Physicochemical properties of yam tuber according to its longitudinal axis

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ABSTRACT

Yam is a tuber with a longitudinal growth gradient, resulting in heterogeneous slices after cooking. This poses the problem of delimiting the distal, medial and proximal parts. The aim of the present study is therefore to obtain information on the longitudinal distribution of physicochemical properties and the proportion that the distal, median and proximal parts of the yam tuber might represent. To this end, three 28 cm tubers of the "Assawa" variety were cut longitudinally. Some physicochemical properties of the slices and flour were determined. A general variation was observed from proximal to distal parts. Firmness of yam tissue decreased from 1.2 N ± 0.05 to 0.5 N ± 0.1. Apparent viscosity decreased from 235 mPa.s ± 3.4 to 212.4 mPa.s ± 1.1. The water content of yam tubers increased from 58.5% ± 0.9 to 89.1% ± 0.8. Protein content decreases from the proximal end to the apex of the yam tuber (4.88 ± 0.02 to 4.8 ± 0.01). The longitudinal distribution of physico-chemical properties enabled us to objectively delimit the length and proportion of the whole tuber that the distal, medial and proximal parts could represent. Thus, on a tuber of around 28 cm, the distal part could be estimated at 28.57% (8 cm), the medial part at 28.57% (8 cm) and the proximal part at 21.43% (6 cm). The medial-distal and proximal-medial parts occupy 7.14 to 14.29% or 2 and 4 cm of the tubercle respectively. This delimitation makes it possible to obtain tuber portions with a homogeneous texture, which is useful for yam processing applications

Keywords*: yam tuber, longitudinal axis, proximal, medial and distal parts*

1. INTRODUCTION

Yam is a tuberous plant widely grown in tropical and subtropical regions of the world. The tuber is rich in starch and is widely consumed by the local population, especially in West Africa. Word yam production is estimated at over 88 million tonnes of which West Africa produces over 84 million tonnes. Production has been rising steadily over the past three years, from 77 million tons in 2020 to over 84 million tons in 2022. Ivorian production, meanwhile, stagnated at around 7.6 million tones over the same period (FAOSTAT, 2023).

The tuber is a complex plant organ whose nutritional and medicinal compound content is subjective to species, variety, climatic conditions and agricultural practices (Obidiegwu et al 2020; Fauziah et al. 2020; Shan et al., 2020; Lolge et al. 2022). Indicating the nutrient content of a yam without error means giving ranges of values that take this multitude of values into account. The data reported for several yam species indicate respective contents of 0.09 to 18.7%; 0.03 to 9.36%; 0.17 to 18.2%; 0.54 to 84.3%; and 0.05 to 8.81% in protein, lipid, fiber, starch and ash. The *D. alata* species appears to be the richest in protein and starch, according to the same source (Obidiegwu et al 2020 ; Oke et al. 2020 ; Quintana et al. 2023 ; Argaw et al. 2024 ; Datir et al. 2024).

In Côte d'Ivoire, yam is the leading foodstuff in terms of starchy fruits, roots and tubers, accounting for 47.46% of production, ahead of cassava (39.34%) and plantain (13.2%) (FAOSTAT**,** 2023). The "Assawa" variety of the *Dioscorea rotundata* species is not only one of the varieties most commonly found on the market, but also one of the most widely consumed. It is a white-fleshed variety with good culinary skills for dishes such as pounded yam and others where textural quality is required. The work of Afolabi et al. (2023) on five varieties of *D rotundata* showed that they all scored well for the sensory attributes of pounded yam (stretchability, stickiness, mouldability, smoothness, colour, hardness). Of course, the textural quality of pounded yam is subject to species, variety and post-harvest treatments (ILesanmi et al 2022). But variations intrinsic to the tuber and preparation conditions could have an impact on pounded yam quality. Indeed, the work of Brunnschweiler 2004, Degbeu et al 2008, Degbeu et al 2019 has shown longitudinal variation within the yam tuber in general. The degree of cooking of yam slices varies according to the portion of the tuber. The proximal and median parts give firmer slices after cooking than the distal part. This variability results from the higher dry matter content of the proximal part. This makes the technological operations of cooking the whole yam more complex, as the heat applied seems to be excessive for the distal part of the yam. In practice, a variable portion of the distal part is removed during peeling of the tuber (Otegayo et al 2021). This empirical practice depends on the consumer's know-how and, above all, on the physiological state of the tuber. For an early or immature tuber, the portion eliminated is significant. The aim of this study is to obtain information on the longitudinal distribution of physico-chemical properties and the proportion that the distal, medial and proximal parts could represent on the whole yam tuber.

2. MATERIAL AND METHODS

The plant material used consists of tubers of *Dioscorea-rotundata* yam of the "Assawa" variety harvested and stored for 4 months at 26°C in the store. The tubers selected for handling each weigh about 960 g and measure about 30 cm. These tubers are dormant and do not have digitation. This, facilitates measurement as well as an equal transverse division into slices along the longitudinal axis of the tuber. The study focused on the physicochemical properties of each yam slice

2.1. METHODS

The tubers were washed, peeled and then cut into round slices 2 cm thick. Tuber segmentation (Figure 1) was done from the proximal to the distal end using a Siemens electric kitchen slicer with a stainless-steel blade. The resulting slices were partly processed into flour, while others were directly tested.

To obtain the flour, pieces of tuber were peeled and soaked in sodium bisulphite (1%) to prevent browning of the pulp. The pulp is then cut into 0.3 mm thick strips, then spread on aluminum foil and dried in an oven (MEMMERT, 854, Schwabach, Germany) at 45°C for 48 hours. The dried sample is then crushed in a blender, sieved (sieve mesh 200 µm) and packaged in pots.

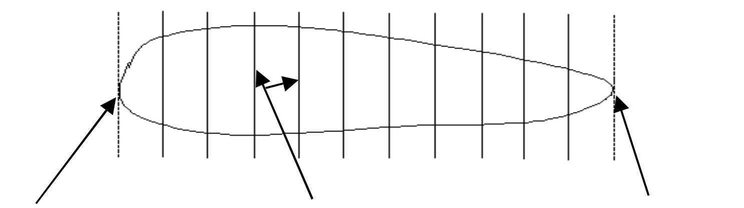

Figure 1: Diagram of the cutting of the yam tuber along the longitudinal axis. Vertical lines indicate the direction of the cut. The 2 cm strips correspond to yam slices.

2.1.1. DETERMINATION OF THE FIRMNESS OF YAM TISSUE

The firmness of yam slices was measured using a penetrometer (FRUIT-TESTER, Effigi-Alfonsine, Italie). The diameter of the probe is 11 mm. The probe is driven into the yam slice to a depth of 11 mm, and the penetration force expressed in Newtons is recorded. The crushing face corresponds to the upper surface of the slice taken in the direction of the distal part towards the proximal end (head).

2.1.2. PROXIMAL ANALYSIS

The moisture content was determined according to the AOAC method (1990) by drying 5 g of yam flour sample in the oven (MEMMERT, 854, Schwabach, Germany) at 105 °C for 24 h. After cooling in a dryer and weighing, the moisture content is determined. This allows the dry matter content to be deduced.

The ash content was determined according to the AOAC 1990 method. Thus, 10 g of sample was incinerated in a muffle furnace (P. SELECTA, Select-Horn 96, Barcelona, Spain) at 550 °C for 24 hours. The sample removed from the furnace is left to cool in the desiccant and the ash content is determined by weighing

The protein content was determined from the determination of total nitrogen by the Kjeldhal method (AOAC 1990). Two (2) g of flour were introduced into a Matras tube to which were added 25 mL of sulphuric acid (98%), 6 g of catalyst (94% sodium sulphate and 4% copper sulphate). The whole is mineralized in a digester (TECATOR, 2006, Höganäs, Sweden) at 400 °C for 2 h to obtain a slightly dark green coloration. To the mineralized mixture obtained, 10 mL of sodium hydroxide (40%) is added and distilled (TECATOR, 2200, Höganäs, Sweden) for 10 min in the presence of 20 ml of 2% boric acid solution containing a mixed end-of-reaction indicator (methyl red + bromocresol green) to obtain a purple colour. The

distillate is recovered and dosed by a titrating solution of sulphuric acid (0.1 N). The protein content is obtained by converting the nitrogen content using a factor of 6.25.
The determination of reducing sugars was carried out according to the method of AOAC (1990) using the DNS. Five (5) g of flour are put in a 10 ml flask and 50 ml of distilled water at 60 °C added. The mixture is stirred and then cooled. The filtrate is then collected in a 1000 ml flask and brought to the gauge line with distilled water. The DO is read at 546 nm after heating with the DNS. All tests were performed in three replicates.

2.1.3. DETERMINATION OF THE VISCOSITY OF FLOUR GEL FROM YAM SLICES

The viscosity was determined using the rheometer (Brookfield DV-III ULTRA programmable, model RV, Chicago, USA). The flour gel was prepared at 4% (w/w) on a dry matter basis. Sixteen (16) g of starch was taken from a beaker (pyrex) and the mass was supplemented to 400 g. The starch milk is cooked at 250°C for 30 minutes under minimum stirring on a heated agitator (AM4, Italy) previously heated. After cooking, the gel is cooled to 30°C and then read. Frost flow measurement has been carried out with the #3-disc probe of the viscometer. This probe has a diameter of 1.3658 mm and a thickness of 0.63 mm. The probe is then immersed in the gel to the single line indicated by the manufacturer. The program carried out by this study consists of measuring the flow of the frost as a function of a velocity gradient from 20 rpm to 230 rpm with 5 s of duration per velocity.

2.2. STATISTICAL ANALYSIS

Data analysis was performed by SPSS 16.0 software. The comparison of the average of the different portions was made by the DUNCAN test at the 5% threshold.

3. RESULTS

3.1. EVOLUTION OF THE FIRMNESS OF YAM TISSUE

The study of tissue firmness (Table 1) reveals a decrease in hardness from the proximal to the distal end along the longitudinal axis of the tubercles. This evolution shows that the distal region is less hard than the proximal region. Firmness decreases from 1.2 N ± 0.05 to 0.5 N ± 0.1. Statistical analysis makes it possible to delineate the zones within which the firmness is identical ($P < 0.01$). Thus, from the proximal part to the distal end, an estimated proportion of 21.43 % representing 6 cm for the proximal part, another of 35.72%, i.e. 10 cm corresponding to the middle part and finally 28.57% (8 cm) for the distal part. Two intermediate parts to the three zones, each representing 2 cm, have also been delineated. These are the medio-distal and medio-proximal parts, each representing 7.14% of the tuber.

Table 1: Evolution of the firmness of the yam tuber from the proximal part to the distal end

Tuber portion (cm)	Firmness (N)	Part of the tuber	Percentage of tuber (%)
Proximal			
4	1,2 ± 0,1[a]		
6	1,2 ±0,1[a]	Proximal	21,43
	1,2 ±0,1[a]		
8	1,1 ± 0,1[ab]	Mid-proximal	7,14
10	0,9 ± 0,1[b]		
12	0,8 ± 0,1[b]		
14	0,8 ± 0,1[b]	Median	35,72
16	0,7 ± 0,1[b]		
18	0,7 ± 0,1[b]		
20	0,6 ± 0,1[bc]	Mid-Distal	7,14
22	0,5 ± 0,1[c]		
24	0,5 ± 0,1[c]		
26	0,5 ± 0,1[c]	Distal	28,57
28	0,5 ± 0,1[c]		
Distal			

The values assigned to the same letter are not significantly different (P < .01)

3.2. EVOLUTION OF THE VISCOSITY OF YAM FLOUR GEL FROM THE PROXIMAL PART TO THE DISTAL END

The apparent viscosity of the flour gels of the different tuber slices decreases from the proximal to the distal end (Table 10). The values obtained decrease from 235.03 ± 3.4 mPa.s to 212.41 ± 1.1 mPa.s. From the proximal end to the distal zone, the portions with mean apparent viscosities that do not differ significantly (P < 0.01) allow a delineation of the proximal, medial, distal and intermediate parts. The proportion of the proximal part is estimated at 21.43% or 6 cm, the middle part represents 28.57% corresponding to 8 cm and finally that of the distal part is at 28.57%, i.e. 8 cm. The medio-distal intermediate zone represents 14.29% and corresponds to 4 cm, while the medio-proximal zone represents 2 cm or 7.14% of the tubercle.

Table 2: Evolution of the viscosity of the flour gel from the proximal part to the distal end.

Tuber portion (cm)	Apparent viscosity (mPa.s)	Part of the tuber	Percentage of tuber (%)
Proximal end			
2	235,1 ± 3,4^{a}		
4	234,7 ± 2,1^{a}	Proximal	21,43
6	234,4 ± 1,3^{a}		
8	233,4 ± 1,1^{ab}	Mid-proximal	7,14
10	231,6 ± 1,3^{b}		
12	230,5 ± 2,3^{b}		
14	230,2 ± 3,7^{b}	Médian	28,57
16	230,1 ± 1,2^{b}		
18	229,9 ± 3,4^{bc}	Mid-Distal	14,29
20	229,3 ± 2,3^{bc}		
22	224,5 ± 1,3^{c}		
24	220,8 ± 1,3^{c}		
26	216,6 ± 2,3^{c}	Distal	28,57
28	212,4 ± 1,1^{c}		
Distal			

The values assigned to the same letter are not significantly different (P < .01)

3.3. EVOLUTION OF YAM MOISTURE FROM THE PROXIMAL TO THE DISTAL END

The moisture content of yam tubers increases from the proximal to the distal end (Table 3). Water content increases from 58.5% ± 0.9 to 89.1% ± 0.8 at the distal end. Statistical analysis of the data enables us to estimate the different proportions of the tuber (P < 0.01). The delimited zones are homogeneous, with the exception of the median part, where one value seems to differ from the others. The proximal part measures 6 cm and corresponds to 21.42% of the tuber. The medial part measures 8 cm, i.e. 28.57% of the tuber. The distal zone is also 8 cm long, and accounts for 28.57%. The intermediate medio-distal zone measures 2 cm and represents 7.14% of the tuber. The medio-proximal zone is 4 cm, i.e. 14.29% of the length of the tubercle.

Tabe 3: Moisture evolution from proximal to distal end of yam tuber

Tuber portion (cm)	Water content (g/100g de ms)	Part of the tuber	Percentage of tuber (%)
Proximal end			
2	58,5 ± 0.9^{a}		
4	60,4 ± 0,8^{a}	Proximal	21,43
6	60,9 ± 0,9^{a}		
8	61,5 ± 0,4^{ab}		14,29
10	65,2 ± 0,5^{b}	Mid-proximal	
12	66,4 ± 0,8^{cd}		
14	67,6 ± 0,4^{cd}	Median	28,57
16	69,9 ± 0,8^{de}		
18	71,9 ± 0,5^{e}		

20	80,2 ± 0,7^{f}	Mid-Distal	7,14
22	88,2 ± 0,4^{g}		
24	88,4 ± 0,4^{g}		
26	88,5 ± 0,5^{g}	Distal	28,57
28	89,1 ± 0,8^{g}		
Distal			

The values assigned to the same letter are not significantly different (P < .01)

3.4. CHANGES IN PROTEIN CONTENT FROM PROXIMAL TO DISTAL END OF YAM TUBER

Protein content decreases from the proximal end to the apex of the yam tuber (Table 4) . Statistical analysis of the data reveals 5 different zones from proximal to distal end (P < 0.01). The proximal part is easily delimited with a proportion of 28.57%, or 8 cm. The second delimited zone is the medio-proximal part, 4 cm long, i.e. 14.29% of the tubercle. The next section, which could be identified as the median zone, is characterized by a range of different contents. It is 10 cm long, corresponding to 35.71% of the tuber. The fourth is the medio-distal part, measuring 2 cm (14.29%). The distal part is 4 cm long and represents 14.29%.

Table 4: Changes in protein content from proximal to distal end of yam tuber

Tuber portion (cm)	Protein content (g/100g dry matter)	Part of the tuber	Percentage of tuber (%)
Proximal end			
2	4,876 ± 0,02^{a}		
4	4,875 ± 0,01^{a}	Proximal	28,57
6	4,874 ± 0,01^{a}		
8	4,874 ± 0,03^{a}		
10	4,864 ± 0,01^{b}	Mid-proximal	14,29
12	4,862 ± 0,01^{b}		
14	4,859 ± 0,01^{c}		
16	4,856 ± 0,01^{d}		
18	4,853 ± 0,01^{e}	Median	35,71
20	4,847 ± 0,03^{f}		
22	4,841 ± 0,01^{g}		
24	4,838 ± 0,01^{h}	Mid-Distal	7,14
26	4,836 ± 0,01^{hi}		
28	4,834 ± 0,01^{i}	Distal	14,29
Distal			

The values assigned to the same letter are not significantly different (P < .01)

3.5. CHANGES IN REDUCING SUGARS ALONG THE LONGITUDINAL AXIS OF THE TUBER

Reducing sugar content increases from the proximal to the distal end (Table 5). Statistical analysis of the data does not allow us to easily delimit the three parts: proximal, median and distal. In the middle section, the grades obtained differ from one another. It represents the largest portion with 35.71%, or 10 cm of the tuber's length. Values in this zone increase from 1.619% ± 0.11 to 1.723% ± 0.05. The proximal part represents 21.423% of the tuber, corresponding to 6 cm. Values are homogeneous at this level. The intermediate zones on either side of the median part represent 14.29%, or 4 cm each. The distal part also corresponds to 4 cm, or 14.29% of the length of the tuber.

Table 5: Changes in reducing sugar content along the longitudinal axis of the tuber

Tuber portion (cm)	Reducing sugar content (g/100g dry matter)	Part of the tuber	Percentage of tuber (%)
Proximal			
2	1,440 ± 0,01^{a}		
4	1,445 ± 0,03^{a}	Proximal	21,43
6	1,455 ± 0,04^{a}		

8	1,506 ± 0,01[b]		14,29
10	1,585 ± 0,01[b]	Mid-proximal	
12	1,619 ± 0,11[c]		
14	1,638 ± 0,13[cd]		
16	1,652 ± 0,12[de]	Median	35,71
18	1,671 ± 0,13[e]		
20	1,723 ± 0,05[f]		
22	1,773 ± 0,01[g]		14,29
24	1,781 ± 0 01[g]	Mid-Distal	
26	1,798 ± 0,01[gh]		
28	1,818 ± 0,01[h]	Distal	14,29
Distal			

The values assigned to the same letter are not significantly different (P < .01)

3.6. CHANGE IN ASH CONTENT FROM PROXIMAL TO DISTAL END

Ash content decreases from the proximal to the distal end of the tuber (table 6). Statistical analysis of the data reveals three main zones. The two extremes (distal and proximal) each represent 21.43% of tuber length. The median part corresponds to 28.56%, or 8 cm, and the two intermediate zones to 14.29% each.

Table 6: Changes in ash content along the longitudinal axis of the yam tuber

Portion du tubercule (cm)	Ash content (g/100g dry matter)	Tuber portion	Percentage of tuber (%)
Tuber portion			
2	1,270 ± 0,02[a]	Proximale	
4	1,250 ± 0,03[a]		21,43
6	1,240 ± 0,03[a]		
8	1,205 ± 0,04[ab]		14,29
10	1,145 ± 0,04[bc]	Médio-proximale	
12	1,115 ± 0,04[cd]		
14	1,10 ± 0,04[cd]	Médiane	
16	1,08 ± 0,03[cd]		28,56
18	1,055 ± 0,04[d]		
20	0,980 ± 0,07[e]		14,29
22	0,915 ± 0,05[f]	Médio-distale	
24	0,896 ± 0 05[fg]		
26	0,873 ± 0,04[fg]	Distale	21,43
28	0,836 ± 0,05[g]		
Extrémité distale			

The values assigned to the same letter are not significantly different (P < .01)

4. DISCUSSION

This discussion will be guided by the objective of the study, which is to delineate the three parts of the tuber.

The firmness of yam tissue decreases from the proximal to the distal end. This may be due to the existence of a maturity gradient along the longitudinal axis of the tuber (Degbeu et al 2019). Indeed, histological study has shown that cell wall thickening is more pronounced in the proximal part, as is starch content. In terms of tissue firmness and water content, the three parts of the tuber have more or less equal proportions in terms of length. The proximal part would represent 21.43% (6 cm) versus 28.57% (8 cm) for the medial and distal parts. But on the basis of protein and reducing sugar content, the proportions of the three parts are as follows: 14.29% (4 cm) for the distal part, 35.71% for the median and 21.43% (6 cm) for the proximal end. The same applies to ash content, with the exception of the distal part.

In all the tests carried out, the proximal part represented 21.43% (6 cm) of the tuber, the median part from 28.57 to 35.71% (8 to 10 cm), and the distal end from 14.29 to 21.43%. Apart from these three parts, an intermediate zone of 7.14 to 14.29% (2 to 4 cm) was observed between the distal and medial parts, on the one hand, and between the proximal and medial ends, on the other.

The high-water content in the distal part could be due to residual growth activity localized in this zone according to the morphogenesis study carried out by Degbeu et al (2019). This growth is ensured by the highly hydrated meristem cells with their voluminous vacuoles observed in the histological study. Growth also mobilizes a considerable supply of the simple sugars needed to form starch. This may explain the high content of reducing sugars in the distal part of the tuber. The high-water content of this part of the tuber would explain its low firmness. The first part of the study also revealed the abundance of starch grains towards the middle and proximal parts of the tuber, as well as a thickening of the cell wall. This could explain the high firmness observed in these parts of the tuber. The work of Brunnschweiler (2004) produced similar results. The high ash and protein content in the middle and proximal parts could be due to a bioaccumulation phenomenon.

5. CONCLUSION

At the end of this study, it emerged that the longitudinal distribution of the physico-chemical properties of the tuber of yam variety "assawa" differs from the proximal part to the distal part. This made it possible to objectively delimit the length and proportion that the distal, medial and proximal parts could represent on the whole tuber. Thus, on a tuber of around 28 cm, the distal part could be estimated at 28.57% (8 cm), the medial part at 28.57% (8 cm) and the proximal part at 21.43% (6 cm). The medial-distal and proximal-medial parts occupy 7.14 to 14.29% or 2 and 4 cm of the tubercle respectively. This delimitation makes it possible to obtain tuber portions with a homogeneous texture, which is useful for yam processing applications.

REFERENCES

FAOSTAT. (2023). Crop production data. retrieved from: https://www.fao.org/faostat/en/#data/QCL)

Obidiegwu, J. E., Lyons, J. B., Chilaka, C. A. (2020). The Dioscorea genus (Yam) - an appraisal of nutritional and therapeutic potentials. Food, 9, 1304. **https://doi.org/10.3390/foods9091304**

Fauziah, Mas'udah, S., Hapsari, L., Nurfadilah, S. (2020). Biochemical composition and nutritional value of fresh tuber of water yam (*Dioscorea alata* L.) local accessions from East Java, Indonesia. Agrivita Journal of Agricultural Science, 42(2), 255–271. https://doi.org/10.17503/agrivita.v0i0.2552

Shan, N., Wang, P., Zhu, Q., Sun, J., Zhang, H., Liu, X., Cao, T., Chen, X., Huang, Y., Zhou, Q. (2020). Comprehensive characterization of yam tuber nutrition and medicinal quality of *Dioscorea opposita* and *D. alata* from different geographic groups in China. Journal of Integrative Agriculture, 19(11), 2839–2848. https://doi.org/10.1016/S2095-3119(20)63270-1

Lolge, R. M., Agarkar, B. S., Kshirsagar, R. B., Patil, B.M. (2022). Evaluation of nutritional, physicochemical and functional properties of yam. Biological Forum –An International Journal, 14(4a), 258-263.

Oke, E. K., Idowu, M. A., Sobukola, O. P., Bakare, H. A. (2020). Nutrient composition, functional, physical and pasting properties of yellow yam (*Dioscorea cayenensis*) and jack bean (*Canavalia ensiformis*) flour blends. Carpathian journal of food science and technology, 12(5), 52-71. https://doi.org/10.34302/crpjfst/2020.12.5.4

Quintana, S. E., Pérez-mendoza, J., Zapateiro, L. A. G., (2023). Physicochemical, structural and rheological properties of hawthorn yam (*Dioscorea rotundata*) flour. Current Research in Nutrition and Food Science, 11(3), 954-963. https://dx.doi.org/10.12944/CRNFSJ.11.3.04

Argaw, S. G., Beyene, T. M., Woldemariam, H. W., Esho, T. B., Worku, S. A., Gebremeskel, H. M., Mekonnen, K. N. (2024). Chemical, structural, and techno-functional characterization of yam (Dioscorea) flour from South West Ethiopia. Heliyon, 10, e31148. https://doi.org/10.1016/j.heliyon.2024.e31148

Datir, S., Kumbhar, R., Kumatkar, P. (2024). Understanding physiological and biochemical mechanisms associated with post-harvest storage of Yam tuber (Dioscorea sp.). Technology in Horticulture, 4, e004. https://doi.org/10.48130/tihort-0024-0001

Afolabi, F., Matsumoto, R., Akinwande, B., Otegbayo, B., Asfaw, A. (2023). Effect of mineral fertilisation on tuber yield and quality in yams (*Dioscorea alata* and *Dioscorea rotundata*). Agriculture, 13, 2240. https://doi.org/10.3390/agriculture13122240

Ilesanmi, J.O.Y., Hussein, J.B., Falope, O.J., Filli, K.B. (2022). Impacts of pretreatments and drying techniques on the physiochemical, microbial, and sensory properties of white yam (*Dioscorea rotundata*) flour. Carpathian journal of food science and technology, 14(4), 168-179. https://doi.org/10.34302/crpjfst/2022.14.4.13

Brunnschweiler, J. (2004) Structure and texture of yam (Dioscorea spp.) and processed yam products PhD Thesis, University of Zurich, 162 pp

Degbeu, K. C., Amani, N. G., Aoussi, C. S., Yao, D. N. (2008). Longitudinal distribution and physicochemical properties of yam (Dioscorea spp.) tuber starches. Food 2 (1), 52-56.

Degbeu, K. C., Coulibaly, A., Tetchi, A. F., Amani, N. G. (2019). Histological study of the polarity of yam tuber (Dioscorea spp.) at the beginning of tuberization. Asian Food Science Journal, 2(2), 1-15. DOI: 10.9734/AFSJ/2019/v12i230078

Otegbayo, B., Tanimola, A., Oluinka, O. (2021). Sensory Characterization of Pounded Yam. Biophysical Characterization of Quality Traits, WP2. Iwo, Nigeria: RTBfoods Laboratory Standard Operating Procedure, 15 p.

AOAC. Official Methods of Analysis. Association of Official Analytical Chemists. 15th ed. Washington D.C; 1990.