International Journal of Organic agricultural Research & Development
Volume 21 (3) (2026)

INFLUENCE OF INORGANIC FERTILIZERS RATES ON NUTRITIONAL QUALITY OF TIGER NUT (*Cyperus esculentus* L.) IN TWO AGRO-ECOLOGICAL ZONES

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ABSTRACT

Tiger nut (*Cyperus esculentus* L.) is an underutilized crop with considerable nutritional and health benefits, yet information on fertilizer effects on its nutritional quality remains scarce. This study evaluated the influence of inorganic fertilizer rates on the nutritional quality of tiger nut across two agro-ecological zones in Nigeria. Experiments were conducted at Igboora and Ogbomoso using a Randomized Complete Block Design with three replications. Treatments comprised urea (0, 30, 45, 60, 75 kg N/ha), single super phosphate (0, 30, 45, 60, 75 kg P_2O_5/ha), and muriate of potash (0, 30, 60, 90, 120 kg K_2O/ha). Data collected on vitamin composition, antioxidant content, proximate composition, and elemental composition were subjected to Analysis of Variance, with means separated using Duncan's Multiple Range Test at $p \leq 0.05$. Results demonstrated that fertilizer application significantly ($p<0.05$) enhanced all nutritional parameters at both locations. Vitamin C, B1, B3, and E concentrations increased progressively with fertilizer rates, with 75 (42.35 mg/100g), 135 kg P_2O_5/ha (46.65 mg/100g), and 135 kg K_2O/ha (43.55 mg/100g) producing the highest vitamin C values at Igboora. Antioxidant content (alkaloids, saponins, steroids) followed similar trends, peaking under 135 kg K_2O/ha (82.90 mg/100g steroids). Proximate composition showed that crude protein was highest at 60 kg N/ha (8.62%), while fat content peaked at 135 kg K_2O/ha (29.15%). Elemental composition revealed significant increases in potassium, calcium, phosphorus, iron, and zinc with fertilization, with 135 kg producing the highest zinc content (1.55 mg/100g). Igboora consistently recorded higher values than Ogbomoso across most parameters, attributed to superior initial soil fertility. The study concludes that fertilizer application, particularly at higher rates, significantly improves the nutritional quality of tiger nut tubers, with potassium demonstrating the most pronounced effects. Optimal fertilizer recommendations depend on the target nutritional parameter and end-use purpose. These findings provide critical information for developing fertilizer management strategies to enhance tiger nut nutritional quality and support its utilization in food and nutraceutical applications.

Keywords: Tiger nut, inorganic fertilizer, nutritional quality, vitamins, antioxidants, proximate composition, elemental composition

INTRODUCTION

Tiger nuts (*Cyperus esculentus*) also called underground walnut or yellow nuts belongs to the sedges family. It is a tiny tuber that can be roasted or used as sweet meat (Rebezov *et al.*, 2023). Tiger nut is erect, with yellowish-green leaves, triangular stem about 20 to 60 cm tall and golden-brown flower head. Superficial rhizomes that lead to the production of many tubers which store proteins, starches and other nutrients. Like other sedges, the plant is most frequently found inhabiting wet marshes and edges of streams and ponds where it grows in coarse turfs (Bazine and Arslanoğlu, 2020). In Nigeria, the Hausas call it "Aya", Yorubas "Imumu", the Igbos "Ofio", or "aki Hausa", in southern Nigeria. Tiger nut has many other common names which include, Zulu nut, yellow nut grass, ground almond, Chufa, edible rush, rush nut, duck potato etc. In spite of all these common names, tiger nuts tubers are familiar as tiger nut because it was first cultivated during Mesopotamia which is a cradle of civilization between the two rivers Tigris (Tiger) and Euphrates (Maduka and Ire, 2018). Tiger nuts are

widely cultivated around the world, however, the research on it is insufficient, which greatly limits their application (Novor and Donkor, 2024). In Nigeria, tiger nut is well grown in the middle belt and northern region, where it is sold locally and consumed uncooked. Three varieties are usually cultivated namely; yellow, brown and black. Among these only two varieties; yellow and brown are readily available in Nigeria market (Emurigho *et al.*, 2020).

Application of fertilizers ensures that plant receives the necessary nutrient required for optimal growth. Fertilizers contain essential nutrients required by the plant, including nitrogen, phosphorus and potassium. Nitrogen is equally said to be the motor of plant growth, and encourages early establishment of tiger nut plants, leading to increased biomass accumulation. Nitrogen application improves tuber initiation and development by ensuring a balance between vegetative and reproductive growth. Nitrogen fertilizer increases the number of tubers per plant and their fresh weight, leading to higher yields. Combining nitrogen with organic amendments (manure or compost) enhances soil health and long-term productivity (Adedayo *et al.*, 2026).

Phosphorus is essential for early root establishment and tuber formation. It stimulates root elongation and branching, allowing better water and nutrient absorption (Tan *et al.*, 2024). It promotes carbohydrate metabolism, ensuring sufficient energy for tuber development. It increased tuber set and uniform tuber growth, enhancing oil and protein content in tubers, increasing their commercial value. Phosphorus accelerates early tuber formation and reduced crop duration, which is beneficial in short growing seasons. Applying phosphorus near the root zone improves uptake efficiency, and the application of 30-60 kg P_2O_5 per hectare gave optimal tiger nut growth and yield (Abo-Elwafa and Ewees, 2020).

Potassium is vital for regulating water balance and nutrient transport in plants. It improves root growth and enhances nutrient absorption efficiency (Tan *et al.*, 2023). It increases chlorophyll content, leading to higher photosynthetic efficiency (Naumann *et al.*, 2020). Potassium strengthens plant cell walls and reduces susceptibility to fungal and bacterial infections. Applying potassium close to the root zone enhances uptake efficiency. The application of 60-90 kg K_2O per hectare has been recommended for optimal tiger nut growth and yield. Despite the nutritional and health benefits of tiger nuts, the production of tiger nut has attracted very little scientific and technological attention in the recent past. A lot of research has been done on yield improvement of tiger nut, but there has never been any report on the actual N, P and K requirements for tiger nut. Information regarding tiger nut nutrient requirements is scarce in published literature and fertilizer recommendation of tiger nut are varied from one agro-ecological zone to the others. This study therefore, determine the appropriate N, P, and K fertilizers rate required for optimum growth, yield and nutritional quality of tiger nut.

MATERIALS AND METHODS

Experimental Site Description

The experiments were conducted at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, and College of Agriculture and Technology, Igboora. Ogbomoso is located on latitude 8°10'N and longitude 4°10'E in the Southern Guinea Savanna Zone of Southwest Nigeria. Igboora is located in Latitude 7° 24 40.6'N and Longitude 3° 17 46.3'E, 397m above the sea level with two seasons of rainfall from April to October and dry season November to March.

Experimental Materials

Tiger nut yellow variety seeds were obtained from Kunlende market, Ilorin, Kwara State.

Fertilizer: N-fertilizer (Urea), P- fertilizer (Single Super Phosphate), K-fertilizer (Muriate of Potash) were obtained from Irorun Agbe Agro-allied Limited, Ogbomoso, Oyo State.

Soil Sampling and Analysis

Before the preparation of the site for tiger nut production, pre-planting collection of soil sample was carried out using soil auger at a depth of 0-15 cm, for laboratory analysis of the soil physical and chemical properties. The soil texture was also determined (Smyth and Montgomery, 1962; Bridges, 1997). Samples were bulked into composite sample. The sample was air dried, crushed and sieved through a 2 mm mesh respectively for the determination of particle size, pH, total nitrogen, organic carbon, available phosphorus, iron, copper, zinc, the exchangeable cations (Ca, Mg, Na and K) and exchangeable acidity. Bouyoucos (1951) hydrometer method was used to investigate particle size analysis by using sodium hexametaphosphate as a dispersant. Soil pH was determined in a 1:1 soil water ratio and 2:1 soil: KCl ratio

Total N was determined by using Kjeldahl method (Bremner, 1965) while the colorimeter was used to determine available P and exchangeable cations. Phosphorus and exchangeable cations were determined by

Mehlich 3 extractant (Mehlich, 1984). Phosphorus was determined colorimetrically while the cations were determined using Atomic Absorption Spectrophotometer (Model Buck 200A), and organic carbon was determined by chromic acid (Heanes, 1984).

Table 1 Physical and Chemical Properties of the Soil used

Parameter	Igboora	Ogbomoso
PH [H_20]	6.07	6.48
%Organic carbon	1.72	0.87
%Total nitrogen	0.26	0.17
Phosphorus(mg/kg)	33.6	9.97
Exch acidity(cmol\kg)	0.6	0.02
Ca(cmol\kg)	2.75	3.65
Mg (cmol\kg)	1.06	0.76
K(cmol\kg)	0.39	0.36
Na (cmol\kg)	0.24	0.54
Sand%	79	89.4
Salt%	11	5.8
Clay%	10	4.8

Land Preparation and Field Layout

The land was cleared and beds were constructed manually. The experimental field size was 40 m by 5.6 m and was divided into 45 beds of 1.2 m by 2.2 m each. The beds were replicated thrice, with each replicate having fifteen (15) treatments. Inter row bed spacing of 1 m was between replicates and intra row bed spacing of 0.5 m was used to allow easy movement in the experimental field.

Treatments and Experimental Design

Treatment involves three nutrient sources at five rates, each as follows:

Urea fertilizer: 5 levels of N rates – 0, 30, 45, 60 and 75 kg N/ha

SSP fertilizer: 5 levels of P rates – 0, 30, 45, 60 and 75 kg P_2O_5/ha

MOP fertilizer: 5 levels of K fertilizer – 0, 30, 60, 90 and 120 kg K_2O/ha

The trial was laid out in a Randomized Complete Block Design (RCBD), replicated three times.

Cultural Practices

Planting: Tiger nut seeds were soaked in water for 24 hours prior to planting. Two seeds of tiger nuts were planted per hole at depth of 7 cm and at plant spacing of 30 cm × 30 cm (Fabunmi and Oshikoya, 2016). The tiger nuts were treated with Seedrex (a mixture of permethrin and carbendazim) so as to prevent insect attack and rodents from eating them.

Thinning: Two seeds sowed per hole were thinned down to one seedling two weeks after planting to avoid overcrowding of the tiger nut plants.

Fertilizer Application: Fertilizer was applied four weeks after sowing using spot application to enhance plant performance.

Weeding: Weeding was done with the use of hoe and hand weeding at three weeks interval.

Phytonutrient Analysis

Flavonoid content: Total flavonoids content was extracted from 100 mg sample in 30% ethanol and 5% sodium nitrite was added to the supernatant and allowed to stand for 5 min, afterward 10% aluminium nitrate solution was added followed by the addition of sodium hydroxide. The absorbance was taken at 510 nm and standard curve of rutin was used for calculation.

Determination of vitamin C: 100 g sample was cut into small pieces and ground with a mortar and pestle. 10 cm^3 of distilled water was added several times and decanted into 100 mL volumetric flask. The ground pulp was strained through a cheese cloth; filtrate was collected and washed into volumetric flask. The extracted solution was made up to 100 mL with distilled water. 20 mL aliquots of the sample solution was pipetted into a 250 mL conical flask, 150 mL distilled water and 1 mL starch solution was added. The sample was titrated with 0.005 M iodine solution. The end point of the titration was identified as first permanent trace of dark blue colour due to the starch-iodine complex. The titration was repeated twice with further aliquot of sample solution until a constant result was obtained.

Determination of moisture content: The moisture content of tiger nut was measured using the oven-drying method. A known weight of tiger nut was dried in a hot air oven at 105°C until it reached a constant weight. The sample was then cooled in a desiccator and reweighed.

It is calculated using the formula:

Moisture content (%) = (W2 - W3) / (W2 - W1) × 100

Where:

W1 = weight of empty container

W2 = weight of container + fresh tiger nut

W3 = weight of container + dried tiger nut

Determination of ash content: The ash content of biological material is an analytical term for the inorganic residue that remains after organic matter has been burnt off. The crucibles were dried in an oven at 90°C for 30 min, and were transferred into the desiccator to cool and weighed; 5 g of each of the samples was weighed into the crucible and heated in a muffle furnace set at 500°C for 2 hours after which the crucible

was transferred into desiccator to cool and weighed. The percentage ash was then calculated as follows:

Crude Ash (%) = [(W3 - W1) / (W2 - W1)] × 100

Where:

W1 = weight of crucible

W2 = weight of crucible and sample before ashing

W3 = weight of crucible and sample after ashing

3.8.4 Antioxidant properties

The antioxidant properties of tiger nut (*Cyperus esculentus*) were analyzed using spectrophotometric and chromatographic methods as follows:

Determination of Total Antioxidant Capacity (TAC):

Ferric Reducing Antioxidant Power (FRAP) assay – absorbance at 593 nm

Phosphomolybdate Assay – absorbance at 695 nm

Determination of Free Radical Scavenging Activity:

DPPH Radical Scavenging Assay – absorbance at 517 nm

ABTS Radical Scavenging Assay – absorbance at 734 nm

Quantification of Antioxidant Compounds:

Total Phenolic Content (TPC) – Folin-Ciocalteu reagent, absorbance at 765 nm

Total Flavonoid Content (TFC) – $AlCl_3$ colorimetric method, absorbance at 415 nm

High-Performance Liquid Chromatography (HPLC) for antioxidants: HPLC-DAD was used for identifying and quantifying phenolic acids, flavonoids, and tannins in tiger nut extracts

was done with the use of hoe and hand weeding at three weeks interval.

Data Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using SAS 9.0 package and means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS

Effects of N, P and K Fertilizers Rates on Vitamin Composition of Tiger Nut at Different Weeks After Sowing (WAS)

The application of nitrogen fertilizer application significantly ($P<0.05$) influenced vitamin C, B1, B3, and E content at both locations as 75 kg N/ha (75 kg N/ha) recorded the highest values for vitamin C (42.35 mg/100g), vitamin B1 (4.36 mg/100g), vitamin B3 (5.28 mg/100g), and vitamin E (0.06 mg/100g), while the control recorded the lowest values (32.50, 2.43, 2.57, and 0.03 mg/100g respectively). At Ogbomoso, 75 kg N/ha also produced the highest concentration of all four vitamins (41.35, 4.26, 5.16, and 0.05 mg/100g), while the control produced the least (31.71, 2.37, 2.51, and 0.03 mg/100g). Vitamin concentrations increased progressively and significantly with nitrogen rate at both locations with 75 kg N/ha as the optimal rate (Table 2)

Phosphorus fertilizer application significantly ($P<0.05$) influenced vitamin composition at both locations. In Igboora, vitamin C was highest at 45 Kg P_2O_5/ha (46.65 mg/100g), while vitamins B1, B3, and E were highest at 75 Kg P_2O_5/ha (4.86, 4.80, and 0.06 mg/100g respectively). The control recorded the lowest values for all four vitamins (34.65, 2.43, 2.71, and 0.04 mg/100g). In Ogbomoso, vitamin C peaked at 45 Kg P_2O_5/ha (45.50 mg/100g) while B1, B3, and E peaked at 75 Kg P_2O_5/ha (4.74, 4.68, and 0.06 mg/100g). The results show that phosphorus application at higher rates (135 kg P_2O_5/ha) had the best performance and significantly enhanced vitamin accumulation in tiger nut tubers.

In Igboora, 120 Kg P_2O_5/ha (120 Kg P_2O_5/ha) recorded the highest values for vitamin C (43.55 mg/100g), B1 (5.01 mg/100g), B3 (5.97 mg/100g), and E (0.06 mg/100g), while the control recorded the lowest values (33.30, 2.49, 3.00, and 0.03 mg/100g). In Ogbomoso, 120 Kg P_2O_5/ha also produced the highest concentration of all four vitamins (42.50, 4.89, 5.83, and 0.06 mg/100g), while the control produced the lowest (32.50, 2.43, 2.93, and 0.03 mg/100g). The Igboora location consistently recorded higher values than Ogbomoso, while at the same time the vitamin concentrations increased progressively with potassium rate at both locations.

Table 2: Effects of N, P and K Fertilizers and Rates on Vitamin Composition of Tiger Nut

Fertilizer	Rate (kg/ha)	Ogbomoso				Igboora			
		VIT C	VIT B1	VIT B3	VIT E	VIT C (mg/100g)	VIT B1	VIT B3	VIT E
	0	31.71 e	2.37 d	2.51 e	0.03 c	32.50 e	2.43 e	2.57 e	0.03 d
	30	32.83 d	2.43 d	2.65 d	0.03 c	33.63 d	2.49 d	2.72 d	0.03 d
N	45	36.55 c	2.55 c	2.73 c	0.04 b	37.45 c	2.61 c	2.80 c	0.04 c
	60	39.46 b	3.63 b	3.92 b	0.04 b	40.45 b	3.72 b	4.02 b	0.04 b
	75	41.35 a	4.26 a	5.16 a	0.05 a	42.35 a	4.36 a	5.28 a	0.06 a
	0	33.80 d	2.37 e	2.64 e	0.04 e	34.65 e	2.43 e	2.71 e	0.04 e
	30	35.70 c	2.69 d	2.74 d	0.04 d	36.65 d	2.76 d	2.81 d	0.04 d
P	45	45.50 a	3.42 c	3.96 c	0.05 c	46.65 a	3.50 c	4.06 c	0.05 c
	60	42.50 b	4.69 b	4.46 b	0.05 b	43.55 c	4.81 b	4.57 b	0.06 b
	75	44.70a	4.74a	4.68a	0.06a	45.80b	4.86a	4.80a	0.06a
	0	32.50 e	2.43 d	2.93 d	0.03 d	33.30 e	2.49 d	3.00 d	0.03 d
	30	35.70 d	2.69 c	2.89 d	0.04 c	36.60 d	2.76 c	2.96 d	0.04 c
K	60	37.85 c	3.72 b	3.76 c	0.05 b	38.80 c	3.82 b	3.86 c	0.05 b
	90	40.95 b	4.83 a	4.90 b	0.05 b	41.95 b	4.95 a	5.02 b	0.05 b
	120	42.50a	4.89a	5.83a	0.06a	43.55a	5.01a	5.97a	0.06a

Means followed by the same letter(s) within a column (for each location separately) are not significantly different at $p \leq 0.05$.

Effects of N, P and K Fertilizers Rates on Antioxidant Content of Tiger Nut at Different Weeks After Sowing (WAS)

Nitrogen fertilizer application significantly ($P<0.05$) influenced alkaloid, saponin, and

steroid content at both locations. In Igboora, 75 kg N/ha (75 kg N/ha) recorded the highest alkaloid (4.36 mg/100g), saponin (0.19 mg/100g), and steroid (78.40 mg/100g) content, statistically similar to 60 Kg N/ha for alkaloids and saponins. The control recorded the lowest values (4.13, 0.17, and 67.25 mg/100g respectively). At Ogbomoso, 75 kg N/ha also produced the highest concentration ofall three antioxidants (4.25, 0.19, and 76.50 mg/100g), while the control produced the lowest (4.03, 0.16, and 65.60 mg/100g).

The Igboora location consistently recorded higher antioxidant values, with 60-75 kg N/ha significantly enhances antioxidant accumulation in tiger nut tubers.

Phosphorus fertilizer application significantly ($P<0.05$) influenced antioxidant content at both locations. In Igboora, alkaloid content was highest at 45 Kg P_2O_5/ha (4.25 mg/100g), while saponin and steroid content were highest at 75 Kg P_2O_5/ha (0.19 and 78.75 mg/100g). The control recorded the lowest values for saponin and steroid (0.17 and 68.95 mg/100g). In Ogbomoso, alkaloid content was highest at 45 Kg P_2O_5/ ha (4.14 mg/100g), while saponin and steroid content were highest at 75 Kg P_2O_5/ha (0.19 and 76.81 mg/100g). The control recorded the lowest values (0.16 and 67.25 mg/100g). The Igboora location consistently recorded higher antioxidant values than Ogbomoso.

Potassium fertilizer application significantly ($P<0.05$) influenced alkaloid, saponin, and steroid content at both locations. At Igboora, 120 Kg P_2O_5/ha recorded the highest alkaloid (4.39 mg/100g), saponin (0.20 mg/100g), and steroid (82.90 mg/100g) content, while the control recorded the lowest values (4.16, 0.16, and 72.35 mg/100g respectively). At Ogbomoso, 120 Kg P_2O_5/ha also produced the highest concentration of all three antioxidants (4.28, 0.19, and 80.90 mg/100g), while the control produced the lowest (4.06, 0.16, and 70.60 mg/100g). The Igboora location recorded higher values across all treatments, showing superior soil fertility. Antioxidant concentrations increased progressively with potassium rate at both locations.

Table 3: Effects of N, P and K Fertilizers and Rates on Antioxidant Content of Tiger Nut

Fertiliz er	Rate (kg/ha)	Ogbomoso			Igboora		
		Alkaloids	Saponins	Steroids (mg/100g)	Alkaloids	Saponins	Steroids
N	0	4.03 c	0.16 d	65.60 e	4.13 d	0.17 d	67.25 e
	30	4.07 c	0.17 c	68.63 d	4.17 c	0.18 c	70.35 d
	45	4.13 b	0.18 b	70.95 c	4.24 b	0.18 b	72.75 c
	60	4.22 a	0.18 a	74.13 b	4.33 a	0.19 a	76.00 b
	75	4.25 a	0.19 a	76.50 a	4.36 a	0.19 a	78.40 a
P	0	4.10 b	0.16 e	67.25 e	4.20 c	0.17 e	68.95 e
	30	4.05 c	0.17 d	70.10 d	4.15 e	0.17 d	71.85 d
	45	4.14 a	0.17 c	72.35 c	4.25 a	0.18 c	74.15 c
	60	4.08 b	0.18 b	74.50 b	4.18 d	0.18 b	76.35 b
	75	4.13 a	0.19 a	76.81 a	4.23 b	0.19 a	78.75 a
K	0	4.06 c	0.16 e	70.60 e	4.16 d	0.16 e	72.35 e
	30	4.07 c	0.17 d	73.70 d	4.17 d	0.17 d	75.55 d
	60	4.14 b	0.18 c	75.85 c	4.24 c	0.18 c	77.75 c
	90	4.26 a	0.18 b	77.50 b	4.36 b	0.18 b	79.40 b
	120	4.28 a	0.19 a	80.90 a	4.39 a	0.20 a	82.90 a

Means followed by the same letter(s) within a column (for each location separately) are not significantly different at $p \leq 0.05$.

Effects of N, P and K Fertilizers Rates on Proximate Composition of Tiger Nut at Different Weeks After Sowing (WAS)

Application of nitrogen fertilizer significantly ($P<0.05$) influenced crude protein, crude fibre, fat, ash, and moisture content at both locations (Table 4a). In Igboora, crude protein and ash were highest at 60 Kg N/ha (8.62% and 6.10%), while crude fibre, fat, and moisture were highest at 75 kg N/ha (11.25%, 26.40%, and 49.90%). The control recorded the lowest values across all parameters (7.93%, 10.08%, 20.10%, 5.90%, and 48.25%). In Ogbomoso, crude protein and ash were highest at 60 Kg N/ha (8.41% and 5.95%), while crude fibre, fat, and moisture were highest at 75 kg N/ha (10.97%, 25.76%, and 48.67%). The Igboora location consistently recorded higher values across most proximate parameters compared to Ogbomoso.

In Igboora, crude protein was highest at 45 Kg P_2O_5/ha (8.15%), crude fibre and fat were highest at 75 Kg P_2O_5/ha (11.65% and 27.40%), ash was highest at 60 Kg P_2O_5/ha (6.33%), and moisture was highest at 75 Kg P_2O_5/ha (50.15%). At Ogbomoso, crude protein was highest at 45 Kg P_2O_5/ha (7.95%), crude fibre and fat were highest at 75 Kg P_2O_5/ha (11.35% and 26.73%), ash was highest at 60 Kg P_2O_5/ha (6.17%), and moisture was highest at 75 Kg P_2O_5/ha (48.92%). Just as other nutritive parameters, Igboora location recorded higher values across most parameters

In Igboora, 120 Kg P_2O_5/ha recorded the highest values for crude protein (8.37%), crude fibre (12.00%), fat (29.15%), ash (6.70%), and moisture (49.60%), while the control recorded the lowest values for all five parameters (7.96%, 10.18%, 19.70%, 6.05%, and 48.60%). In Ogbomoso, 120 Kg P_2O_5/ha recorded the highest values for crude protein (8.17%), crude fibre (11.71%), fat (28.43%), ash (6.54%), and moisture (48.41%). The control recorded the lowest values (7.76%, 9.93%, 19.23%, 5.90%, and 47.44%).

Table 4a: Effects of N, P and K Fertilizers and Rates on Proximate Composition of Tiger Nut (CP, CF and Fat)

er	(kg/ha)	Ogbomoso			Igboora		
		CP (%)	CF (%)	Fat (%)	CP (%)	CF (%)	Fat (%)

	0	7.73 c	9.83 e	19.60 e	7.93 c	10.08 e	20.10 e
	30	7.83 bc	9.95 d	21.50 c	8.03 c	10.20 d	22.05 c
N	45	7.93 bc	10.71 c	20.83 d	8.13 bc	10.98 c	21.35 d
	60	8.41 a	10.93 b	23.70 b	8.62 a	11.20 b	24.30 b
	75	8.16 ab	10.97 a	25.76 a	8.36 ab	11.25 a	26.40 a
	0	7.85 b	9.84 d	18.63 e	8.05 c	10.09 e	19.10 e
	30	7.76 d	9.93 c	20.42 d	7.96 e	10.18 d	20.95 d
P	45	7.95 a	10.92 b	22.83 c	8.15 a	11.20 b	23.40 c
	60	7.81 c	10.87 b	24.57 b	8.01 d	11.15 c	25.20 b
	75	7.92 a	11.35 a	26.73 a	8.12 b	11.65 a	27.40 a
	0	7.76 c	9.93 d	19.23 e	7.96 c	10.18 e	19.70 e
	30	7.81 bc	10.09 d	22.06 d	8.01 c	10.35 d	22.60 d
K	60	7.93 b	10.56 c	24.62 c	8.13 b	10.82 c	25.25 c
	90	8.09 a	10.76 b	26.79 b	8.29 a	11.03 b	27.45 b
	120	8.17 a	11.71 a	28.43 a	8.37 a	12.00 a	29.15 a

Means followed by the same letter(s) within a column (for each location separately) are not significantly different at $p \leq 0.05$.

Table 4b: Effects of N, P and K Fertilizers and Rates on Proximate Composition of Tiger Nut (Ash and MC)

Fertilizer	Rate (kg/ha)	Ogbomoso		Igboora	
		Ash (%)	MC (%)	Ash (%)	MC (%)
	0	5.75d	47.11 d	5.90 d	48.25 e
	30	5.83c	47.82 c	5.98 c	48.95 d
N	45	5.87b	47.95 c	6.02 b	49.10 c
	60	5.95 a	48.27 b	6.10 a	49.45 b
	75	5.83 c	48.67 a	5.98 c	49.90 a
	0	5.85 c	47.83 c	6.00 d	49.05 d
	30	5.94 b	47.83 c	6.09 c	49.05 d
P	45	6.13 a	47.91 c	6.28 b	49.10 c
	60	6.17 a	48.62 b	6.33 a	49.85 b
	75	5.85 c	48.92 a	6.00 d	50.15 a
	0	5.90 d	47.44 c	6.05 d	48.60 c
	30	5.95 cd	47.54 bc	6.10 d	48.70 c
K	60	6.15 bc	47.79 abc	6.30 c	48.95 bc
	90	6.37 ab	48.18 ab	6.53 b	49.35 ab
	120	6.54 a	48.41 a	6.70 a	49.60 a

Means followed by the same letter(s) within a column (for each location separately) are not significantly different at $p \leq 0.05$ (DMRT).

Effects of N, P and K Fertilizers Rates on Elemental Composition of Tiger Nut at Different Weeks After Sowing (WAS)

Statistical analysis revealed that nitrogen fertilizer application significantly ($P<0.05$) influenced potassium, calcium, phosphorus, iron, and zinc content at both locations (Table 5a). At Igboora, 75 kg N/ha (75 kg N/ha) recorded the highest values for potassium (289.65 mg/100g), calcium (56.75 mg/100g), phosphorus (179.10 mg/10g), iron (3.04 mg/100g), and zinc (1.20 mg/100g), while the control had the lowest values for all five elements (264.60, 44.55, 160.40, 2.86, and 0.95 respectively). At Ogbomoso, 75 kg N/ha also recorded the highest values for potassium (282.60 mg/100g), calcium (55.35 mg/100g), phosphorus (174.75 mg/10g), iron (2.97 mg/100g), and zinc (1.17 mg/100g). The control had the lowest values (258.12, 43.48, 156.50, 2.78, and 0.93 respectively).

In Igboora, 75 Kg P_2O_5/ha (135 kg P_2O_5/ha) recorded the highest values for potassium (289.05 mg/100g), calcium (56.10 mg/100g), phosphorus (180.65 mg/10g), and zinc (1.20 mg/100g), while iron was highest at 60 Kg P_2O_5/ha (2.98 mg/100g), statistically similar to 75 Kg P_2O_5/ha(2.99 mg/100g). The control recorded the lowest values across all five elements. In Ogbomoso, 75 Kg P_2O_5/ha recorded the highest values for potassium (282.00 mg/100g), calcium (54.75 mg/100g), phosphorus (176.27 mg/10g), and zinc (1.17 mg/100g), while iron was highest at 60 Kg P_2O_5/ha (2.91 mg/100g). The Igboora location recorded higher elemental concentrations across all treatments.

In Igboora, 120 Kg P_2O_5/ha (120 Kg P_2O_5/ha) recorded the highest values for potassium (289.20 mg/100g), calcium (64.95 mg/100g), phosphorus (184.75 mg/10g), iron (3.04 mg/100g), and zinc (1.55 mg/100g), while the control recorded the lowest values for all five elements (267.00, 45.55, 164.50, 2.78, and 0.95 respectively). In Ogbomoso, 120 Kg P_2O_5/ha recorded the highest values for potassium (282.15 mg/100g), calcium (63.35 mg/100g), phosphorus (180.25 mg/10g), iron (2.97 mg/100g), and zinc (1.51 mg/100g). The control recorded the lowest values (260.40, 44.45, 160.50, 2.71, and 0.93, respectively).

Table 5a: Effects of N, P and K Fertilizers and Rates on Elemental Composition of Tiger Nut (K, Ca and P)

Fertilizer	(kg/ha)	Ogbomoso			Igboora		
		K (mg/100g)	Ca (mg/100g)	P (mg/10g)	K (mg/100g)	Ca (mg/100g)	P (mg/10g)
	0	258.12 e	43.48 e	156.50 e	264.60 e	44.55 e	160.40 e
	30	264.15 d	45.70 d	160.95 d	270.75 d	46.85 d	164.95 d
N	45	270.75 c	48.25 c	166.60 c	277.50 c	49.45 c	170.75 c
	60	274.50 b	52.50 b	170.50 b	281.35 b	53.80 b	174.75 b
	75	282.60 a	55.35 a	174.75 a	289.65 a	56.75 a	179.10 a
	0	266.25 c	52.00 c	160.70 c	268.80 e	47.65 e	161.80 e
	30	275.75 b	59.60 b	173.50 b	273.75 d	48.60 d	166.75 d
P	45	284.75 a	67.05 a	183.90 a	277.40 c	52.10 c	169.90 c
	60	266.25 c	52.00 c	160.70 c	284.30 b	53.95 b	175.10 b
	75	275.75 b	59.60 b	173.50 b	289.05 a	56.10 a	180.65 a
	0	264.10 c	51.65 c	165.90 c	267.00 e	45.55 e	164.50 e
	30	274.95 b	60.60 b	179.60 b	273.25 d	53.00 d	169.80 d
K	60	289.17 a	66.32 a	188.40 a	281.10 c	55.85 c	177.00 c
	90	264.10 c	51.65 c	165.90 c	285.25 b	61.90 b	181.15 b
	120	274.95 b	60.60 b	179.60 b	289.20 a	64.95 a	184.75 a

Means followed by the same letter(s) within a column (for each location separately) are not significantly different at $p \leq 0.05$ (DMRT).

Table 5b: Effects of N, P and K Fertilizers and Rates on Elemental Composition of Tiger Nut (Fe and Zn)

Fertilizer	Rate (kg/ha)	Ogbomoso		Igboora	
		Fe (mg/100g)	Zn (mg/100g)	Fe (mg/100g)	Zn (mg/100g)
	0	2.78 d	0.93 d	2.86 e	0.95 e
N	30	2.84 c	0.96 c	2.91 d	0.98 d
	45	2.90 b	1.11 b	2.98 c	1.14 c
	60	2.94 ab	1.15 a	3.01 b	1.18 b
	75	2.97 a	1.17 a	3.04 a	1.20 a
	0	2.87 b	1.03 c	2.80 c	0.97 e
	30	2.91 b	1.15 b	2.83 c	0.99 d

K	60	3.44 a	1.31 a	2.99 c	1.20 b
	90	2.85 b	1.20 a	3.02 b	1.25 b
	120	2.94 b	1.21 a	3.04 a	1.55 a

Means followed by the same letter(s) within a column (for each location separately) are not significantly different at $p \leq 0.05$ (DMRT).

DISCUSSION

Vitamin Composition

The progressive increase in vitamin C, B1, B3, and E concentrations with rising fertilizer rates demonstrates that fertilization directly influences tuber biochemistry beyond agronomic performance. This finding aligns with Novor *et al.* (2025), who reported that fertilizer type and rate were dominant drivers of compositional change in tiger nut across different seasons and locations. The consistency of vitamin responses between Igboora and Ogbomoso, despite substantial differences in growth and yield, suggests vitamin biosynthesis responds primarily to nutrient supply rather than site-specific conditions. The physiological mechanisms underlying these responses differ among nutrients: nitrogen's contribution under N75 likely reflects its direct involvement in amino acid metabolism and enzyme cofactor production, as several B-vitamins function as coenzymes within nitrogen-dependent pathways. Potassium's superior performance across all vitamins under K135 plausibly stems from its role in enzyme activation, osmotic regulation, and translocation of photosynthetic products from leaves to developing tubers (Tan *et al.*, 2024). Phosphorus enhances vitamin B1 accumulation through ATP-dependent biosynthesis pathways, with Havlin *et al.* (2016) emphasizing that adequate phosphorus supply underwrites the energy budget required for biochemical work in developing tubers. The dose-dependent vitamin accumulation observed in this study, particularly the vitamin C peak under P75 (46.65 mg/100g), is consistent with findings by Zheng *et al.* (2024) on nitrogen-driven gains in photosynthetic capacity. The practical implication is that nutritional quality in tiger nut can be reliably enhanced through fertilizer management without extensive consideration of growing location, providing opportunities for targeted biofortification strategies.

Antioxidant Content

The significant increases in alkaloids, saponins, and steroids with fertilizer application indicate that primary nutrient supply supports both primary metabolism and secondary metabolite production. The near-equivalence of antioxidant values across both sites, contrasting with sharp site differences in growth and yield, reinforces that tuber biochemistry tracks treatment more reliably than location (Novor *et al.*, 2025). The divergent responses of different antioxidant compounds to specific fertilizers suggest distinct biosynthetic pathways: alkaloids, drawing mainly on nitrogen-derived amino acid precursors, peaked at intermediate P75 (4.25 mg/100g), while saponins and steroids, running through isoprenoid pathways dependent on phosphorus-fueled energy metabolism, peaked at P135 (0.19 and 78.75 mg/100g respectively) (Novor and Donkor, 2024). Potassium's particularly strong effect on steroid content (82.90 mg/100g at K135) aligns with potassium's established role in maintaining cell turgor and ferrying metabolic precursors toward storage tissue (Tan *et al.*, 2023). This finding has direct relevance for functional food marketing, as these secondary metabolites are central to tiger nut's antioxidant and health benefits (Wongnaa *et al.*, 2019). Fadeyi *et al.* (2023) demonstrated that organic amendments can further enhance biochemical defense status, suggesting potential for combining mineral and organic fertilization to optimize antioxidant accumulation. The observed increases in these bioactive compounds under fertilizer treatment indicate that agronomic management can deliberately shape tiger nut's phytochemical profile, supporting its utilization in nutraceutical applications. However, alkaloid biosynthesis appeared comparatively insensitive to nitrogen supply within the tested range, warranting further investigation into optimal rates for specific antioxidant compounds.

Proximate Composition

Crude protein, fibre, fat, and ash all exhibited dose-dependent increases with fertilizer application, though some parameters showed non-linear responses where values declined beyond optimal rates. The highest crude protein values under N60 (8.62% at Igboora) reflect nitrogen's central role in amino acid and protein synthesis, consistent with Adedayo *et al*., (2026) and Zheng *et al.* (2024) who reported nitrogen-driven gains in leaf area and canopy photosynthetic capacity feeding into greater protein deposition in tubers. The fat response under phosphorus (27.40% at P135) and potassium (29.15% at K135) fits with these nutrients' roles in lipid metabolism: phosphorus supports phospholipid synthesis and energy-transfer steps of fatty acid production, while potassium enables enzyme activation and osmotic conditions favouring oil accumulation (Naumann *et al.*, 2020). This has practical importance, as tiger nut is recognized as a non-conventional oilseed of commercial interest, and fertilizer regimes that reliably increase fat content are directly useful for oil extraction purposes. The convergence of proximate values between the two sites, despite divergent growth

and yield responses, reinforces that composition is governed mainly by fertilizer input rather than site-specific conditions (Novor *et al.*, 2025). The nitrogen-driven proximate gains align with similar findings in potato and maize, where balanced macronutrient management shifted tuber and grains quality traits (Adedayo *et al*., 2026; Tucho *et al.*, 2024). The observation that N60 favours protein-rich material while K120 favours oil-rich material suggests fertilizer regimes can be chosen to match intended end-use, whether for flour, oil, or general processing. This flexibility in managing tiger nut composition through fertilization has direct implications for processors and farmers targeting specific markets.

Elemental Composition

The significant increases in potassium, calcium, phosphorus, iron, and zinc with fertilization demonstrate that nutrient application enhances uptake of elements beyond those directly applied, indicating synergistic effects likely mediated by improved root development under adequate fertility (Adedayo *et al*., 2026). The zinc response under K135 (1.55 mg/100g compared to 0.95 at control at Igboora) deserves particular attention, given widespread zinc deficiency among populations reliant on tiger nut as dietary staple, suggesting a biofortification pathway achievable through potassium fertilization without compromising yield (Munialo *et al.*, 2024). Potassium's contribution to mass flow provides a coherent explanation for enhanced accumulation of divalent cations such as calcium and zinc under higher potassium treatment (Tan *et al.*, 2024). Phosphorus encourages root proliferation and root-hair development, expanding the soil volume plants can effectively mine for cations, accounting for the strong elemental response under P135 (Fabunmi and Amalahu, 2019). The close agreement in elemental values between sites, despite different growth responses, fits the recurring theme that composition traits in tiger nut are governed mainly by fertilizer input (Novor *et al.*, 2025). This aligns with broader arguments that under-researched crops like tiger nut deserve greater research investment due to their untapped potential for food and nutrition security (Munialo *et al.*, 2024). The consistent elemental enrichment under fertilization has implications for addressing micronutrient deficiencies, particularly in regions where tiger nut constitutes a dietary staple. However, the finding that magnesium and iron were highest in unfertilized controls suggests complex interactions warranting further investigation into the mechanisms governing mineral accumulation in tiger nut.

CONCLUSION

This study conclusively demonstrates that inorganic fertilizer application significantly enhances the nutritional quality of tiger nut (*Cyperus esculentus* L.) across vitamin, antioxidant, proximate, and elemental composition parameters. Higher fertilizer rates consistently produced superior nutritional outcomes, with potassium showing particularly pronounced effects on most parameters. The Igboora location outperformed Ogbomoso on yield-related traits, while nutritional composition tracked fertilizer treatment more closely than location, suggesting quality can be reliably managed through fertilizer inputs. These findings provide a scientific basis for developing fertilizer recommendations that optimize tiger nut's nutritional value for specific end-uses.

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