International Journal of Plant & Soil Science

Volume 38, Issue 8, Page 12-26, 2026; Article no.IJPSS.162329
ISSN: 2320-7035

Impact of the Environment to Biochemical Parameters of Six Genotypes Tubers of Tiger Nut (*Cyperus esculentus* L. Grown) Evaluated in Burkina Faso

Nogueba Abraham Kombelème [a*], Nattan Gamsore [a], Ouandèguem Michel Sawadogo [a], Jeanne Nikiema [b], Koussao Some [b] and Pauline Bationo/Kando [a]

[a] Plant Genetics and Improvement Team, Biosciences Laboratory, Department of Plant Biology and Plant Physiology, UFR/SVT, University Joseph KI-ZERBO, 03 BP 7021 Ouagadougou, 03, Burkina Faso.
[b] Institute for the Environment and Agricultural Research (INERA) of Kamboinse Plant Production Department, 03 BP 7047 Ouagadougou, 03, Burkina Faso.

Authors' contributions

This work was carried out in collaboration among all authors. Author NAK collected the data, followed the field study and participated in the biochemical analysis and drafted of the manuscript. Author NG followed the tests, supervised the work and participated correction of the manuscript. Authors OMS and JN participated the correction of the manuscript. Author KS participated in the correction of the manuscript. Author PB/K corrected the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i86194

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/162329

Original Research Article

Received: 13/05/2026
Accepted: 11/07/2026
Published: 15/07/2026

Abstract

Food and nutritional insecurity remains a major challenge, increasing the need to characterise underutilised crops with potential dietary value. This study evaluated the influence of production environment on the biochemical composition of tubers from six tiger nut (*Cyperus esculentus* L.) genotypes grown at

**Corresponding author: E-mail: abrahamkombelem@gmail.com;*

Cite as: *Kombelème, N. A., Gamsore, N., Sawadogo, O. M., Nikiema, J., Some, K., & Bationo/Kando, P. (2026). Impact of the Environment to Biochemical Parameters of Six Genotypes Tubers of Tiger Nut (Cyperus esculentus L. Grown) Evaluated in Burkina Faso. International Journal of Plant & Soil Science, 38(8), 12–26. https://doi.org/10.9734/ijpss/2026/v38i86194*

Ouagadougou and Bobo-Dioulasso, Burkina Faso, during the 2021–2022 agricultural season. Dried tubers were milled into coarse flour, and moisture, ash, protein, lipid, carbohydrate, β-carotene, and energy values were determined using standard analytical procedures. Analysis of variance and genotype × environment analysis were used to assess biochemical variability and environmental effects, while GGE biplot analysis was applied to compare genotype performance across locations. Across the two environments, lipid content ranged from 21.46% to 33.82%, carbohydrate content from 53.94% to 63.82%, protein content from 0.05% to 4.67%, ash content from 2.62% to 10.49%, and moisture content from 3.59% to 7.89%. β-Carotene content ranged from 0.16 to 0.28 µg/100 mg, and energy value ranged from 440.33 to 535.02 kcal/100 g. The environmental effect was not significant for carbohydrate or ash content but was significant for protein, lipid, moisture, and β-carotene contents. Genotypic and genotype × environment effects also contributed to the observed variation. The findings indicate that biochemical performance differed among genotypes and locations, supporting the evaluation of tiger nut materials for varietal improvement and crop promotion in Burkina Faso.

Keywords: Cyperus esculentus L.; tiger nut; genotype; production environment; biochemical composition; lipid content; carbohydrate content; β-carotene; genotype × environment interaction; Burkina Faso.

1. Introduction

Africa's abundant plant resources help to meet the nutritional and therapeutic needs of its population. However, many of these resources remain poorly known and underutilised, despite their promising nutritional profiles and potential to help address malnutrition (Food and Agriculture Organization of the United Nations et al., 2021; Food and Agriculture Organization of the United Nations, 2023). Malnutrition accounts for approximately 45% of deaths among children under five years of age in Africa (Ndiaye, 2021). This form of malnutrition is often associated with stunting, an increased risk of serious illness, and high mortality rates (Djomdi, 2015; Food and Agriculture Organization of the United Nations, 2024). Sub-Saharan Africa remains the region with the highest prevalence of undernutrition, at 22.7%. In Burkina Faso, more than 3.4 million people experience food insecurity due to a multifaceted crisis characterised by armed conflict and intercommunal violence (Food and Agriculture Organization of the United Nations et al., 2021). In this context, promoting products derived from underutilised species, such as tiger nut, and diversifying dietary habits may help to address these challenges. However, limited knowledge of the biochemical composition and nutritional value of the tubers may hinder their utilisation. Therefore, following the characterisation of the phenotypic traits of tiger nut genotypes cultivated in West Africa (Kombeleme *et al*., 2024; Haoua *et al.,* 2024), it is necessary to determine the nutritional value of these genotypes to identify materials combining improved agronomic performance with high nutritional value for tiger nut varietal selection programmes in Burkina Faso.

Recent literature describes tiger nut tubers as an underutilised food resource with a diverse nutritional profile, including lipid, carbohydrate, protein, fibre, mineral and bioactive fractions, which supports continued investigation of their composition and food uses (Edo et al., 2024; Lenická et al., 2025).

Studies of tiger-nut-derived foods further show that processing can alter measured nutritional and biochemical characteristics, while the crop can be developed into value-added plant-based products such as yoghurt and fermented milk (Okafor et al., 2024; Ogodo et al., 2025).

At the component level, recent analysis of tiger nut seed meal has identified nutritionally and functionally distinct protein fractions, indicating that detailed biochemical characterisation can reveal attributes not captured by general compositional descriptions (Yu et al., 2024).

Despite this growing body of evidence, comparative information remains limited on how contrasting production environments influence the biochemical composition of genetically distinct tiger nut genotypes cultivated in Burkina Faso. This gap constrains the identification of genotypes that combine favourable biochemical profiles with consistent performance across locations.

The overall objective of this study was to determine the biochemical and nutritional composition of tubers from cultivated *Cyperus esculentus*. Specifically, the objectives were to:

(i) evaluate the biochemical components of tubers from the genotypes; and
(ii) determine the effect of the environment on the biochemical parameters.

2. Material and Methods

2.1 Material

2.1.1 Plant Material

The plant material consisted of tubers from six tiger nut genotypes with known phenotypic and genotypic characteristics. Six genotypes were selected for each environment (Ouagadougou and Bobo-Dioulasso) based on their agronomic performance. P181J, K3JT, and M3J performed best in both environments. The P123JT genotype had a high yield (2.73 t/ha) in Ouagadougou and a low yield (1.40 t/ha) in Bobo-Dioulasso. The N1MC and N2BR genotypes had low yields in both environments (Table 1).

Table 1. List of the six genotypes and their characteristics

Codes	Country	Shape	Color	Env	YT (t/ha)	Tuber size (LOT/DTT)
N2BR	Niger	Round	Brown	Ouagadougou	1,31	1,20
M3J	Mali	Oval	Yellow	Ouagadougou	3,6	1;30
P123JT	Burkina Faso	Oval	Yellowish	Ouagadougou	2,73	1,43
K3JT	Burkina Faso	Elongated	Yellowish	Ouagadougou	2,54	1,8
N1MC	Niger	Round	Light brown	Ouagadougou	1,57	1,13
P181J	Burkina Faso	Oval	Yellowish	Ouagadougou	4,07	1,55
K3JT	Burkina Faso	Oval	Yellowish	Bobo Dioulasso	2,41	1,8
P123JT	Burkina Faso	Oval	Yellowish	Bobo Dioulasso	1,4	1,43
N1MC	Niger	Round	Light brown	Bobo Dioulasso	0,71	1,13
P181J	Burkina Faso	Oval	Yellow	Bobo Dioulasso	2,04	1,55
N2BR	Niger	Round	Brown	Bobo Dioulasso	0,58	1,20
M3J	Mali	Round	Yellow	Bobo Dioulasso	1,92	1,30

Legend: Env = environment, YT: Tubers yield, LOT/DTT: tuber length/tuber diameter

2.1.2 Description of the Experimental Sites

Two trials were conducted at the research stations of the Institute for the Environment and Agricultural Research in Kamboinsé, Ouagadougou (INERA/K), and Farako-Bâ, Bobo-Dioulasso (INERA/FB), during the 2021–2022 agricultural season. The INERA/K station is located approximately 12 km north of central Ouagadougou, at 12°28′ north latitude and 1°33′ west longitude, at an altitude of 296 m. According to Guinko (1985), the climate of Kamboinsé lies between the 600 and 900 mm isohyets. The soils of Kamboinsé are classified as leached ferruginous soils overlying deeper sandy material (Ouedraogo *et al.,* 2010). The station recorded 1,001.7 mm of rainfall (Figure 1) during the 2021–2022 rainy growing season, with temperatures ranging from 26.1 °C to 33.6 °C during the crop cycle (July to November). This trial site was designated environment 1 (E1). The INERA Farako-Bâ research station is located at 4°20′ west longitude and 11°06′ north latitude, at an altitude of 405 m, approximately 10 km south-west of Bobo-Dioulasso along the Bobo-Banfora road (National Road No. 7). The soils of Farako-Bâ are red and slightly ferralitic in the northern and western plots and ferruginous in the south, with a 2% slope (Guinko, 1985). They are highly permeable and susceptible to erosion. Their low clay and organic matter contents reduce their cation-exchange capacity. The station recorded 1,262.4 mm of rainfall (Fig. 1) during the 2021–2022 rainy agricultural season, with temperatures ranging from 20.6 °C to 33.6 °C during the crop cycle (August to November). This trial site was designated environment 2 (E2).

2.1.3 Description of the Biochemical Characterization Site

The biochemical characterisation was conducted at the Laboratory of Biochemistry and Food and Nutritional Technologies (LABIOTAN), Joseph KI-ZERBO University, Ouagadougou.

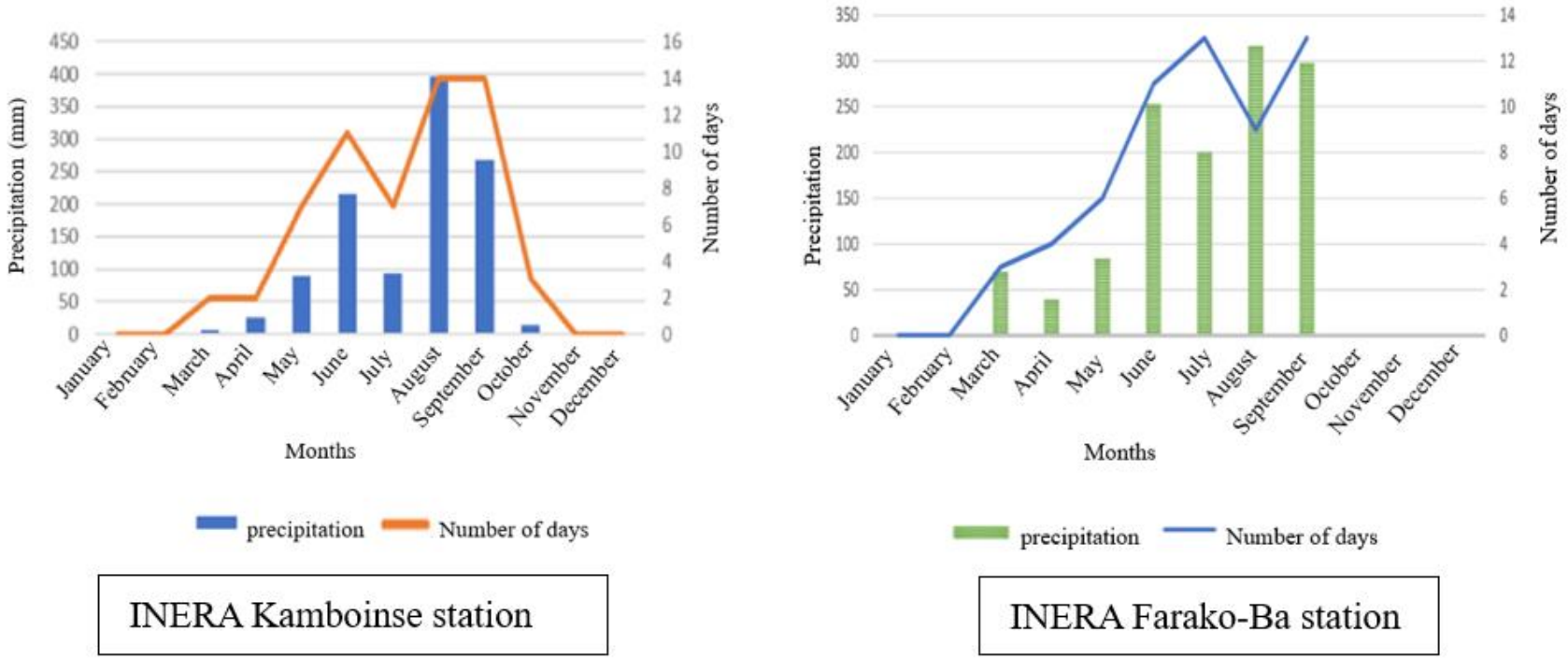

Fig. 1. Ombrothermic curves for the INERA Kamboinse and INERA Farako-Ba stations during the 2021-2022 agricultural season (Weather station, 2022)

2.2 Methods

2.2.1 Sampling and Evaluation Methods Used

The tubers were classified into three shapes: round, oval, and elongated (Figure 2). Dried tubers from each tiger nut sample were ground into coarse flour using an aluminium mortar. The resulting powders were labelled for laboratory analysis (Fig. 3).

Fig. 2. Different forms of tiger nut tubers: A = round, B = oval, C = elongated

2.2.2 Determination of Moisture Content

The moisture content of the samples was determined according to the standard method of the Association of Official Analytical Chemists (1990). Three grams (3 g) of flour were weighed into pre-washed and dried porcelain pans. The samples were placed in a ventilated oven at 105 °C for 24 h, cooled in a desiccator for 30 min, and then weighed (Figure 4). The tests were conducted in triplicate. Moisture content, expressed as a percentage, was calculated using the following formula:

$$\% \text{ H} = \frac{\text{PE}-(\text{MF}-\text{M0})}{\text{PE}} \times 100$$

With PE: Test Sample (g); M0: Empty weight of the baskets (g); MF: Final weight (baskets + dry matter) after oven drying (g); % H: Moisture content (%)

Fig. 3. Crude tuber flour obtained in the laboratory
A-Crude flour from yellow tubers, B-Crude flour from yellowish tubers

Fig. 4. Procedure for determining moisture and ash content
A-Placing the crucibles containing the flour in an oven, B-Cooling in a desiccator

2.2.3 Ash Content Determination

Ash content was determined in accordance with ISO 2171:2007 (International Organization for Standardization, 2007). For this determination, 3 g of each sample were weighed into clean, dry, pre-tared porcelain crucibles and placed in a furnace at 600 °C. After 5 h of incineration, the crucibles were removed from the furnace, cooled in a desiccator for 30 min, and weighed (Fig. 5). Ash content, expressed as a percentage of dry matter (DM), was calculated using the following equation:

$$\%\frac{\mathrm{C}}{\mathrm{MS}} = \left(\frac{\mathrm{Pf}-\mathrm{Pv}}{Pe} \times 100\right) \mathrm{x}\ \frac{100}{100-\%H}$$

% C/MS: percentage of ash relative to dry matter; Pe: Test sample; Pf : Final weight (crucible + calcined sample); Pv: Empty weight of the crucibles.

Fig. 5. Samples after 5 hours of incubation

2.2.4 Determination of Lipids or Fats

The lipid content of the samples was determined using the Soxhlet method in accordance with ISO 659:2009 (International Organization for Standardization, 2009), with hexane as the extraction solvent, as described by Luque de Castro and Priego-Capote (2010), with a slight modification to the sample weight. Thus, 2 g of flour from each sample (Pe) were placed in a filter-paper cartridge and inserted into the Soxhlet extractor. The

extractor was connected to a pre-weighed flask (Pv) containing 200 mL of hexane, and the assembly was attached to the Soxhlet apparatus. Extraction was conducted under reflux for 5 h, after which the solvent was evaporated.

The lipid content relative to dry matter was calculated using the following formula:

$$\mathrm{TL/MS(\%)} = \left[\frac{\mathrm{Pf} - \mathrm{Pv}}{\mathrm{Pe}} \times 100\right] \times \frac{100}{100 - \%\mathrm{H}}$$

TL/MS (%): Fat-to-dry matter ratio; Pf: Final weight; Pv: Empty weight of the flask; Pe: Test sample; % H: Mass percentage of water previously determined.

2.2.5 Total Protein Assay

Total protein was measured using the method of Bradford (1976). The Bradford method is a colorimetric assay based on the change in absorbance at 595 nm resulting from the binding of Coomassie Blue G-250 to basic amino acids (arginine, histidine, and lysine) and hydrophobic amino acid residues in proteins. For extraction, 500 mg of powder was homogenised in 10 mL of 0.1 M NaCl for 5 h at 150 rpm at room temperature. After centrifugation at 4,400 rpm for 30 min at 4 °C, the supernatant was collected and used to determine soluble protein content (Figure 6). A 50 µL aliquot of extract at the specified concentration was mixed with 250 µL of Bradford reagent. After incubation for 2 min, absorbance was measured at 595 nm against a blank consisting of 50 µL of extract and 250 µL of NaCl. The values obtained were extrapolated from a BSA calibration curve. Protein content was expressed as BSA equivalents per 100 g of dry matter and was calculated using the following formula:

$$\mathrm{TP} = \frac{\mathrm{C} \times \mathrm{D}}{\mathrm{Ci}} \times 100$$

TP: Protein content of the sample (mg E BSA/100 g or % DM);
C: Sample concentration measured in µg/mL;
D: Dilution factor;
Ci: Initial sample concentration (mg/mL).

Fig. 6. Extract after homogenization in NaCl

2.2.6 Determination of Carbohydrates and Energy Value

The carbohydrate content of the flour samples was determined by difference in accordance with ISO 2911:1976 (International Organization for Standardization, 1976).

$$\%\ \text{Carbohydrates} = 100 - (\%\ \text{Proteins} + \%\ \text{Lipids} + \%\ \text{Moisture} + \%\ \text{Ashes})$$

Energy value was calculated in accordance with Regulation (EU) No. 1169/2011 (European Parliament & Council of the European Union, 2011), using the coefficients assigned to proteins, carbohydrates, and fats (Atwater & Benedict, 1899).

$$\text{Energie Value (Kcal / 100g)} = [\%\ \text{Carbohydrates} \times 4\ (\text{Kcal}) + \%\ \text{Proteins} \times 4\ (\text{Kcal}) + \%\ \text{Lipids} \times 9\ (\text{Kcal})]$$

2.2.7 β-Carotene Assay

Maceration was used for extraction. A 100 mg portion of ground raw tiger nut flour was weighed, and 5 mL of acetone/hexane (70:30, v/v) was added. The mixture was stirred for 1 min and centrifuged at 4,500 rpm for 10 min. The supernatant was collected for carotenoid quantification using the method described by Nagata and Yamashita (1992). After extraction, sample absorbance was measured spectrophotometrically at 453, 505, and 663 nm. The β-carotene content, expressed as µg/100 mg of raw flour, was calculated using the following formula:

$$T = 0{,}216\ A663 - 0{,}304\ A505 + 0{,}452\ A453$$

T = β-carotene content in µg/100 mg of raw tiger nut flour; Ci = initial concentration of the samples; A663 = absorbance at 663 nm; A505 = absorbance at 505 nm; A453 = absorbance at 453 nm.

2.2.8 Measured Biochemical Parameters

The measured parameters were energy value (VE; kcal/100 g); protein, lipid, carbohydrate, moisture, and ash contents (expressed as percentages of dry matter [DM]); and β-carotene content (µg/100 mg).

2.2.9 Data Analysis

Excel 2016 was used for data entry and processing. RStudio version 4.5.0 was used to analyse the biochemical data. Descriptive statistics and analysis of variance (ANOVA) were used to assess biochemical variability among the genotypes. The Newman–Keuls multiple-comparison test was used to compare genotype performance across the two environments. A combined analysis of variance was conducted to determine the effects of genotype, environment, and genotype × environment interaction on the biochemical parameters. GGE biplot analysis was used to identify the genotypes with the best biochemical performance in each environment.

3. Results and Discussion

3.1 Variability in the Biochemical Composition of Tubers and Comparison of Average Genotype Performance Across Environments

The descriptive statistics and analysis of variance showed significant ($P < 0.05$), highly significant ($P < 0.001$), and very highly significant ($P < 0.0001$) differences among the genotypes for all biochemical parameters measured at the 5% significance level (Table 2). Protein content ranged from 0.05% to 4.67%, with a mean of 1.54%. Ash content ranged from 2.62% to 10.49%, with a mean of 6.97%. Moisture content ranged from 3.59% to 7.89%, with a mean of 5.31%. Lipid content ranged from 21.46% to 33.82%, with a mean of 25.97%. Carbohydrate content ranged from 53.94% to 63.82%, with a mean of 60.21%. β-Carotene content ranged from 0.16 µg to 0.28 µg, with a mean of 0.20 µg. Energy value ranged from 440.33 to 535.02 kcal/100 g, with a mean of 480.73 kcal/100 g.

Comparison of mean genotype performance at the two sites revealed highly significant differences ($P < 0.0001$) for most parameters. At the Ouagadougou site, P123JT recorded the highest protein and moisture contents, whereas P181J recorded the highest carbohydrate content. At the Bobo-Dioulasso site, N1MC recorded the highest lipid content and energy value, whereas P123JT recorded the highest β-carotene content (Table 3).

Table 2. Results of the descriptive analysis and analysis of variance of biochemical parameters in the environments

Biochemical parameters	Minimum	Maximum	Average	Standard Deviation	F	P-value
Proteins	0,05	4,67	1,54	1,09	2,85	0,02
Ashes	2,62	10,49	6,97	1,60	3,09	0,01
Moisture	3,59	7,89	5,31	1,14	3,67	0,001
Lipids	21,46	33,82	25,97	3,48	11,26	< 0,0001
Carbohydrates	53,94	63,82	60,21	2,72	3,23	0,01
β-carotene	0,16	0,28	0,20	0,03	8,05	< 0,0001
VE	440,33	535,02	480,73	24,66	10,85	< 0,0001

VE: Energy Value (kcal/100 g); proteins, lipids, carbohydrates, moisture, and ashes are expressed as a percentage of DM (dry matter); β-carotene (µg/100 mg), P-value <0.05: significant at the 5% level; P-value <0.001: highly significant at the 5% level; P-value <0.0001: very highly significant at the 5% level

Table 3. Comparison of the average performance of the biochemical parameters measured for the genotypes at the two trial sites (Ouagadougou and Bobo Dioulasso)

				Ouagadougou			
Genotypes	**Proteins**	**Ash**	**Moisture**	**Lipids**	**Carbohydrates**	**β-carotene**	**VE**
M3J	1,78b	6,90 a	5,48d	23,18 c	**62,65 a**	**0,19 a**	466,35 c
N2BR	1,59 b	6,26 a	4,61 e	**29,01 a**	58,50 b	**0,19 a**	**501,60 a**
P123JT	**4,19 a**	6,40 a	**7,79 a**	22,441 cd	59,16 b	**0,18 a**	455,42 cd
N1MC	0,65 c	6,48 a	5,49d	**26,62 b**	60,73 a	**0,18 a**	485,21 b
P181J	1,41 b	8,09 a	6,27 c	21,51 d	**62,70 a**	**0,17 a**	450,10 d
K3JT	1,12 bc	9,42a	**6,86 b**	22,68 cd	59,89 a	0,15 b	448,23 d
P-value	**0,0001**	**0,173^{ns}**	**0,0001**	**0,0001**	**0,05**	**0,001**	**0,0001**
Bobo Dioulasso							
M3J	1,77 b	6,72 b	**4,98 a**	**28,06 b**	58,45 b	0,23 b	493,46 bc
P123JT	0,79 c	7,94 a	**4,80 a**	24,78 c	**61,67 a**	**0,27 a**	472,92 e
P181J	0,05 d	7,10 b	4,54 a	26,32 c	**61,97 a**	0,20 c	485,03 cd
N1MC	**2,64 a**	5,25 d	3,61 b	**33,70 a**	54,79 c	0,17 d	**533,06 a**
N2BR	0,87 c	6,01 c	**4,52 a**	**28,60 b**	59,98 ab	0,19 c	500,87 b
K3JT	1,57 b	7,08 b	**4,69 a**	24,72 c	**61,91 a**	0,17 d	476,47 de
P-value	**0,0001**	**0,0001**	**0,0001**	**0,0001**	**0,0001**	**0,0001**	**0,0001**

Legend: Mean values with the same letters are not statistically different; a, b, and c: value classes derived from the Newman-Keuls test comparison, such that a > b > c; P-value < 0.0001: highly significant at the 5% level; P-value < 0.05: significant at the 5% level; ns: not significant.

Table 4. Effect of genotype, environment, and the genotype × environment interaction on the components of energy value

Sources	Df	Sum of Squares			Mean Square			F-test			Explained Variance		
Parameters		**Pro**	**Lip**	**Car**	**Pro**	**Lip**	**Car**	**Pro**	**Lip**	**Car**	**Pro**	**Lip**	**Car**
G	5	14,1	325,4	96,61	2,82	65,08	19,32	18,8***	80,5***	5,81***	**25,36**	**57,27**	**27,75**
E	1	3,12	143,3	7,91	3,12	143,32	7,91	20,8*	177,3***	2,38NS	**5,61**	**25,22**	**2,27**
G×E	5	33	70,3	123,8	6,6	14,06	24,77	44***	17,4***	7,44***	**59,34**	**12,37**	**12,37**
Residues	36	5,39	29,1	119,8	0,15	0,8	3,33						
Total	47	55,61	568,2	348,1									

*Df: degrees of freedom, G: Genotypes, E: Environment, G×E: Genotype × Environment interaction, Pro: Proteins, Car: carbohydrates, Lip: lipids, *: significant at p < 0.05, ***: highly significant, NS: Not Significant*

Table 5. Effect of genotype, environment, and the genotype × environment interaction on the mineral content and β-carotene content of the tubers

Sources	Df	Sum of Squares			Mean Square			F-test			Explained Variance		
Parameters		**Ash**	**Moisture**	**β-carotene**	**Ash**	**Moisture**	**β-carotene**	**Ash**	**Moisture**	**β-carotene**	**Ash**	**Moisture**	**β-carotene**
G	5	32,22	18,7	0,02	6,44	3,74	0,004	3,48***	71,7***	39,7***	**26,87**	**30,42**	**46,51**
E	1	3,95	29,2	0,007	3,95	29,2	0,007	2,13NS	559,7***	69,8***	**3,29**	**47,50**	**16,28**
G×E	5	16,97	11,69	0,01	3,39	2,33	0,002	1,83NS	44,8***	20,2***	**14,15**	**19,02**	**23,26**
Residues	36	66,74	1,88	0,003	1,85	0,05	0,0001						
Total	47	119,89	61,47	0,043									

*Legend: Df: degrees of freedom; G: Genotypes; Environment; G×E: Genotype × Environment interaction; *: significant at p < 0.05; **: highly significant; ***: very highly significant; NS: Not Significant.*

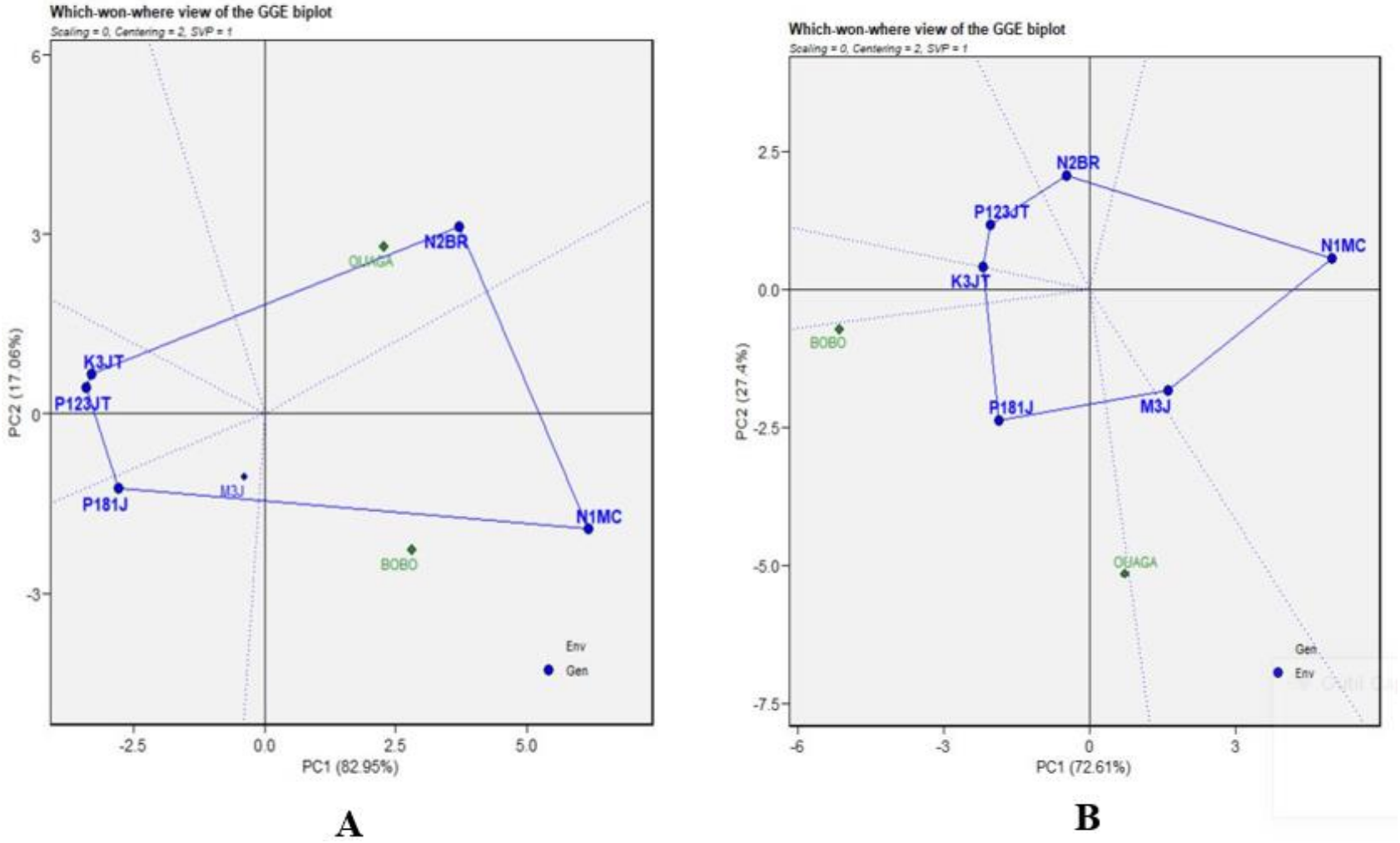

Fig. 7. GGE biplot of the biochemical performance of the six genotypes across environments. A—Lipid performance; B—Carbohydrate performance

3.2 Genotype × Environment Interaction on Biochemical Parameters

The combined analysis of variance showed that genotype and genotype × environment interaction had highly significant effects ($P < 0.0001$) on lipid, carbohydrate, moisture, protein, and β-carotene contents (Tables 4 and 5). The environmental effect was highly significant ($P < 0.0001$) for moisture, lipid, and β-carotene contents and significant ($P < 0.05$) for protein content. Genotype had a highly significant effect ($P < 0.0001$) on ash content. The contribution of genotype was greater than that of the other factors for all variables except protein and moisture contents. Protein content was influenced most strongly by genotype × environment interaction (59.34%), whereas moisture content was influenced most strongly by the environment (47.50%).

3.3 Average Performance of Genotypes Based on Parameters of Interest: Carbohydrates, Lipids, and Beta-carotene, using the GGE (Génotypes + Interaction Genotypes × Environment) Biplot Method

The GGE 'which-won-where' biplot showed the biochemical performance of the six genotypes in each environment. Figure 7A shows two components (PC1, 82.95%; PC2, 17.06%) that accounted for 100% of the variability in lipid content. In environment 1 (Ouagadougou), N2BR, located at the vertex of the polygon, was the best-performing genotype, with a lipid content of 29.01%. In environment 2 (Bobo-Dioulasso), N1MC, located at the vertex of the polygon in the corresponding sector, performed best, with a lipid content of 33.70%. For carbohydrate content, Figure 7B shows two components (PC1, 72.61%; PC2, 27.40%) that accounted for 100% of the variability. The P181J genotype, distributed across both sectors, had high carbohydrate contents in both environments (62.70% in Ouagadougou and 61.97% in Bobo-Dioulasso), indicating stable performance. In contrast, M3J, located near the Ouagadougou sector, had a carbohydrate content of 62.65%, while K3JT, located near the Bobo-Dioulasso sector, had a content of 61.91%.

Biochemical characterisation of the genotypes revealed considerable variability among materials cultivated in West Africa. Regardless of the environment, lipid and carbohydrate contents were high. These proportions indicate the high capacity of tiger nut tubers to store these biochemical compounds compared with other root and tuber crops, such as cassava (0.1–0.8%; Mohammed *et al*., 2011), sweet potato (9%; Ndangui, 2015), and taro (0.33–1.17%; Aboubakar, 2009), in which these compounds occur at lower concentrations. Tiger nut may also be one of the few tuber crops with a high fat content, comparable with oilseed crops such as groundnut and sesame. Tiger nut oil is comparable in quality to olive oil (Owusu Nyarko & Owusu Boateng, 2016). It could provide an alternative means of addressing the oil-production deficit in Burkina Faso in the context of food sovereignty. Because its carbohydrate content exceeds 60%, tiger nut may be a source of prebiotics. Studies have reported resistant starch in tiger nut tuber carbohydrates (Owusu Nyarko & Owusu Boateng, 2016). Resistant starch is an indigestible fibre that passes through the intestine and can nourish beneficial bacteria in the gut microbiota (Yertai *et al*., 2025). Consumption of resistant starch may help to lower blood glucose levels (Owusu Nyarko & Owusu Boateng, 2016; Wu *et al*., 2024). Genotypes from Niger had high fat contents, followed by those from Mali and Burkina Faso, whereas the genotypes from Burkina Faso had high carbohydrate contents. These variations may be related to differences in tuber size and colour and to the soil and climatic conditions at the genotypes' places of origin. Previous studies of tiger nut in different countries have reported similar variation. Bado *et al*. (2015) reported carbohydrate and fat contents of 67.40% and 26.92%, respectively, in Burkina Faso. Djomdi (2015) reported 49.78% carbohydrate and 25.08% fat in tubers from Cameroon; Ndiaye (2021) reported 63.83% carbohydrate and 24.72% fat in tubers from Senegal and China; and Yang *et al*. (2022) reported 18.28% fat. Although present at lower levels, the other parameters were not negligible. The ash content of the tubers indicates the presence of minerals that may contribute to consumers' nutritional security. The protein content of the tubers was higher than that reported for taro, cassava, and sweet potato (Ban-Koffi *et al*., 2009). The low β-carotene content, representing provitamin A, may be associated with several factors, including pigmentation and the degree of tuber maturity. Similar studies have reported low β-carotene contents in tiger nut (Bado *et al.,* 2015; Onuigbo et al., 2024). The estimated energy value, ranging from 440.33 to 535.02 kcal/100 g, was high. Energy value is closely related to fat, protein, and carbohydrate contents, with fat contributing most strongly. This high energy value may benefit consumers when the tubers are processed into flour for baking or into horchata (tiger nut milk). In this regard, tiger nut juice may contribute to meeting demand for energy-rich beverages. Furthermore, the energy content of tiger nut may help to meet the energy requirements of older adults (Ndiaye, 2021). Tiger nut may therefore contribute to efforts to address food and nutritional insecurity. The environmental effect was not significant for carbohydrate or ash content but was significant for protein, lipid, moisture, and β-carotene contents. These results suggest that genotypes with high

carbohydrate and ash contents could be selected for adaptation across production environments in Burkina Faso. For lipid content, however, genotype selection may need to consider the agroclimatic production zone. Although the environmental effect was significant, its contribution was smaller than that of genotype, indicating a substantial genotypic contribution to lipid synthesis.

4. Conclusion

The evaluation of six tiger nut genotypes across Ouagadougou and Bobo-Dioulasso demonstrated substantial variation in the biochemical composition of their tubers. Carbohydrates and lipids were the principal components, with overall mean values of 60.21% and 25.97%, respectively, while the mean energy value was 480.73 kcal/100 g. Protein, ash, moisture, and β-carotene contents also varied among the evaluated materials. Genotype, environment, and genotype × environment interaction contributed differently to the observed biochemical variation. Carbohydrate and ash contents were not significantly affected by environment, indicating greater consistency across the two locations. In contrast, protein, lipid, moisture, and β-carotene contents were environmentally influenced. N2BR showed the highest lipid content in Ouagadougou, whereas N1MC showed the highest lipid content and energy value in Bobo-Dioulasso. P181J maintained comparatively high carbohydrate content in both environments. These results provide a basis for selecting genotypes according to targeted biochemical traits. However, confirmation across additional locations and agricultural seasons is required before firm recommendations are made for breeding, varietal improvement, processing, or wider crop promotion in Burkina Faso.

5. Limitations

This study was limited to six tiger nut genotypes evaluated in two environments and may therefore not represent the broader diversity of *Cyperus esculentus* cultivated in West Africa. Biochemical analyses were conducted on dried tuber flour, and seasonal variation was not assessed. Soil conditions, crop management, maturity stage, and post-harvest handling may have influenced some traits but were not examined in detail. The study also relied mainly on laboratory biochemical analyses and statistical comparisons, without evaluating sensory properties, processing performance, or consumer acceptability. Multi-location and multi-season studies are required to confirm genotype stability.

Acknowledgements

The authors would like to thank the members of "Laboratoire Biosciences" and " Biochemistry and Food and Nutritional Technologies (LABIOTAN) " of "Université Joseph KI ZERBO"; and the "Center of Research Environmental Agricultural and Formation of Kamboinse" for their support in carrying out the study.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all authors, including contributions to study design, data generation, content development, results, interpretation, and related scholarly work. The authors acknowledge the use of Grammarly and ChatGPT for grammar checking, language refinement, and reference formatting. These AI-assisted tools were not credited as authors and did not replace the authors' intellectual contributions or scholarly judgement. All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the authors. The authors accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

References

Aboubakar. (2009). *Optimisation des paramètres de production et de conservation de la farine de taro (Colocasia esculenta)* [Doctoral dissertation, Institut National Polytechnique de Lorraine and Université de Ngaoundéré]. https://theses.fr/2009INPL005N

Association of Official Analytical Chemists. (1990). *Official methods of analysis of the Association of Official Analytical Chemists* (K. Helrich, Ed.; 15th ed., Vol. 1). https://sibr.nist.gov/record/official-methods-analysis-15th-edition-0

Atwater, W. O., & Benedict, F. G. (1899). *Experiments on the metabolism of matter and energy in the human body* (Bulletin No. 69). U.S. Department of Agriculture, Office of Experiment Stations. https://catalog.hathitrust.org/Record/009703311

Bado, S., Bazongo, P., Son, G., Kyaw, M. T., Forster, B. P., Nielen, S., Lykke, A. M., Ouédraogo, A., & Bassolé, I. H. N. (2015). Physicochemical characteristics and composition of three morphotypes of *Cyperus esculentus* tubers and tuber oils. *Journal of Analytical Methods in Chemistry, 2015*, Article 673547. https://doi.org/10.1155/2015/673547

Ban-Koffi, L., Nemlin, G. J., Le Fèvre, S., & Kamenan, A. (2009). Caractérisation physico-chimique et potentialités thérapeutiques du pois sucré (*Cyperus esculentus* L. [Cyperaceae]). *Agronomie Africaine, 17*(1), 63–71. https://doi.org/10.4314/aga.v17i1.1658

Bradford, M. M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilising the principle of protein-dye binding. *Analytical Biochemistry, 72*(1–2), 248–254. https://doi.org/10.1016/0003-2697(76)90527-3

Djomdi. (2015). *Contribution à l'amélioration du procédé de production de lait de souchet (Cyperus esculentus L.)* [Doctoral dissertation, Université de Ngaoundéré].

Edo, G. I., Ugbune, U., Ezekiel, G. O., Onoharigho, F. O., & Agbo, J. J. (2024). *Cyperus esculentus* (tiger nut): Its application in agriculture, food, health and nutrition. A review. *Vegetos, 37*(3), 757–766. https://doi.org/10.1007/s42535-023-00672-8

European Parliament & Council of the European Union. (2011). Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers. *Official Journal of the European Union, L 304*, 18–63. https://eur-lex.europa.eu/eli/reg/2011/1169/oj

Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, United Nations Children's Fund, World Food Programme, & World Health Organization. (2021). *The state of food security and nutrition in the world 2021: Transforming food systems for food security, improved nutrition and affordable healthy diets for all*. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cb4474en

Food and Agriculture Organization of the United Nations. (2023). *The state of food and agriculture 2023: Revealing the true cost of food to transform agrifood systems*. https://doi.org/10.4060/cc7724en

Food and Agriculture Organization of the United Nations. (2024). *The state of food and agriculture 2024: Value-driven transformation of agrifood systems*. https://doi.org/10.4060/cd2616en

Guinko, S. (1985). Contribution à l'étude de la végétation et de la flore du Burkina Faso (ex-Haute-Volta): Origine botanique de quelques outils et objets artisanaux en bois. *Journal d'Agriculture Traditionnelle et de Botanique Appliquée, 32*(1), 235–239. https://doi.org/10.3406/jatba.1985.3938

Haoua, B., Sani, I. S., Bibata, A., Iro, D. G., Toudou, A., & Yacoubou, B. (2024). Estimates of genetic parameters and agronomic variability of nutsedge (*Cyperus esculentus* L.) ecotypes collected in Niger. *Asian Journal of Plant Science and Research, 14*(2), Article 313. https://doi.org/10.36648/2249-7412.14.2.313

International Organization for Standardization. (1976). *Sweetened condensed milk—Determination of sucrose content—Polarimetric method* (ISO Standard No. 2911:1976). https://www.iso.org/standard/7951.html

International Organization for Standardization. (2007). *Cereals, pulses and by-products—Determination of ash yield by incineration* (ISO Standard No. 2171:2007). https://www.iso.org/standard/37264.html

International Organization for Standardization. (2009). *Oilseeds—Determination of oil content (Reference method)* (ISO Standard No. 659:2009). https://www.iso.org/standard/43169.html

Kombeleme, N. A., Some, K., Tiama, D., Tonde, H. W., Yamwemba, S., & Bationo/Kando, P. (2024). Genetic diversity of genotypes of tiger nut (*Cyperus esculentus* L.) using morphological descriptors in Burkina Faso. *International Journal of Biosciences, 25*(3), 21–31. https://doi.org/10.12692/ijb/25.3.21-31

Lenická, D., Fatrcová Šramková, K., Kováčiková, E., Gálik, B., Tomášová, K., Błaszczyk-Altman, M., Prčík, M., Bella, V., Huai, Y., Sun, P., & Kňažická, Z. (2025). Potential of tiger nuts (*Cyperus esculentus* L.) as a functional food: Nutritional composition, health-promoting properties, utilization, and contributions to sustainable agriculture. *Journal of Central European Agriculture, 26*(3), 733–748. https://doi.org/10.5513/JCEA01/26.3.4825

Luque de Castro, M. D., & Priego-Capote, F. (2010). Soxhlet extraction: Past and present panacea. *Journal of Chromatography A, 1217*(16), 2383–2389. https://doi.org/10.1016/j.chroma.2009.11.027

Mohammed, N. A., Mohamed Ahmed, I. A., & Babiker, E. E. (2011). Nutritional evaluation of sorghum flour (*Sorghum bicolor* L. Moench) during processing of injera. *World Academy of Science, Engineering and Technology, 51*, 58–62.

Nagata, M., & Yamashita, I. (1992). Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruit. *Nippon Shokuhin Kogyo Gakkaishi, 39*(10), 925–928. https://doi.org/10.3136/nskkk1962.39.925

Ndangui, C. B. (2015). *Production et caractérisation de farine de patate douce (Ipomoea batatas Lam.): Optimisation de la technologie de panification* [Doctoral dissertation, Université de Lorraine and Université Marien Ngouabi]. https://hal.univ-lorraine.fr/tel-01751669

Ndiaye, B. (2021). *Contribution à la valorisation des tubercules de souchet (Cyperus esculentus L.): Apport nutritionnel, itinéraires technologiques et propriétés galactogènes* [Doctoral dissertation, Université Cheikh Anta Diop de Dakar]. https://bibnum.ucad.sn/viewer.php?c=ths&d=ths_2021_0042

Ogodo, A. C., Daniel, B. N., & Hammuel, C. (2025). Assessment of nutritional and biochemical properties of tiger nut milk fermented with strains of lactic acid bacteria. *Asian Basic and Applied Research Journal, 7*(1), 539–555. https://doi.org/10.56557/abaarj/2025/v7i1197

Okafor, C. A., Afunwa, R. A., Ojukwu, M., Onyia, E. C., & Eneh, O. (2024). Comparison of yoghurt attributes prepared from tiger nut (*Cyperus esculentus* L.) and different forms of cow milk. *Asian Food Science Journal, 23*(9), 11–18. https://doi.org/10.9734/afsj/2024/v23i9740

Onuigbo, O. T., Nwamarah, J. U., Oparaji, E. H., Onuigbo, A. C., & Ogwo, B. O. (2024). Appraisal of proximate composition in tiger nut yogurts and selected commercially available yogurts in Enugu, Enugu State, Nigeria: A comparative study. *Journal of Applied Life Sciences International, 27*(1), 39–50. https://doi.org/10.9734/jalsi/2024/v27i1636

Ouedraogo, J. T., Sawadogo, M., Tignegre, J.-B., Drabo, I., & Balma, D. (2010). Caractérisation agro-morphologique et moléculaire de cultivars locaux de niébé (*Vigna unguiculata*) du Burkina Faso. *Cameroon Journal of Experimental Biology, 6*(1), 31–40. https://doi.org/10.4314/cajeb.v6i1.56878

Owusu Nyarko, R., & Owusu Boateng, P. (2016). Tiger nuts: A healthier pseudo-nut of all nuts in the tropics. *International Journal for Innovative Research in Multidisciplinary Field, 2*(12), 307–312.

Weather Station. (2022). *Meteorological records from the INERA Kamboinsé and INERA Farako-Bâ stations for the 2021–2022 agricultural season* [Unpublished dataset]. Institut de l'Environnement et de Recherches Agricoles. https://www.inera.bf/

Wu, Y., Mao, Q., Zhao, G., & Ye, F. (2024). Tiger nut (*Cyperus esculentus*) starch: Extraction, composition, structure, properties, modification and uses. *Sustainable Food Technology, 2*(3), 635–651. https://doi.org/10.1039/D3FB00246B

Yang, X., Niu, L., Zhang, Y., Ren, W., Yang, C., Yang, J., Xing, G., Zhong, X., Zhang, J., Slaski, J., & Zhang, J. (2022). Morpho-agronomic and biochemical characterisation of accessions of tiger nut (*Cyperus esculentus* L.) grown in the north temperate zone of China. *Plants, 11*(7), Article 923. https://doi.org/10.3390/plants11070923

Yertai, Y., Shao, Z., Gao, Y., Wei, Y., Li, W., Xie, L., & Mamet, T. (2025). Starch-flavonoid interactions from *Cyperus esculentus* L. (tiger nut) oil cake: Insight into structural and physicochemical properties and digestibility. *Food Chemistry: X, 30*, Article 102999. https://doi.org/10.1016/j.fochx.2025.102999

Yu, Y., Jiang, X., Lu, X., Zhang, T., Cai, R., Zheng, H., & Gao, F. (2024). Nutritional, structural and functional properties of protein fractions from tiger nut (*Cyperus esculentus* L.) seed meal. *Journal of Food Measurement and Characterization, 18*, 9867–9878. https://doi.org/10.1007/s11694-024-02925-9

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/162329