essential nutrients [16].

Fermentation is an economical and simple approach to enhancing the nutritional quality of maize-based foods by reducing their anti-nutritional factors (ANFs). It is a biochemical modification of the primary food matrix caused by microorganisms and their enzymes [17]. White and yellow maize varieties can be used to produce a fermented popular semisolid food called Pap, and [18] reported that traditional pap or “ogi” fermentation may improve protein and amino acid yields. Pap is a low-cost, easily obtainable fermented food that contributes to good health across Africa [18]. Germination is a biological process [19]. Research has shown that germinated cereals and legumes contain higher volumes of amino acids and other nutritional and functional components, which contribute to overall health and help manage metabolic disorders [20]. Sprouted grains contain polyphenols that help the body defend against oxidative stress and provide antioxidant protection against various chronic diseases [21]. Despite the known benefits of fermentation and germination, there is limited comparative research on how these processes affect the antinutrient and food properties of yellow maize. This study aimed to assess the effects of both methods on the nutritional quality of yellow maize.

### Materials and Methods

#### Sample collection and preparation

The yellow maize grains that were used in this research were obtained at the Lafia Market in Nasarawa State, Nigeria. The grains were also handpicked to eliminate damaged and undesired materials. The purified maize samples were further subdivided into three portions, which were based on varied processing methods, namely, raw maize (RM), fermented maize (FM), and germinated maize (GM). In the case of the raw sample (RM), the grains were fully washed using clean water to take away all the surface impurities, dried in the open atmosphere conditions in the laboratory, and milled into flour. The flour was put in airtight containers, and



further lab analysis was done. The sample of fermented maize (FM) had been made by wetting the grains in potable water at room temperature for 72 h. The soaking water was changed every 24 h to lessen microbial spoilage and simulate domestic activities. The grains were washed with clean water after fermentation, and dried in a hot-air oven at 60 °C. The grains were dried and milled afterwards and sieved to give the resultant flour. In the case of the germinated maize sample (GM), the grains were initially moistened in water within 24 h so as to commence the process of hydration. The moist jute sacks were used to place the soaked grains, which were then left to sprout for a period of 72 h. Once sown, the grains were dehulled by hand to remove rootlets and outshells, dried in the oven at 60 °C, ground, and then strained out to make fine flour.

The processing procedures that were employed in this research were aimed to be similar to the normal household preparation procedures, but at the same time, control over the conditions of the process was kept to avoid sample contamination.

#### Proximate composition

Protein content was measured using the Kjeldahl method ( $N \times 6.25$ ). Moisture, fat, and ash contents determination was carried out using methods 934.01, 996.06, and 923.03 of the Association of Official Analytical Chemists (AOAC) [22].

#### Anti-nutrient content determination

Methods described by the AOAC [22], as well as Paul *et al.* [23], were used to determine the concentrations of oxalate, saponins, alkaloids, flavonoids, tannins, cyanide, phytate, and total phenols.

#### Amino acid analysis

Ion Exchange Chromatography (IEC), as described by Aremu *et al.* [24, 25] was used to analyze amino acids. Each sample was analyzed for 76 min at a gas flow rate of 0.50 mL min<sup>-1</sup> and a temperature of 60 °C, with reproducibility within  $\pm 3$  %. The net height of each peak recorded by the TSM, corresponding to individual amino acids, was measured and calculated. Amino acid content represents the average of two determinations, with nor-leucine used as the internal standard. Tryptophan was quantified separately following alkali (NaOH) hydrolysis using a colorimetric assay.

#### Determination of quality of dietary protein and predicted protein efficiency ratio (P-PER)

Protein quality was determined by relating the available amino acids in the sample to established nutritional demands. Amino acid score (AAS) was then estimated according to equation 1 [26];

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

P-PER of the samples was calculated by their amino acid composition according to Equation-2 [27] as follows:

$$P\text{-PER} = -0.468 + 0.454 (\text{Leucine}) - 0.105 (\text{Tyrrosine}) \dots (2)$$

#### Statistical analysis

Analyses were conducted in triplicate, and findings are given as mean  $\pm$  standard deviation. Mean values, standard deviations, and coefficients of variation were calculated using Microsoft Excel software.

### Results and Discussion

The proximate compositions of raw (RM), fermented (FM), and germinated yellow maize (GM) (*Zea mays* L.) are presented in Table 1. There were significant differences among the accessions for all proximate parameters. The crude protein content ranged from  $8.06 \pm 0.05$  g/100 g dw (GM),  $12.56 \pm 0.08$  g/100 g dw (RM), and  $13.56 \pm 0.08$  g/100 g dw (FM). These results align with those of Adejumo *et al.* [28]. The moisture level in corn seeds is an important measure of seed quality and is essential in grain testing [18]. The FM (4.41 %) had a lower moisture content than the three samples reported by Akinsola *et al.* [8], but the RM (6.61 %) was close to the control value (6.73 %) reported by Akinsola *et al.* [8]. The untreated state contributes to a high moisture content, which significantly affects seed storage and shelf life [28]. GM had the highest fat content ( $2.76 \pm 0.04$  g/100 g dw), whereas FM had the lowest ( $1.93 \pm 0.04$  g/100 g). The carbohydrate content varied from  $71.99 \pm 0.33$  g/100 g dw (GM),  $73.58 \pm 0.04$  g/100 g dw (RM), to  $74.03 \pm 0.26$  g/100 g dw (FM). These differences indicate that the carbohydrate content and storage stability of maize are affected by processing methods [29, 30]. The fatty acid content ranged from 1.54% (FM) to 2.21 % (GM). Germination can increase the total lipid yield in grains, as demonstrated by the high values recorded in previous studies [31]. This increase may be attributed to the production of lipids associated with seed growth and the subsequent structural changes that occur after the breakdown of other chemical constituents [32, 33].

Enzymes of microbial and endogenous type are actively involved in the degradation and remodeling of macromolecules. More specifically, the process of fermentation by microorganisms is known to process lipids as a component of energy-producing processes, thus modifying the composition of the substrate [34, 35]. These biochemical activities, alongside the changes in carbohydrate and protein fractions, are implicated by the recorded changes in energy value among the processed samples. FM had the highest energy content (1560.44 kJ/100 g), then the RM at 1543.56 kJ/100 g, and the lowest level was 1462.97 kJ/100 g in GM. The relatively low energy levels of the germinated sample could be explained by the use of the stored reserves during the sprouting process. Carbohydrates and lipids are mobilized to promote embryonic growth. The ash content, giving an index of total mineral matter, had only significant differences between the treatments. RM was the highest at 2.10 per cent, then GM (1.94 per cent) and finally FM (1.89 per cent). The slight change that is found upon the processing and especially during



the germination process may be linked to the loss of minerals through the process of leaching of the minerals in the soaking and steeping processes. These results correspond to the report by Chauhan *et al.* [12], who found that the ash content of blue maize decreased during the 72 h germination period, with a reduction in the content of the raw maize of 2.23 percent to a range of 1.90 percent. Similarly, Agblemanyo and Abrokwah

[36] recorded a relatively low ash content (1.64 %) in the fermented yellow maize, which further supports the fact of variability that can be attributed to genotype and processing environments. Anti-nutritional factors, whether naturally occurring or synthetic, can hinder nutrient absorption, impair digestion and utilization, and lead to negative effects [36].

**Table 1: Proximate composition (%) of raw, fermented, and germinated yellow maize (*Zea mays* L.)**

Parameters (%)	Raw yellow Maize (RM)	Fermented yellow maize (FM)	Germinated yellow maize (GM)	Mean	SD	CV%
Crude Protein	12.56 ± 0.08	13.56 ± 0.08	8.06 ± 0.05	11.39	2.93	25.72
Fat	2.14 ± 0.06	1.93 ± 0.04	2.76 ± 0.04	2.28	0.43	18.95
Ash	2.10 ± 0.06	1.89 ± 0.01	1.94 ± 0.01	1.98	0.11	5.56
Crude Fibre	3.03 ± 0.04	4.20 ± 0.13	10.19 ± 0.18	5.81	3.84	66.08
Moisture	6.61 ± 0.08	4.41 ± 0.07	5.24 ± 0.07	5.42	1.11	20.48
Carbohydrate	73.58 ± 0.04	74.03 ± 0.26	71.99 ± 0.33	73.20	1.07	1.46
Fatty Acids	1.71 ± 0.06	1.54 ± 0.04	2.21 ± 0.04	1.82	0.35	19.10
Energy (kg/100 g)	1543.56 ± 4.31	1560.44 ± 4.46	1462.97 ± 3.38	1522.32	5.09	3.42

All values are expressed as mean standard deviation of three determinations on a dry weight basis  
SD = Standard Deviation; CV = Coefficient of Variance

**Table 2: Antinutritional factors of raw, fermented, and germinated yellow maize (*Zea mays* L.)**

Parameter	Raw yellow maize (RM)	Fermented yellow maize (FM)	Germinated yellow maize (GM)	mean	SD	CV (%)
Oxalate (%)	1.32 ± 0.01	0.36 ± 0.01	1.77 ± 0.02	1.15	0.72	62.52
Saponins (%)	0.33 ± 0.02	0.20 ± 0.00	0.39 ± 0.01	0.31	0.10	31.63
Alkaloids (%)	7.28 ± 0.08	12.48 ± 0.03	9.68 ± 0.03	9.81	2.60	26.50
Flavonoids (%)	5.59 ± 0.20	10.39 ± 0.09	8.66 ± 0.16	8.21	2.43	29.60
Tannins (mg/100 g)	8.38 ± 0.09	5.39 ± 0.04	9.17 ± 0.25	7.65	1.99	26.01
Cyanide (mg/100 g)	0.79 ± 0.02	0.04 ± 0.01	0.18 ± 0.01	0.34	0.40	117.65
Phytate (mg/100 g)	289.87 ± 0.80	450.56 ± 0.63	350.35 ± 0.21	363.59	81.17	22.32
Total Phenol (%)	0.50 ± 0.01	0.14 ± 0.03	0.05 ± 0.00	0.08	0.05	65.00

SD = Standard Deviation; CV = Coefficient of Variance

Table 2 presents the anti-nutritional factors of raw, fermented, and germinated yellow maize (*Zea mays* L.). The composition of anti-nutrients varied significantly among the accessions. Phytate recorded the highest concentration across the three samples, ranging from 289.87 ± 0.80, 350.35 ± 0.21, and 450.56 ± 63 (mg/100 g) for the raw, germinated, and fermented maize samples, respectively. Grains store phosphorus as phytic acid. Its presence may influence the bioavailability of minerals and the solubility, functionality, and digestibility of proteins and carbohydrates [36, 37]. Phytic acid is most concentrated in the bran of grains [37]. The higher phytate content in fermented maize results from dry matter loss during microbial activity [12]. The phytate content of the three accessions was much lower than that reported for white and yellow corn by Marfo *et al.* [38] and much lower than that reported by Sokrab *et al.* [39] for 2 d of germination of the sample maize used, but within the range of values after the third day of germination. Fermented maize recorded the highest alkaloid (12.48

%) and flavonoid (10.39 %) content, followed by germinated maize (9.68 and 8.66 %, respectively), and raw maize with the lowest values (7.28 and 5.59 %, respectively). Saponins were among the lowest anti-nutritional components recorded in the three accessions. Values ranged from 0.20 ± 0.00, 33 ± 0.02, and 39 ± 0.01 percent. At high levels, saponins are toxic and can interfere with nutrient uptake by enzyme inhibition and nutrient binding, such as with zinc. However, in the presence of cholesterol, they demonstrate potent cholesterol-lowering effects [40]. They can also lead to hypoglycemia, impair protein digestion, vitamin and mineral uptake in the gut, and the development of a leaky gut [41]. The lower values recorded for the total phenol content are a result of the reduction in phenolic compounds during germination, and the value of fermented maize is attributed to enzymatic degradation and metabolism, which break down phenolics as substrates for growth and energy [15]. Table 3 shows significant differences in amino acid content among the three samples. The most abundant



amino acid in the samples was glutamic acid, with 15.36 (FM), 13.02 (GM), and 12.34 (RM) g/100 g, followed by leucine, with 12.61 (GM), 10.42 (RM), and 2.39 (FM) g/100 g. Tryptophan was the least prevalent amino acid across the three accessions, with concentrations of 0.63 g/100 g (GM), 0.74 g/100 g (FM), and 1.05 g/100 g (RM). Tryptophan is involved in melatonin synthesis, often called the ‘sleep hormone.’ Its impact on the human body is significant [42]. Wyatt *et al.* conducted a study in which volunteers with insomnia received a tryptophan supplement before bed for 10 consecutive nights [43]. Compared to placebo, these individuals experienced longer sleep duration and felt more refreshed in the morning. In one of the studies by Smith *et al.* [44] reported that bipolar patients who received supplementation with this amino acid had fewer relapses, whereas women on a tryptophan-deficient diet showed a notable rise in depressive symptoms. The decline in value of germinated corn is due to its use during seedling growth, while microbial metabolism is responsible for the lower value of fermented corn [12]. The processing of cereals is a known factor that significantly affects the amino acid profile; fermentation often reduces specific essential amino acids, depending on the duration and microbial activity [12, 16].

These results align with the FAO data summary [11], which also reports relatively higher leucine values than those of other essential amino acids. Similarly, Victor and Ogumba [45] reported leucine as the most abundant essential amino acid, with values ranging from 7.13–

7.44 g/100 g of crude protein. Egbedike *et al.* [46] reported a similar value for leucine, 7.26 to 7.55 g/100 g crude protein, as the highest essential amino acid. Even though leucine values found in the present paper are less than those of GM in certain past studies, the general trend is the same, as leucine is predominant among essential amino acids in maize, as has been established. Aspartic acid was second only to glutamic acid in the samples analyzed of the non-essential amino acids. The values obtained were 5.92 g/100 g crude protein in FM, 6.27 g/100 g crude protein in GM, and 8.84 g/100 g crude protein in RM. The amino acids in non-treated grains are largely in their native form, which could be the reason why the amount of aspartic acid was rather high. Lysine is an essential amino acid commonly thought to be limiting in cereal-based diets and plays a very important role in human nutrition. It participates in protein synthesis, helps to maintain the immune system, and promotes calcium absorption by helping to increase the effect of vitamin D, thus benefiting bone and dental health. The RM, FM, and GM contained 4.14, 3.74, and 3.45 g/100 g lysine, respectively. Research indicates that lysine can influence behavioral functions. A study conducted in Japan by Smriga *et al.* [47] offered the women 2.64 g of lysine daily for one week and assessed their behavior prior to the treatment and after the treatment. The findings indicated that there was a great decrease in anxiety and reduced levels of stress hormones, which implies that a deficiency encourages negative moods.

**Table 3: Amino acid profile of raw, fermented, and germinated yellow maize (*Zea mays* L.)**

Parameters	Raw yellow maize (RM)	Fermented yellow maize (FM)	Germinated yellow maize (GM)	Mean	SD	C V (%)
Leucine*	10.42	2.39	12.61	8.47	5.38	63.52
Lysine*	4.14	3.74	3.45	3.78	0.35	9.26
Isoleucine*	3.27	3.50	3.21	3.33	0.15	4.59
Phenylalanine*	4.52	4.88	4.52	4.64	0.21	4.48
Tryptophan*	1.05	0.74	0.63	0.81	0.22	26.91
Valine*	3.80	4.30	3.89	4.00	0.27	6.75
Methionine*	1.23	1.42	1.31	1.32	0.10	7.20
Proline*	4.16	7.31	6.09	5.85	1.59	27.18
Arginine	6.19	5.33	4.73	5.42	0.73	13.54
Tyrosine	3.44	3.61	3.27	3.44	0.17	4.94
Histidine*	2.36	3.32	2.81	2.83	0.48	16.96
Cystine	1.27	1.57	1.27	1.37	0.17	12.63
Alanine	4.09	5.16	4.82	4.69	0.55	11.67
Glutamic acid	12.34	15.36	13.02	13.57	1.58	11.65
Glycine	3.42	3.51	3.16	3.36	0.18	5.42
Threonine*	4.02	3.44	3.11	3.52	0.46	13.07
Serine	3.62	4.29	4.16	4.02	0.36	8.96
Aspartic acid	8.84	5.92	6.27	7.01	1.59	22.68
P-PER	3.90	0.24	4.91	3.02	2.46	81.46
Leucine/Isoleucine	3.19	0.68	3.93	2.60	1.70	65.38
pIm	4.81	4.53	4.78	4.71	0.15	3.18

\* = Essential amino acid



**Table 4: Concentration of essential, non-essential, acidic, neutral, sulphur, aromatic etc. of raw, fermented, and germinated yellow maize (*Zea mays* L.)**

Parameter	Raw yellow maize (RM)	Fermented yellow maize (FM)	Germinated yellow maize (GM)	Mean	SD	CV (%)
TAA	82.18	79.79	82.33	81.43	1.43	1.75
TNEAA	43.21	44.75	40.70	42.89	2.05	4.77
% TNEAA	52.58	56.68	49.44	52.70	3.32	6.30
TEAA with Histidine	38.97	35.04	41.63	38.55	3.32	8.61
TEAA without Histidine	36.31	31.72	38.82	35.72	3.63	10.16
% TEAA with Histidine	47.42	43.92	50.56	47.30	3.32	7.02
% TEAA without Histidine	44.55	39.75	47.15	43.82	3.75	8.56
EAAA	21.51	13.63	22.82	19.32	4.97	25.93
EArAA	4.52	4.88	4.52	4.64	0.21	4.48
TNAA	48.31	46.12	52.05	48.83	3.00	6.14
% TNAA	58.79	57.80	63.22	59.94	2.89	4.81
TAAA	21.18	21.28	19.29	20.58	1.12	5.45
% TAAA	25.77	26.67	23.43	25.29	1.67	6.61
TBAA	12.69	12.39	10.99	12.02	0.91	7.55
TSAA	2.50	2.99	2.58	2.69	0.26	9.78
% Cystine in TSAA	50.80	52.51	49.22	50.84	1.65	3.24

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, TAA – Total Amino Acid, TNEAA- Total Non-Essential Amino Acid, TEAA-Total Essential Amino Acid

Table 4 presents the different amino acid classes identified in the RM, FM, and GM samples. The Total Amino Acid (TAA) values were 82.18 (RM), 79.79 (FM), and 82.33 (GM). No significant differences ( $P > 0.05$ ) were observed in the following classes of amino acids identified in raw, fermented, and germinated yellow maize: TAA, TNEAA, EArAA, %TNAA, TAAA, %TAAA, TBAA, TSAA, and %Cystine in TSAA. A significant difference ( $p < 0.05$ ) was observed in the following parameters: %TNEAA, TEAA (with and without histidine), %TEAA (with and without histidine), EAAA, and TNAA. The slight increase in TAA in GM is attributed to the activation of proteolytic enzymes during germination, which break down storage proteins into free amino acids [48]. The FM reflects the utilization of amino acids as nitrogen

sources, which can lead to partial reduction during fermentation [49].

Table 5 presents the essential amino acid (EAA) scores of the maize samples calculated using the FAO/WHO provisional amino acid scoring pattern [50]. The amino acid scoring pattern observed in this study suggests that fortification with selected essential amino acids would be necessary to achieve a more balanced protein profile. Specifically, isoleucine (Ile), lysine (Lys), the sulphur bearing amino acids (methionine + cysteine; Met + Cys), as well as valine (Val) were constantly lower than the requirements in the processed and unprocessed samples. This implies that regardless of the mode of treatment, these amino acids are important limitations to the entire protein quality.

**Table 5: Amino acid scores of raw, fermented, and germinated yellow maize (*Zea mays* L.)**

EAA	PAAESP (g/100 g) Protein	Raw yellow maize (RM)		Fermented yellow maize (FM)		Germinated yellow maize (GM)	
		EAAC	EAAS	EAAC	EAAS	EAAC	EAAS
Isoleucine	4.0	3.27	0.82	3.50	0.88	3.21	0.80
Leucine	7.0	10.42	1.49	2.39	0.34	12.61	1.80
Lysine	5.0	4.14	0.83	3.74	0.75	3.45	0.69
Methionine + Cystine(TSAA)	3.5	2.50	0.71	2.99	0.85	2.58	0.74
Phenylalanine + Tyrosine	6.0	7.96	1.33	8.49	1.42	7.79	1.30
Threonine	4.0	4.02	1.01	3.44	0.86	3.11	0.78
Tryptophan	1.0	1.05	1.05	0.74	0.74	0.63	0.63
Valine	5.0	3.80	0.76	4.30	0.86	3.89	0.78
TOTAL	35.5	37.16	8.00	29.59	6.70	37.27	7.52

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

A further analysis of the limiting amino acids indicated that there was a bit of a difference between the treatments. Ile, Lys, Met + Cys, and Val were found to be limiting in the raw maize. In case of the fermented maize, the list was a little more extended and included Ile, leucine (Leu), Lys, Met + Cys, threonine (Thr), tryptophan (Try), and Val. Ile, Lys, Met + Cys, Thr, Try, and Val were limiting in the germinated maize. The appearance of other restrictive amino acids in the processed samples can be due to biochemical changes that happen during fermentation and germination, such as degradation of amino acids, microorganism use, or reallocation of amino acids in proteins. Despite these restrictions, the rest of the necessary amino acids in all the samples met the provisional reference pattern of the FAO/WHO. This observation implies that although processing did change the proportions of some of the indispensable amino acids relative to each other, it did not detract from the overall sufficiency of most of the essential amino acids. This would therefore mean that focused supplementation instead of wholesale reformulation would be required to improve the biological value of the maize protein.

### Conclusion

The results of the research indicate that the processing methods used had quantifiable influence on the proximate composition and amino acid composition of yellow maize. There were significant differences between the raw, fermented, and germinated samples, showing that the changes can be important in the nutritional quality that is biochemically modified during processing. Germination was correlated with an overall increase in the total amino acid content and a relative increase in the quality of the protein. This effect can be related to enzyme activity in sprouting, as this stimulates the mobilization and partial hydrolysis of storage proteins and therefore makes more amino acids available. By comparison, fermentation led to apparent changes in amino acid distribution with increased concentrations of some non-essential amino acids (NEAAs). This can probably be explained by the occurrence of microbial metabolism and proteolytic activity during the fermentation process.

However, out of the methods of processing that were considered, germination seems to be particularly promising as the method of enhancing the protein content of maize that could be used by humans in its natural form, and could be made relatively cheap.

**Conflict of interest:** The authors declare no conflicts of interest.

### References

- [1] International Institute of Tropical Agriculture (n.d.). *Maize (Zea mays L.)*. IITA. Retrieved December 5, 2025, from <https://www.iita.org/cropsnew/maize/>
- [2] Jilo, T. (2022). Nutritional benefit and development of quality protein maize (QPM) in Ethiopia: Review article. *Cereal Research Communications*, 50, 559–572. <https://doi.org/10.1007/s42976-021-00211-8>
- [3] Yu, T., Zhang, J., Ma, X., Cao, S., Li, W. & Yang, G. (2024). A multi-omics view of maize's (*Zea mays L.*) response to low temperatures during the seedling stage. *Int. J. of Molecular Sci.*, 25(22), 12273. <https://doi.org/10.3390/ijms252212273>
- [4] Piperno, D. R., Ranere, A. J., Holst, I., Iriarte, J. & Dickau, R. (2009). Starch-grain and phytolith evidence for early ninth-millennium B.P. maize from the Central Balsas River Valley, Mexico. *Proceedings of the National Academy of Sciences of the United States of America*, 106(13), 5019–5024. <https://doi.org/10.1073/pnas.0812525106>
- [5] Gaut, B. S., D'Éez, C. M. & Morrell, P. L. (2018). Genomics and the archaeological record: The domestication of maize. *Current Opinion in Plant Biology*, 42, 23–31.
- [6] Goodman, M. M. & Galinat, W. C. (1988). The history and evolution of maize. *Critical Reviews in Plant Sci.*, 7(3), 197–220. <https://doi.org/10.1080/07352688809382264>
- [7] Adiaha, M. S. (2017). The impact of maize (*Zea mays L.*) and its uses for human development: A review. *Int. J. of Scientific World*, 5(1), 93–95. <https://doi.org/10.14419/ijsw.v5i1.7585>
- [8] Akinsola, O. T., Alamu, E. O., Otegbayo, B. O., Menkir, A. & Maziya-Dixon, B. (2021). Nutritional properties of ogi powder and sensory perception of ogi porridge made from synthetic provitamin A maize genotype. *Frontiers in Nutrition*, 8, Article 685004. <https://doi.org/10.3389/fnut.2021.685004>
- [9] Kahajdova, Z. & Karovicova, J. (2007). Fermentation of cereals for a specific purpose. *J. of Food and Nutrition Res.*, 46, 51–57.
- [10] Kumar, P., Choudhary, M., Hossain, F., Singh, N. K., Choudhary, P., Gupta, M., Singh, V., Chikappa, G. K., Kumar, R., Kumar, B., Jat, S. L. & Rakshit, S. (2019). Nutritional quality improvement in maize (*Zea mays L.*): Progress and challenges. *The Indian Journal of Agricultural Sciences*, 89(6), 895–911. <https://doi.org/10.56093/ijas.v89i6.90756>
- [11] FAO (2022). *Maize in Human Nutrition*. Food and Agriculture Organization of the United Nations.



- [12] Chauhan, D., Kumar, K., Ahmed, N., Pal Singh, T., Thakur, P. S., Hyder Rizvi, Q.-U.-E., Yadav, A. N. & Dhaliwal, H. S. (2022). Effect of processing treatments on the nutritional, anti-nutritional, and bioactive composition of blue maize (*Zea mays* L.). *Current Research in Nutrition and Food Science J.*, 10(1), 171–182. <https://doi.org/10.12944/CRNFSJ.10.1.12>
- [13] Avezum, L., Rondet, E., Mestres, C., Achir, N., Madode, Y., Gibert, O., Lefevre, C., Hemery, Y., Verdeil, J.-L. & Rajjou, L. (2022). Improving the nutritional quality of pulses via germination. *Food Reviews International*. Advance online publication. <https://doi.org/10.1080/87559129.2022.2063329>
- [14] Igbua, F. Z., Adejo, S. O., Igoli, N. P. & Daagema, A. A. (2020). Antinutrients and bioavailability of nutrients in maize, cassava and soybeans composite flour. *Asian Food Sci. J.*, 16(2), 5–12. <https://doi.org/10.9734/AFSJ/2020/v16i230167>
- [15] Oluwajoba, E. O., Akinyosoye, F. A. & Adetuyi, F. C. (2018). Reduction of antinutrients in maize through fermentation. *Journal of Food Biochemistry*, 42(6), e12568.
- [16] Gunathunga, C., Senanayake, S., Jayasinghe, M. A., Brennan, C. S., Truong, T., Marapana, U. & Chandrapala, J. (2024). Germination effects on nutritional quality: A comprehensive review of selected cereals and pulses changes. *Journal of Food Composition and Analysis*, 128, 106024. <https://doi.org/10.1016/j.jfca.2024.106024>
- [17] Cui, L., Li, D. & Liu, C. (2012). Effect of fermentation on the nutritive value of maize. *Int. J. of Food Sci. & Techn.*, 47(4), 755–760. <https://doi.org/10.1111/j.1365-2621.2011.02904.x>
- [18] Olaniran, A. F. & Abiose, S. H. (2019). Nutritional evaluation of enhanced unsievedogi paste with garlic and ginger. *Preventive Nutr. and Food Sci.*, 24(3), 348–356. <https://doi.org/10.3746/pnf.2019.24.3.348>
- [19] Malek, M. & Ghaderi-Far, F. (2022). Dynamics of seed dormancy and germination at high-temperature stress is affected by priming and phytohormones in rapeseed (*Brassica napus* L.). *J. of Plant Physiol.*, 269, 153614. <https://doi.org/10.1016/j.jplph.2021.153614>
- [20] Kewuyemi, Y. O., Kesa, H. & Adebo, O. A. (2022). Biochemical properties, nutritional quality, colour profile and techno-functional properties of whole grain sourdough and malted cowpea and quinoa flours. *International Journal of Food Science & Technology*, 57(3), 1527–1543. <https://doi.org/10.1111/ijfs.15512>
- [21] Wang, J., Ma, Y. & Huang, X. (2023). Changes in physio-biochemical metabolism, phenolics and antioxidant capacity of different Chinese pea varieties during germination. *Int. J. of Food Sci. & Techn.*, 58(1), 167–180. <https://doi.org/10.1111/ijfs.16185>
- [22] AOAC (Association of Official Analytical Chemists) (1980). *Official Method of Analysis of the AOAC*. W. Horwitz (Ed.), Thirteenth Edition, Washington DC. <https://archive.org/details/gov.law.aocac.methods.1980/page/n5/mode/2up>.
- [23] Paul, A. D., Southgate, A. T. & Russel, J. (1976). *First Supplement to McCane and Widdowson's The Composition of Foods*. HMSO, London.
- [24] Aremu, M. O., Olaofe, O. & Akintayo, E. T. (2006). Mineral and amino acid composition of Bambara groundnut (*Vigna suoterranean*) and Kerstings groundnut (*Kerstingiella geocarna*) flour. *International Journal of Chemistry*, 16, 57–64.
- [25] Aremu, M. O., Olaofe, O., Basu, S. K., Abdulazeez, G. & Acharya, S. N. (2010). Processed cranberry bean (*Phaseolus coccineus*) seed flours for African diet. *Canadian J. Plant Science*, 90, 719 – 728. <https://doi.org/10.4141/cjps09149>
- [26] FAO/WHO (1991). *Protein Quality Evaluation Report of Joint FAO/WHO Expert Consultative FAO Food and Nutrient*. FAO, Rome, Italy.
- [27] Alsmeyer, R. H., Cuningham, A. E. & Hapich, M. L. (1974). Equations predicted (PER) from amino acid analysis. *Food Techn.*, 28, 34–38.
- [28] Adejumo, B. A., Ajayi, O. B. & Fadahunsi, I. F. (2020). Effect of germination and fermentation on the nutritional quality of maize. *Journal of Applied Sciences and Environmental Management*, 24(3), 507–512.
- [29] Al Taher, F. & Nemzer, B. (2023). Effect of germination on fatty acid composition in cereal grains. *Foods*, 12(17), 3306. <https://doi.org/10.3390/foods12173306>
- [30] Christian, E. E., Stanley, C. I. & Emmanuel, C. I. (2019). Proximate and mineral composition of *Sesamum indicum* L. seed. *Med. & Anal. Chem. Int. J.*, 3(4), 000152.
- [31] Aremu, M. O., Achuri, E. I., Ibrahim, H., Omosobi, M. O., Usman, A., Oko, O. J. & Labaran, L. (2022). Lipid Composition of germinated and non-germinated sorghum (*Sorghum bicolor*) found in Nasarawa State, Nigeria. *Int. J. of Sci.*, 11(1), 22–27. <https://doi.org/10.18483/ijSci.2541>
- [32] Chaves-López, C., Serio, A., Grande-Tovar, C. D., Cuervo-Mulet, R., Delgado-Ospina, J. & Paparella, A. (2014). Traditional fermented foods and beverages from a microbiological and nutritional perspective: The Colombian heritage. *Comprehensive Reviews in Food Science and Food Safety*, 13(5), 1031–1048. <https://doi.org/10.1111/1541-4337.12098>
- [33] Hotz, C. & Gibson, R. S. (2007). Traditional food-processing and preparation practices to enhance the bioavailability of micronutrients in plant-based diets. *J. of Nutr.*, 137(4), 1097–1100. <https://doi.org/10.1093/jn/137.4.1097>

- [34] Adebo, J. A., Njobeh, P. B., Gbashi, S., Oyedeji, A. B., Ogundele, O. M. & Oyeyinka, S. A. (2022). Fermentation of cereals and legumes: Impact on nutritional constituents and nutrient bioavailability. *Fermentation*, 8(2), 63. <https://doi.org/10.3390/fermentation8020063>
- [35] Singh, A., Rehal, J., Kaur, A. & Jyot, G. (2015). Enhancement of attributes of cereals by germination and fermentation: A review. *Critical Reviews in Food Science and Nutrition*, 55(11), 1575–1589. <https://doi.org/10.1080/10408398.2012.706661>
- [36] Agblemany, E. F. & Abrokwah, K. (2019). Effect of traditional fermentation process on the nutrient and anti-nutrient content of maize and African locust beans. *Journal of Food Science and Nutrition Research*, 2(2), 65–75. <https://doi.org/10.26502/jfsnr.2642-11000010>
- [37] Nwadi, O. M. M., Uchegbu, N. & Okonkwo, T. M. (2019). Effect of processing methods on the antinutrient reduction of Bambara groundnut: A review. *Sky Journal of Food Science*, 7(3), 37-41.
- [38] Marfo, E. K., Simpson, B. K., Idowu, J. S. & Oke, O. L. (1990). Effect of local food processing on phytate levels in cassava, cocoyam, yam, maize, sorghum, rice, cowpea and soybean. *J. Agric. Food Chem.*, 38, 1580–1585.
- [39] Sokrab, A. M., Ahmed, I. A. M. & Babiker, E. E. (2012). Effect of germination on antinutritional factors, total, and extractable minerals of high and low phytate corn (*Zea mays* L.) genotypes. *J. of the Saudi Society of Agricultural Sci.*, 11(2), 123–128. <https://doi.org/10.1016/j.jssas.2012.02.002>
- [40] Popova, A. & Mihaylova, D. (2019). Antinutrients in plant-based foods: A review. *The Open Biotechnology Journal*, 13(1), 68–76. <https://doi.org/10.2174/1874070701913010068>
- [41] Johnson, I. T., Gee, J. M., Price, K., Curl, C. & Fenwick, G. R. (1986) Influence of saponins on gut permeability and active nutrient transport in vitro. *J Nutr* 116(11), 2270-7
- [42] Spring, B. (1984). Recent research on the behavioral effects of tryptophan and carbohydrate. *Nutr and Health*, 3(1–2), 55–67. <https://doi.org/10.1177/026010608400300204>
- [43] Wyatt, R. J., Chase, T., Engelman, K., Kupfer, D. J., Scott, J., Sjoerdsma, A., Fram, D. H. & Snyder, F. (1970). Effects of L-tryptophan (a natural sedative) on human sleep. *The Lancet*, 296(7678), 842–846. [https://doi.org/10.1016/S0140-6736\(70\)92015-5](https://doi.org/10.1016/S0140-6736(70)92015-5)
- [44] Smith, K. A., Fairburn, C. G. & Cowen, P. J. (1997). Relapse of depression after rapid depletion of tryptophan. *The Lancet*, 349(9056), 915–919. [https://doi.org/10.1016/S0140-6736\(96\)07044-4](https://doi.org/10.1016/S0140-6736(96)07044-4)
- [45] Victor, I. A. & Ogunba, B. O. (2018). Potential complementary food from quality protein maize (*Zea mays* L.) supplemented with sesame (*Sesamum indicum*) and mushroom (*Oudemansiellalaradicata*). *Journal of Nutrition & Food Sciences*, 8(3), 698. <https://doi.org/10.4172/2155-9600.1000698>
- [46] Egbedike, C. N., Odoh, N. E., Odoh, M. O. & Okorie, P. A. (2024). Evaluation of amino acid profile, protein quality and pasting properties of pap made from fermented maize starch and red kidney beans. *J. Home Econ. Res.*, 30(2). <https://journals.heran.org/index.php/JHER/article/view/23>
- [47] Smriga, M., Ando, T., Akutsu, M., Furukawa, Y., Miwa, K. & Morinaga, Y. (2007). Oral treatment with L-lysine and L-arginine reduces anxiety and basal cortisol levels in healthy humans. *Biomedical Research*, 28(2), 85–90. <https://doi.org/10.2220/biomedres.28.85>
- [48] Obizoba, I.C. and Egbuna, H.I. (1992). Effect of germination and fermentation on the nutritional quality of bambara nut (*Voandzeiasubterranea* L. Thouars) and its product (milk). *Plant Foods for Human Nutrition*, 42, 13-23.
- [49] Nkhata, S. G., Ayua, E., Kamau, E. H. & Shingiro, J. B. (2018). Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Food Science & Nutrition*, 6(2), 2446–2458. <https://doi.org/10.1002/fsn3.846>
- [50] FAO/WHO. (1998). Carbohydrates in Human Nutrition: Report of a Joint FAO/WHO Expert Consultation, 14-18 April 1997, Rome. FAO Food and Nutrition Paper No. 66. Rome.

#### Citing this Article

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