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Effect of Mineral Fertilisation on Tuber Yield and Quality in Yams (*Dioscorea alata* and *Dioscorea rotundata*)

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Abstract: This study assessed the impact of mineral fertilization on tuber yield and food quality of yam genotypes, specifically *Dioscorea alata* and *Dioscorea rotundata*. Four genotypes, each from *D. alata* and *D. rotundata,* were used in field experiments conducted in Ibadan, Nigeria, in the 2017 and 2018 cropping seasons. Experiments were conducted under low soil NPK fertility conditions with and without fertiliser treatments. A recommended NPK rate for the area (90, 50, and 75 Kg N, P, K ha^{-1}) was applied to plots with fertiliser treatment. Tuber yield, functional and pasting properties of yam flour, and sensory attributes of pounded yams were collected. The results showed differential responses of the genotypes to tuber yield and food quality with fertiliser application. Fertiliser application has generally increased fresh tuber yield, but it has affected some genotypes' flour quality and textural attributes of the pounded yams. As regards genotypes Danacha and TDa0200012, fertiliser application has increased tuber yield without causing a decrease in tuber quality hence, suggesting Danacha and TDa0200012 as suitable genotypes for maximizing fertiliser productivity. However, in another genotype Ojuiyawo, fertiliser application effectively increased tuber yield but deteriorated tuber quality. Our results suggested that it is crucial to determine the impact of fertilisation on tuber yield and quality for each genotype and select the appropriate genotype to improve productivity through mineral fertilisation. The results of this study can be widely applied to enhance yam productivity in sub-Saharan Africa and useful for sustainable agriculture in yam-growing areas.

Keywords: Fertiliser application; sensory evaluation; functional and pasting properties of flour; pounded yam

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1. Introduction

Yam (*Dioscorea* spp.) is the collective name for edible species of the genus *Dioscorea* that are found in tropical, subtropical, and temperate regions [1]. Yam is a significant crop in West African food and culture [2], contributing 66.8 million tons (93%) to global production [3]. Yams are a dietary staple for 155 million people, with cultural significance and medicinal uses in some communities [2,4,5]. Enhancing yam productivity is essential for meeting growing demand and ensuring food security in the region. Pounded yams are a popular traditional West African dish, with consumers considering viscous and elastic pounded yams as a high-quality food [6]. In addition to pounded yam, yam flour is an important staple food produced from dried yam tubers in West Africa. The functional and pasting properties of *Dioscorea alata* and *Dioscorea rotundata* flours influence the quality of pounded yams and interspecific differences in these landraces have been reported [7–11]. Baah et al. [9] observed that the trough viscosity of flour is associated with the consistency and elasticity of pounded

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yams, and the final viscosity is most commonly used to evaluate the quality of flour samples because it reflects the capacity for forming viscous pastes after cooking and cooling.

In West Africa's forest-savannah zone, yams are traditionally planted after a 20-year fallow period owing to their nutrient-rich soil requirements [12]. However, population growth and competition for land have reduced the fallow period to less than five years [2,13]. This reduction in the fallow period is a significant obstacle for yam producers because of the decline in soil fertility in intensively cultivated areas [4]. Fertiliser use in sub-Saharan Africa is low because of the perceived lack of profitable opportunities and risks [14]. Research efforts have been directed toward improving the yield of yam tubers using fertilisers. In nutrient-deficient African savanna soils, fertiliser input has a positive effect on yam crops, but this effect is significantly less pronounced in fertile forest soils [15–17]. Nevertheless, crop yield can be improved with appropriate fertiliser input when soil nutrient status is considered. Although the effects of fertiliser application on tuber productivity have been verified, very little information is available regarding the effects of fertiliser application on yam tuber quality traits. A commonly held opinion in West Africa is that chemical fertilisers negatively affect the storage of yam tubers and their organoleptic qualities, mainly with respect to pounded yams [18]. Fertilisation affects the physicochemical properties of sweet potatoes [19] and cassava [20]; however, the effects of fertilisers on yam-based food quality are not well documented. Yam as a traditional staple food crop with a high local preference in West Africa, it is important to understand the effects of fertilisers on its tuber quality. The use of fertilisers is necessary to boost yam productivity and therefore, the effects of fertilisers on tuber quality should be investigated [21]. This study aimed to define yam cultivation best practices by evaluating the effects of fertilisation on tuber yield and quality.

2. Materials and Methods

2.1. Planting materials and experimental design

This study was conducted during the 2017 and 2018 cropping seasons (April to January) at the International Institute of Tropical Agriculture (IITA) experimental field in Ibadan, Nigeria. The genotypes were selected based on their textural qualities, which were determined by consumer preferences. Genotypes were obtained from the yam germplasm of the IITA, Ibadan, Nigeria. The yam genotypes and their origins are listed in **Table 1**. Clean tubers were visually assessed to select those without signs of rot or pests that were then used as the seed tuber material for planting in May 2017 and May 2018. The seed tubers were treated with a mixture of 70 g mancozeb (fungicide) and 75 ml chlorpyrifos (insecticide) in 10 l tap water for 5 min and then dried for 20 h in the shade before planting. The treated seed tubers were planted on ridges that were 1 m apart, with 1 m spacing between plants at a planting density of 10,000 plants per hectare on 15th May 2017 and 14th May 2018. The experimental fields had the following soil chemical properties: soil pH of 5.7 in 2017 and 6.1 in 2018; 0.06% total nitrogen in 2017 and 0.10% in 2018; 0.61% organic carbon in 2017 and 0.36% in 2018; 4.26 mg kg soil^{-1} available phosphorus in 2017 and 2018, and 0.12 cmol[+] kg^{-1} exchangeable potassium in 2017 and 1.19 cmol[+] kg^{-1} in 2018.

Table 1. *The* accession, local name, description and source information for *Dioscoare rotundata* and *Dioscoare alata* genotypes used in this study.

Genotype	Local/another name	Description	Source
D. rotundata			
Danacha	Danacha	Langrace	Zakibiam, Niger state
Hembakwase	Hembakwase	Langrace	Agyaragu, Nasarawa state
Ojuiyawo	Ojuiyawo	Langrace	Igboho, Oyo State
TDr9518544		Breedling line	IITA
D. alata			

TDa0000194		Breedling line	IITA
TDa0200012		Breedling line	IITA
TDa291	Florido	Introduction from Puerto Rico	IITA
TDa9801176		Breedling line	IITA

The field experiment was conducted using a split-plot randomised block design with three replicates and 12 plants per replicate. The main plot consisted of non-fertilised and fertilised treatments, and the subplot consisted of the different genotypes. Based on the chemical properties of the soil in the experimental plot and reported methods [22], the recommended nitrogen (N), phosphorus (P), and potassium (K) fertiliser application was determined for low soil fertility conditions for yam cultivation in Nigeria. The fertilised plots (+F) received 90 N, 50 P, and 75 K kg N per hectare. There was a 3 m channel between the replicates and a 10 m channel between the fertiliser treatments. The NPK fertiliser was applied when yam seed tubers were planted using the side-dressing method. Weeds were manually removed to maintain weed-free plots throughout the experiments.

2.1. Determination of fresh tuber weight

Tubers were harvested after complete senescence of the aerial parts in December 2017 and 2018 for *D. rotundata*, and January 2018 and 2019 for *D. alata*. The number of plants harvested per genotype was recorded. The total weight of the fresh tubers was recorded for all harvested tubers.

2.3. Tuber sampling for sensory evaluation of pounded yam.

Three representative tubers were selected from each replicate of each treatment block and washed. The proximal and distal ends were removed to prevent anisotropic effects. The remaining middle portion was divided into four longitudinal sections, with three segments used to prepare the pounded yam. The remaining segment was used to determine the moisture content of the tubers and to prepare the yam flour.

2.4. Moisture content of tuber and yam flour preparation

Approximately 150 g peeled yam tubers were processed into thin strips using a grater and dried in a conventional oven at 60°C for 72 h until a constant weight was reached to determine the moisture content [10]. The total tuber dry weight was determined by multiplying the total fresh tuber weight by the percent dry matter of the tuber. The resulting dried chips were weighed, recorded, milled into flour, and sieved through a 500-μm screen for further evaluation of the functional and pasting properties of the yam flour samples. The fine flour obtained from each genotype was packaged separately in well-labelled zip-locked bags.

2.5. Functional and pasting properties of yam flour

2.5.1. Water binding capacity

The water binding capacity (WBC) of the yam flour was determined using modified methods reported for cassava starch [23] and yam flour [8]. To perform the analysis, approximately 1 g yam flour and 10 ml distilled water were added to a centrifuge tube. The mixture was manually swirled and shaken for 30 min, followed by centrifugation at 2,200 rpm for 30 min. The supernatant was then decanted and the weight of the sample containing the absorbed water was recorded. The analysis was conducted in triplicate and the mean value was reported as grams of water absorbed per 100 g yam flour.

2.5.2. Swelling power and solubility index

The swelling power and solubility index of yam flour samples were determined using the protocol described by Afoakwa et al. [23]. Yam flour (0.5 g) was placed in a pre-weighed centrifuge tube, to which 10 ml distilled water was added. The mixture was manually agitated and then heated in a shaking water bath at 85°C for 30 min. The samples were allowed to cool for 15 min and centrifuged at 2,200 rpm for 10 min, after which the supernatants were decanted and weighed. The residue remaining in the centrifuge tube was weighed to determine the solubility index. The solubility index was determined by decanting the supernatant into a pre-weighed moisture tube and dried to a constant weight at 110°C before being weighed.

2.5.3. Pasting properties

The pasting properties were determined using a Rapid Visco Analyser (RVA-TecMaster, Parten Instruments, Australia). The modified yam flour protocol used a Perten Instrument [24]. Yam flour samples of 2.5 g *D. rotundata* and 3.0 g *D. alata* were each mixed with 25 ml distilled water in an RVA sample container after correcting for the moisture content of the original yam flour. The mixture was thoroughly stirred, and the canister was fixed to the RVA following the manufacturer's instructions. The RVA was conducted using Thermocline for Windows software (version 3.15.3.347). The time–temperature regime used a heating and cooling cycle set to (1) holding at 50°C for 1 min, (2) heating to 95°C for 3 min 42 s, (3) holding at 95°C for 3 min 30 s, (4) cooling to 50°C for 3 min 48 s, and (5) holding at 50°C for 5 min. The speed of the RVA paddle was 960 rpm during the first 10 s of testing before the speed was subsequently reduced to 160 rpm. The RVA results are displayed as viscosity in rapid viscosity units (RVUs). The corresponding values for peak viscosity, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time, and pasting temperature from the pasting profile were measured using a computer connected to the RVA.

2.6. Sensory evaluation of pounded yam

2.6.1. Pounded yam preparation

Approximately 900 g peeled yam tubers were washed and cut into uniform cubes. The yams were then cooked for 30 min without salt using the cooking regime for a Qasa Yam Pounder and Cooker (QYP-6000, Qlink Corporation, China) with steady heat. After cooking, the knob on the pounder was switched from cooking to pounding mode and the yam samples were pounded for 5 min (*D. rotundata*) or 7 min (*D. alata*) using a spatula to spin the mashed yam around the blade. The yam pounder contained a compartment for water and the same volume of water (350 ml) was used for each yam variety. After pounding, approximately 2 g from each yam sample was wrapped in aluminium foil, stored in labelled zip-locked bags, and placed in a warmer until evaluation. Each yam genotype was cooked separately and labelled.

2.6.2. Panellist selection and training

The panellists for this study were selected based on their availability, familiarity with and passion for consuming pounded yams, and their previous experience in sensory evaluation. The training program consisted of two sessions. During the first session, the attributes and quality descriptors for pounded yams were defined and explained using food samples as previously described [25] with some modification. Training was conducted in a controlled environment to minimise external influences. The evaluated attributes included stretchability, stickiness, moldability, hardness, and smoothness. A preliminary test was conducted during the second session to ensure that the panellists had a comprehensive understanding of the training parameters and were familiar with the scoring method for the pounded yam attributes. The sensory panellists for this study consisted of 20 individuals (10 women and 10 men, aged 20-40 years old) from the southwest region of Nigeria who were familiar with the qualities of well-pounded yams. The sensory evaluation scales to assess the attributes of the samples were provided in **Table 2**.

Table 2. Food descriptors and textural attributes of pounded yam.

Attributes	Intensity scale	Descriptors
Stretchability	Very stretchable	Lafun
	Slightly stretchable	Amala
	Stretchable	Eba
Stickiness (adhesiveness)	Very sticky	Margarine
	Sticky	Moimoi
	Slightly sticky	Semovita
	Non sticky	Fufu
Mouldability (cohesiveness)	Easy to mould	Fufu
	Difficult to mould	Very soft Eba
	Impossible to mould	Margarine
Smoothness	Smooth	Egg yolk
	Small lumps	Oat meal
	Big lumps	Yam porridge
Hardness	Very hard	Boiled unripe plantain
	Hard	Boiled semi-ripe plantain
	Soft	Boiled ripe plantain
	Very soft	Boiled irish potato

Attributes were modified from Otegbayo *et al.* (2005).

2.6.3. Sensory evaluation

The samples were presented at room temperature on disposable plastic plates, with each plate bearing a unique three-digit code number. Sensory evaluation was performed in a partitioned booth to ensure unbiased judgment. The pounded yam samples were evaluated for their stretchability, stickiness, moldability, hardness, and smoothness using descriptive terms that were converted into scores. The general acceptability of the pounded yam samples was rated on a five-point hedonic scale, with each genotype and fertiliser treatment presented in duplicate for three experimental replicates.

2.7. Statistical analysis

The results for both study years are presented as mean values. Significant differences between treatments were analysed using the Student's t-test. Statistical significance was set at $P < 0.05$.

3. Results

3.1. Effect of fertiliser application on fresh and dry weights and moisture content of yam tubers

Table 3 presents the effects of fertiliser application on the fresh and dry weights and the moisture content of the tubers. The fertiliser application significantly increased the fresh tuber weight in Danacha, Ojuiyawo, TDa0000194, and TDa0200012; however, there was no significant effect of fertilization on the fresh weight of Hembakwase, TDr9518544, TDa291, and TDa981176 tubers. Fertilisation also significantly increased the moisture content of the Danacha and Hembakwase tubers, and the dry weight of the Danacha, Ojuiyawo, TDa000194, and TDa0200012 tubers. However, there were no significant differences in the dry weights of TDr9518544, TDa291, and TDa9801176 tubers between non-fertilised and fertilised conditions. Notably, fertiliser application significantly decreased the dry weight of the tubers in Hembakwase. Together, these results showed that the effects of fertiliser application on fresh and dry tuber weight, and moisture content differed among the genotypes.

Table 3. Effect of NPK fertiliser application on yield and yield components of *Dioscorea rotundata* and *Dioscorea alata*.

	Fresh tuber weight (g plant^{-1})			Moisture content (%)			Dry tuber weight (g plant^{-1})		
	Non-F	+F		Non-F	+F		Non-F	+F	
Danacha	1478.5	2099.4	***	63.2	67.5	*	549.1	683.9	*
Hembakwase	1933.1	1904.1		65.0	69.6	**	682.2	574.4	*
Ojuiyawo	1724.9	2364.1	***	68.2	69.5		555.7	725.2	**
TDr9518544	2276.9	2635.7		63.2	67.2		842.9	880.2	
TDa0000194	2329.3	2892.3	**	70.2	71.4		703.0	831.0	*
TDa0200012	1856.8	2589.1	***	72.7	73.1		514.7	685.1	***
TDa291	1518.7	1728.3		69.6	69.2		474.3	527.6	
TDa9801176	2321.7	2485.4		73.5	73.2		620.4	661.4	

Non-F, non-fertilised; +F, NPK fertilised. ***$P < 0.001$, ** $P< 0.01$, *$P< 0.05$, analysed by Student's t-test between Non-F and +F conditions.

3.2. Effect of fertiliser application on the functional properties of yam flour

Fertiliser application increased the water-binding capacity of yam flour, particularly in Hembakwase, TDr9518544, and TDa0000194 genotypes. However, there were no significant differences in the swelling power and solubility index among the tested genotypes when we compared the non-fertilised and fertilised conditions (**Table 4**).

Table 4. Effect of NPK fertiliser application on functional properties of flour from *Dioscorea rotundata* and *Dioscorea alata*.

	Water binding capacity (g/100g)			Swelling power (g/g)		Solubility index (%)	
	Non-F	+F		Non-F	+F	Non-F	+F
Danacha	132.8	140.0		4.4	4.5	8.1	8.0
Hembakwase	137.8	156.4	***	4.4	4.4	8.1	6.8
Ojuiyawo	140.6	144.0		4.5	4.9	9.3	9.0
TDr9518544	143.0	158.5	**	4.6	4.9	7.0	7.8
TDa0000194	146.5	157.4	**	3.9	3.1	11.0	10.4
TDa0200012	147.6	151.3		3.2	3.1	11.1	11.2
TDa291	136.1	143.6		3.4	3.3	11.2	11.7
TDa9801176	144.9	155.0		3.0	3.3	11.6	11.3

Non-F, non-fertilised; +F, NPK fertilised. *** $P<0.001$, **$P<0.01$, analysed by Student's t-test between Non-F and +F conditions.

3.3. Effect of fertiliser application on yam flour pasting properties

Table 5 presents the effects of fertilization on the pasting properties of yam flour. The fertiliser application lowered the peak and final viscosity of yam flour, but there was no significant disparity in peak and final viscosity between the fertilised- and non-fertilised conditions. However, a significant decrease in the trough viscosity was observed in the Hembakwase, TDr9518544, and TDa291 following fertilisation. Fertilisation did not significantly affect the breakdown viscosity of any of the tested genotypes. There was no significant difference in the setback viscosity between the fertilised and non-fertilised treatments, except for Danacha, in which a significant decrease was observed. A significant increase in peak time was observed in TDa0200012 with fertilisation, while the pasting temperature of the tested genotypes was unaffected (**Table 5**).

Table 5. Effect of NPK fertiliser application on the pasting properties of *Dioscorea rotundata* and *Dioscorea alata* flour.

	Peak Viscosity (RVU)		Trough Viscosity (RVU)		Breakdown viscosity (RVU)		Final Viscosity (RVU)		Setback viscosity (RVU)		Peak Time (min)		Pasting Temp. (°C)	
	Non-F	**+F**	**Non-F**	**+F**	**Non-F**	**+F**	**Non-F**	**+F**	**Non-F**	**+F**	**Non-F**	**+F**	**Non-F**	**+F**
Danacha	246.4	239.6	199.4	204.0	47.0	35.6	342.2	273.4	142.8	69.4*	5.3	5.9	82.8	82.6
Hembakwase	237.0	219.4	204.5	162.4*	32.5	57.0	279.3	229.2	74.7	66.8	5.7	5.7	83.2	82.3
Ojuiyawo	256.9	241.7	205.7	175.3	51.2	66.4	309.2	251.5	103.5	76.2	5.5	5.3	82.4	81.6
TDr9518544	243.7	228.8	198.9	149.0*	44.8	79.8	281.9	230.3	83.0	81.3	5.6	5.2	82.0	81.2
TDa0000194	323.9	278.2	300.5	265.4	23.4	12.8	373.8	308.7	73.4	43.3	5.9	6.4	85.3	84.7
TDa0200012	263.8	230.6	251.1	225.1	12.6	5.5	303.4	254.8	52.3	29.7	6.2	7.0*	84.8	84.8
TDa291	329.7	265.2	283.4	233.8*	46.4	31.3	385.4	289.6	102.0	55.7	5.2	5.9	82.8	83.6
TDa9801176	259.8	234.3	249.3	208.4	10.5	25.9	302.2	246.4	52.9	38.0	6.2	6.0	85.5	84.6

Non-F, non-fertilised; +F, NPK fertilised; RVU, rapid viscosity unit. *P< 0.05, analysed by Student's t-test between Non-F and +F conditions.

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3.4. Sensory evaluation of pounded yams grown with or without fertilisation

Table 6 presents the mean scores for the prepared pounded yam sensory attributes. The results indicated that pounded yams made from Danacha, Hembakwase, and TDa0000194 grown in fertilised conditions were less stretchable than those made from tubers harvested from unfertilised conditions. The pounded yams made from TDa9801176 grown under fertilized conditions were more stretchable than those made from TDa9801176 cultivated under non-fertilized conditions. The fertiliser treatment had no effect on the stretchability of pounded yams made from Ojuiyawo, TDr9518544, TDa0200012, and TDa291. Fertiliser application resulted in stickier Hembakwase, Ojuiyawo, and TDa9801176 pounded yams. In contrast, TDa0200012 pounded yams were less sticky when grown in fertilised than unfertilised conditions. Pounded yams made from Hembakwase, Ojuiyawo, and TDa291 grown in fertilised conditions were harder to mould than those made from yams grown in unfertilised conditions, pounded yams made from TDa0000194 grown with fertiliser were easily moulded. All genotypes except TDa0200012 that received NPK fertiliser were significantly softer than those grown in unfertilised conditions. Pounded yams made from Hembakwase, Ojuiyawo, and TDr9518544 tubers grown in fertilised conditions were less smooth (i.e., lumpy) than those grown in unfertilised conditions. Finally, pounded yams made from TDa0000194 and TDa9801176 under fertilised conditions had higher general acceptability scores than those made from tubers grown in unfertilised conditions. Conversely, fertilisation decreased the general acceptability score of pounded yam for Hembakwase, Ojuiyawo, and TDa291 tubers.

Table 6. Effect of NPK fertiliser application on sensory description of *Dioscorea rotundata* and *Dioscorea alata* pounded yam.

	Stretchability		Stickiness		Mouldability		Hardness		Smoothness		General Acceptability	
	Non-F	+F	Non-F	+F	Non-F	+F	Non-F	+F	Non-F	+F	Non-F	+F
Danacha	2.38	2.68***	2.89	2.77	1.04	1.09	2.46	2.22***	1.01	1.00	4.36	4.23
Hembakwase	2.38	2.62***	2.62	2.27***	1.05	1.39***	2.39	1.80***	1.03	1.42***	4.30	3.66***
Ojuiyawo	2.36	2.45	2.41	2.20*	1.31	1.45**	2.19	1.70***	1.14	1.26*	4.03	3.72***
TDr9518544	2.76	2.77	2.61	2.68	1.09	1.05	2.73	2.49***	1.10	1.20*	4.08	3.97
TDa0000194	3.23	3.39*	2.68	2.75	1.65	1.34***	2.46	2.32*	1.13	1.16	3.63	3.92**
TDa0200012	3.49	3.41	2.72	3.00***	1.73	1.65	2.09	2.15	1.35	1.36	3.43	3.49
TDa291	3.07	3.20	2.78	2.67	1.28	1.40*	2.58	2.34***	1.13	1.22	4.13	3.89**
TDa9801176	3.66	3.48***	2.72	2.52*	1.80	1.68	2.36	2.07***	1.41	1.42	3.11	3.39**

Non-F, non-fertilised; +F, NPK fertilised

Stretchability: 1 = very stretchable; 2 = stretchable, 3 = slightly stretchable, 4 = not stretchable;

Stickiness: 1 = very sticky, 2 = sticky, 3 = slightly sticky; 4 = non-sticky

Mouldability: 1 = easy to mould, 2 = difficult to mould, 3 = impossible to mould

Hardness: 1 = very soft, 2 = soft, 3=hard, 4=very hard

Smoothness: 1 = smooth, 2 = small lumps, 3 = big lumps

General acceptability: 1 = dislike extremely; 2 = dislike slightly; 3 = neither like nor dislike; 4 = like moderately; 5 = like extremely

*** P< 0.001, ** P< 0.01, *P< 0.05, analysed by Student's t-test between Non-F and +F conditions

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4. Discussion

Fertilisation most likely affects yam growth and yield by changing soil nutrient availability [12,16]. The experimental plots had low-fertility soil [22], to which chemical fertilisers were applied to increase yam tuber yields. Plant responses to fertilisation varied among the genotypes tested (**Table 3**), suggesting that the effect of fertilisers on tuber yield can be genotype-specific, although these results were consistent with those reported in previous studies [26–28]. The fertiliser had different effects on fresh and dry tuber weights among the genotypes (**Tables 3 and 4**); Danacha, Ojuiyawo, and TDa0200012 responded positively to fertilisation, which was predicted to improve productivity if applied to low-fertility soil conditions.

We investigated the effects of fertilisation on the functional and pasting properties of yam flour (**Tables 4 and 5**). The application of NPK fertilisers affected the water-binding capacity, trough viscosity, setback, peak time, and pasting temperature of the yam flours, and these effects varied among the genotypes tested. Although there was no significant difference in peak and final viscosity of the yam flours, they were affected by fertiliser application. NPK fertiliser application did not significantly affect the swelling power and solubility index of yam flour. The values of the functional and pasting properties of yam flours made from tubers grown with and without fertilisation were comparable to those reported in previous studies [7–11]. Ebúrneo et al. [19] reported that nitrogen fertilisation affects starch grain size, shape, and pasting temperature in potatoes, while Gunaratne et al. [29] showed that fertilisation increased the protein content but decreased the amylose content of rice flour, which affected its functional and pasting properties. In addition, functional and pasting properties have been reported to be affected by the content of starch, protein, and amylose, as well as starch size and shape in cassava - soy protein [30] and wheat-groundnut [31] flour blends. This study revealed that the impact of fertilisation on the functional and pasting properties of yam flour may be attributed to modifications to the chemical constituents, such as starch, protein, and amylose, or the morphology of the starch. However, this study did not evaluate how fertiliser affected the composition of yam flour, and so we cannot discuss how the potential changes in composition could contribute to yam flour quality. Future work is needed to clarify the effect of fertiliser application on the composition of yam flour.

Although NPK fertilisers affected stretchability, stickiness, moldability, hardness, and smoothness of the pounded yam samples, the effects varied among the genotypes we tested (**Table 6**). For example, in Danacha, Hembakwase, and TDa0000194, fertilization decreased the stretchability of pounded yam, while in TDa9801176, the stretchability of pounded yam increased. This result was consistent with those of Vernier et al. [18], who reported inter-varietal differences in the effects of fertiliser application on the elasticity of pounded yams. Therefore, it is important to consider the varying effects of fertilisers on the texture attributes of different varieties of yams. The findings also suggest that it would be beneficial to examine the impact of fertilisation on the texture attribute of pounded yam on a variety-specific basis in fertilisation strategies.

All of the traits associated with the pounded yam sensory attributes studied were affected in Hembakwase grown in fertilised conditions, suggesting that these qualities in this genotype are sensitive to fertiliser application (**Table 6**). Pounded yams made from fertilised Hembakwase tubers had reduced stretchability, were stickier, harder to mould, and were less smooth in texture than those made from unfertilised tubers. There is a consensus that if a yam varietal can be made to produce pounded yams of good textural quality (e.g., smoothness, stretchability, cohesiveness, moderate adhesion, and moderate softness), then it has good food quality [32]. Nindjin et al. [33] reported that the correlation between attribute intensity measurements and preference tests provided evidence that pounded yam choice is primarily determined by its high springiness and ease of moulding. Therefore, the acceptability of the pounded yam made from fertilised Hembakwase tubers decreased because of its reduced stretchability, moulding difficulty, and lack of smoothness.

Although the sensory attributes of Danacha increased with NPK fertilisation, we found that fertilisation had less effect on the functional and pasting properties of the flour (**Table 6**). Danacha was previously reported to be suitable for pounded yams in Oyo North, Nigeria [32] and had the highest acceptability score in both fertilised and non-fertilised treatments. These findings suggest that the NPK fertilisers had no significant effect on Danacha tuber quality. The TDa0200012 genotype increased in yield with fertiliser application and the general acceptability was unaffected, indicated by its decreased stickiness. This suggests that Danacha and TDa0200012 may be suitable for maximising the yield with fertiliser application in low-nutrient soils.

Conversely, while the productivity of Ojuiyawo increased with fertilisation, the attributes of the pounded yam were negatively affected (e.g., harder to mould and lacked smoothness) and its acceptance rate decreased.

Our study revealed that fertiliser application increased the moisture content in Danacha and Hembakwase tubers (**Table 3**), which was consistent with findings reported by Dumont et al. [34]. It is important to note that excessive moisture content may lead to increased rot during storage, making these tubers unsuitable for long-term storage [32]. Moreover, the dry matter content of these tubers from the fertilised plot exceeded the selection criterion by 25% for breeding targets [1].

5. Conclusions

Fertilisers have also been used for other crops in sub-Saharan Africa and the cultivation of yams with fertiliser is becoming increasingly crucial for African yam producers. Our results describe the effects of NPK fertilisation on tuber yield and quality, which were genotype dependent. Tuber productivity was enhanced without the loss of tuber quality by using appropriate genotypes and fertilisation combinations. Conversely, if an unsuitable combination of genotype and fertiliser application is applied, fertilisation may improve tuber productivity but decrease their quality. To enhance productivity via fertilization, it is crucial to determine the impact of fertilization on tuber yield and quality for each variety and select the appropriate variety. This study evaluated the effects of the recommended fertiliser conditions on yam cultivation; however, soil fertility and excessive fertiliser application were not examined. Therefore, it is necessary to investigate how varying the amount of fertiliser could affect yield and tuber quality. We emphasise the need for further research in this field because fertilisers are essential for sustainable and intensive yam production. The results of this study will be widely used to enhance yam productivity in sub-Saharan Africa and useful in developing sustainable agriculture strategies in yam-growing areas.

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Ethical Compliance: All procedures involving human participants performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

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