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Comparative Analysis of the Nutritional Quality of Yam (*Dioscorea* spp.) Tubers Using the Wrap and Plant Technology in Togo

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A B S T R A C T

Yam (*Dioscorea* spp.) is a crucial staple crop in the intertropical zone, but its production is often hindered by nematode infestations causing yield losses and reduced tuber nutritional quality. This study assessed the effects of the "Wrap and Plant" technology on the organoleptic and nutritional properties of tubers harvested from three agroecological zones in Togo. Biochemical analyses measured water, fiber, carbohydrate, protein, and mineral content to evaluate the combined effects of technology and nematode density. Results showed no significant alteration of biochemical composition due to the technology; water ranged from 54.87% to 67.26%, fiber 0.41%–1.94%, ash 2.02%–9.45%, carbohydrates 8.40%–15.49%, and proteins 7.58%–13.38%. AEZ I (low nematode pressure) showed higher fiber and ash; AEZ II (high infestation) experienced reduced protein and increased water, reducing carbohydrates; AEZ III had better nutritional balance. "Wrap and Plant" effectively controls nematodes while preserving yam nutrition and supporting food security.

Introduction

Yam is a tuberous plant important for the nutrition of millions of people throughout the intertropical zone. Over 90% of global yam (*Dioscorea* spp.) production comes from West Africa, particularly the Guinean and Sudanese savanna zones (Cornet, 2005). Annual production is estimated at over 30 million tons, with constant increase over the past 30 years. The main producing countries are: Nigeria (26 million tons); Ghana (4 million tons); Côte d'Ivoire (3 million tons); Benin (2 million tons); Togo (0.6 million tons) (Camara

et al., 2018; Cornet, 2005; Domigos, 1993; Floquet *et al.,* 2012). The genus *Dioscorea* comprises at least six hundred species, about ten of which are cultivated as food plants. Two species account for more than 95% of global production, notably *D. alata* and *D. rotundata* (Darkwa *et al.,* 2019). The species *D. alata*, native to Southeast Asia, is now widely distributed throughout the intertropical zone (Darkwa *et al.,* 2019). In Togo, this species includes several local cultivars such as Laboco, Kabanga koufouloumou, Katchakè, and Lotossou (Ayisah *et al.,* 2019). The second species is *D. rotundata*, whose local cultivars include Kratsi, Hè-abalou, Gnalabou, Modji, and Alago (Dansi *et al.,* 2013). Populations prefer these two species due to their superior organoleptic qualities (Domigos, 1993; FAO, 2007). Yam plays a fundamental role in nutrition in Togo, contributing to the population's food security (Dansi *et al.,* 2013). It is consumed in various forms, essentially at the domestic and artisanal level, notably smoked, boiled, fried, pounded, as puree, flour, or couscous. Beyond these traditional preparations, yam is also subject to semi-industrial and industrial processing, yielding finished products such as flakes, chips, snacks, hydrolysates, and syrups (FAO, 2018). Due to its nutritional richness, yam is an important source of energy, fiber, vitamins, and minerals, contributing to a balanced diet (Fauziah *et al.,* 2020; Obidiegwu *et al.,* 2020; Padhan and Panda, 2020). Its cultivation is established in various regions of Togo and spans several agroecological zones, where its production holds a predominant place among food crops (Dansi *et al.,* 2013). Thus, yam remains a vital component of Togo's food and agricultural economy, with strong cultural and social attachment, and significant development potential through innovations in production and processing (Asiedu and Sartie, 2010; Syombua *et al.,* 2020).

However, yam cultivation faces significant challenges related to the preservation of fresh tubers due to several factors, including nematode attacks.

Indeed, nematodes are microscopic plant-parasitic worms found in the topsoil layer that attack young roots, causing lesions and gall formation (Amara, 2018; RIGHI, 2024). These attacks lead to the death of young yam plants or predispose tubers to invasion by other pathogens (BERTHAUD & BRICAS, 1998; Coyne *et al.,* 2006; Itolou *et al.,*2020 ; Netscher, 1970). To control these worms, the "Wrap and Plant" technology was developed (Pirzada *et al.,* 2023; Sit *et al.,* 2022). The "Wrap and Plant" technology involves coating seed tubers or setts in biodegradable paper made from banana leaves, impregnated with a very low dose of abamectin, a pesticide of natural origin (Ochola *et al.,* 2022b; Asem *et al.,* 2024; Kamau *et al.,* 2024; Espère *et al.,* 2024). This method effectively reduces nematode populations and increases agricultural yields, while minimizing environmental impact (Dedehouanou, 2022; Ochola *et al.,* 2022a; Espère *et al.,* 2024). In Togo, research has validated the efficacy of the "Wrap and Plant" technology for nematode control under field conditions (Espère *et al.,* 2024). However, two aspects have not been investigated: (i) the impact of this technology on the post-harvest nutritional composition of yams, and (ii) the effects of nematodes on the crop's biochemical profiles. Therefore, the objectives of the present study were to evaluate the influence of the "Wrap and Plant" technology on the nutritional quality of harvested tubers and to analyze alterations in their composition induced by both the treatment and nematode infestation.

Materials and Methods

The biological material consisted of yams from the *Dioscorea cayennensis-rotundata* complex, cultivated for seven months in three agroecological zones of Togo: AEZ I: Dry savanna, AEZ II: Humid savanna, and AEZ III: Forest zone (Figure 1).

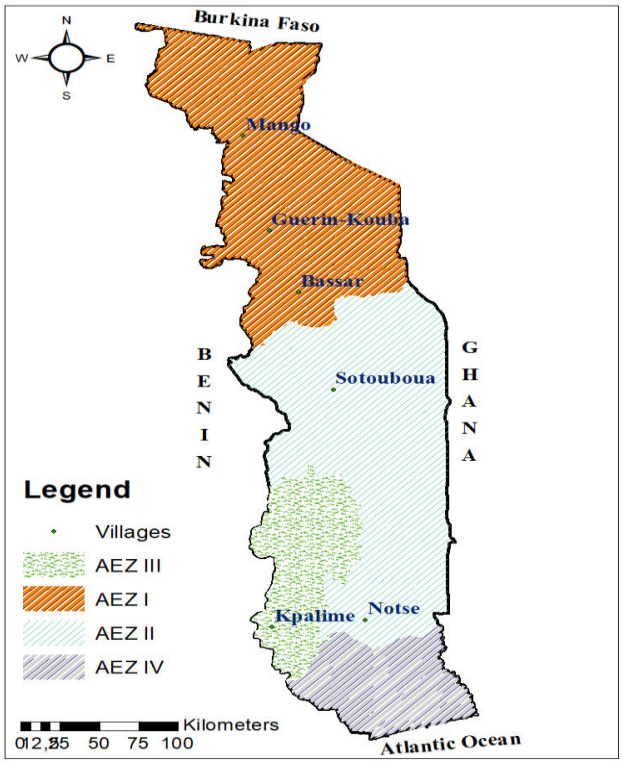


Figure.1 Three agroecological zones of Togo

Three treatment modalities were applied: (i) setts wrapped in banana leaves treated with abamectin (T1) ("Wrap and Plant" with treatment); (ii) setts wrapped in untreated banana leaves ("Wrap and Plant" without treatment), representing the relative control (T2); and (iii) setts planted directly without wrapping or treatment, corresponding to the absolute control (T3, conventional cultivation).

Sampling

Yams used for testing were harvested seven months after planting, from mounds located in the center of each experimental plot to avoid any edge effect. The collected tubers were then transported and stored in 1.2 mm mesh nets until analysis. Organoleptic and biochemical tests were performed on all samples, totaling 90 tubers studied.

Determination of Water Content

Water content was determined according to the method (AOAC International, 1990) as reported by (Souho *et al.,* 2023). This determination is based on the progressive loss of water from a sample by drying in an oven at 105 °C until a constant mass is obtained. For the experiment, 5g of yam sample were placed in the oven using a crucible of known tare weight (m0). The sample was weighed periodically until a constant mass was obtained. Water content was calculated using the following formula: $W(\%)= (m_e-m_s)\ x100/m_e$ where W denotes the water content percentage, m_e the mass of the test portion (g) and m_s the constant mass of the sample after drying (g).

Determination of Ash Content

Crude ash was obtained by incineration at 550°C of the dried and ground sample (Alraddadi, 2020; Daud *et al.,* 2020). This involves burning all the organic matter in the sample. For this, 10g of sample were placed in a muffle furnace using a crucible of known tare weight. Heating was performed at 550°C for 6 hours before cooling the crucible containing the sample in a desiccator. After cooling, the mass of the ash was weighed, and the content was calculated using the following relation: $C\ (\%) = m_2\ x\ 100/m_1$ where m_1 denotes the dry mass of the test portion (g) and m_2 the mass of the ash (g).

Determination of Dietary Fiber Content

Dietary fiber was obtained by successive digestion of samples in acid and basic media. The protocol described by Wolf, (1968) was used for this determination. For this, 2g of dried and ground samples were introduced into a flask containing 50mL of sulfuric acid (0.25 N). The mixture was homogenized and heated under reflux for 30 minutes. After this heating, the contents of the flask were filtered and rinsed with distilled water before the second reflux heating in a basic medium (NaOH, 0.31N). The residue obtained after the second filtration was dried at 105°C in an oven, weighed, and then incinerated at 550°C in a furnace for 3h. After cooling in a desiccator, the contents were weighed, and the fiber content was calculated as follows: $Tb\ (\%) = (m_1-m_2)\ x\ 100\ /\ me$ where m1denotes the mass (g) of the dried residue, m2 the mass (g) of the obtained ash, and me the mass (g) of the test portion.

Determination of Protein Content by Total Nitrogen Dosage

Total nitrogen was determined using the Kjeldahl method (AFNOR, 1984; Devani *et al.,* 1989). The principle of total nitrogen determination first involves the conversion of organic nitrogen to ammonium ions (NH_4^+) in the presence of a catalyst in strong sulfuric acid medium and under heat, then the transformation of NH_4^+ into ammonia in a basic medium which is then trapped by distillation into an excess of acid. The test follows several steps:

Mineralization

One gram of the dried and ground sample was introduced into a mineralization flask containing 50mL of distilled water and 10 mL of concentrated sulfuric acid. The mixture was mineralized at 360°C for 2h in the presence of a catalyst (selenium + potassium sulfate). After cooling to room temperature, the mineralizate was transferred to a 100 ml volumetric flask and made up to the mark with distilled water (Zeng *et al.,* 2022).

Distillation

The mineralizate was poured into a distillation flask, and 25mL of 40% (w/v) NaOH was added, followed by distillation for 10 minutes. The ammonia (distillate) was collected in a beaker containing 20mL of sulfuric acid in the presence of a color indicator: bromothymol blue (Lee *et al.,* 1992).

Titration

The excess acid in the beaker was then titrated with a 0.1 N sodium hydroxide solution until the color changed from green to blue. A blank was performed under the same conditions as the test. The total protein content is expressed as a mass percentage as follows: Tp(%)= (V_2 – V_1) x 14 x 6,25 x N*100/ me where V_2 denotes the volume (ml) of sodium hydroxide solution (0.1 N) used for the blank, V_1 the volume (ml) of sodium hydroxide solution (0.1 N) used for the test (sample), N the normality of the sodium hydroxide solution, m_e the mass (g) of the flour sample, 14 the atomic mass of nitrogen, and 6.25 the conversion factor from nitrogen to protein (Sáez-Plaza *et al.,* 2013a, 2013b).

Determination of Total Sugar Content

Total sugar content was determined by spectroscopy as described by (DuBois *et al.,* 1956). In an acid medium and under heat, sugars are dehydrated, losing a water molecule to form furfural compounds which then transform into a chromophore in the presence of phenol. These molecules have their maximum absorption at 490nm. Specifically, 0.1g of sample powder was heated in a flask with 5mL of a hydrochloric acid (HCl) solution. After heating, this mixture was neutralized with sodium bicarbonate. After centrifugation (100 rpm for 5 minutes), the supernatant was collected and diluted one hundred-fold. Then, 0.5mL of phenol (5% v/v) was added to 0.5mL of the supernatant, and the mixture was left to stand for 10 minutes before adding 2.5mL of concentrated sulfuric acid and heating in a water bath for 30 minutes at 30°C. A blank was prepared under the same conditions with distilled water. Absorbance (DO) readings were taken in duplicate at 490nm using a spectrophotometer, and the total sugar content was determined in glucose equivalent using the equation from the calibration curve below.

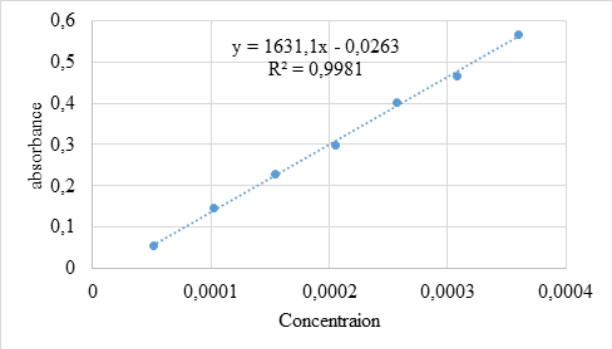


Figure.2 Calibration curve

Data Analysis

Data analysis and processing were performed using R software (version 4.5.0). Histograms were used to compare chemical compositions based on treatments and agroecological zones. A Principal Component Analysis (PCA) was used to explore the relationships between biochemical composition and nematode frequency. Finally, correlations between biochemical parameters, as well as between biochemical composition and nematode density, were assessed using correlation matrices.

Results and Discussion

Biochemical Composition of Harvested Tubers

Analysis of ash content revealed moderate variability between agroecological zones. In zone III, treatment T1 (banana leaves treated with abamectin) was distinguished by a higher mineral richness (6.04%), exceeding values observed with T2 (2.61%) and T3 (2.70%). In contrast, in zones AEZ I and II, differences between treatments were less marked. In AEZ I, values obtained were 3.47 for treatment T1, 2.52 for T2, and 2.68 for T3, while in AEZ II they were 2.88 for T1, 2.48 for T2, and 3.19 for T3 (Figure 3).

Regarding carbohydrates, a clear trend emerged in favor of treatment T2 (untreated banana leaves). In almost all zones, and particularly in AEZ III, T2 reached 14.34% compared to 11.06% for T1 and 13.73% for T3. In AEZ II, T2 also showed the highest value at 13.16%, compared to 11.26% for T1 and 12.27% for T3. However, in AEZ I, T1 recorded the highest value at 11.93%, followed by T3 at 10.57%, while T2 remained lower at 10.42% (Figure 3).

Dietary fiber followed a different dynamic. In AEZ I, T1 reached 1.26% and T2 1.29%, levels higher than T3 which was limited to 0.98%. In AEZ III, the trend reversed, with T3 showing the highest value at 1.06%, compared to 0.80% for T1 and 0.87% for T2. In AEZ II, values remained generally low, ranging from 0.58% for T3 to 0.91% for T2, with T1 intermediate at 0.82% (Figure 3).

For proteins, AEZ III was clearly distinguished by higher levels: T2 peaked at 13.10%, followed by T3 at 12.19% and T1 at 11.75%. Conversely, AEZ II showed a general decrease, with T2 dropping to 8.89% while T1

and T3 remained close to 10.05% and 10.51%. In AEZ I, T3 reached 12.40% and T1 11.84%, higher than T2 which was limited to 10.40% (Figure 3).

Finally, water content remained relatively stable, oscillating between 57.68% in AEZ II with T1 and 65.03% in AEZ III with T2. In AEZ I, it varied from 62.04% for T3 to 62.91% for T1, indicating overall homogeneity between 60% and 65% depending on treatments and zones (Figure 3).

At the national level, the biochemical analysis of yam tubers indicates that their composition consists mainly of water and carbohydrates. Water content is high, close to 60–62%, with a slight superiority under treatment T2 (61.97%) compared to 60.99% in T1 and 60.92% in T3. Carbohydrates constitute the second major component, fluctuating between 11.42% and 12.64%, with the highest concentration observed in tubers from treatment T2 (12.64%), followed by T3 (12.19%) and T1 (11.42%). Protein content averaged between 10.80% and 11.70%, with a slight predominance under treatment T3 (11.70%) compared to T1 (11.21%) and T2 (10.80%). The mineral fraction, expressed by the ash rate, was more important in tubers treated with T1 (4.13%) than in T3 (2.86%) and T2 (2.54%). Finally, fiber content remained low, around 0.87% to 1.02%, with a slightly higher value under treatment T2 (1.02%) compared to T1 (0.96%) and T3 (0.87%) (Figure 4).

Principal Component Analysis (PCA) of the nutritional composition of yam tubers highlights two main axes explaining together 66.4% of the total variability (Dim1: 40.5% and Dim2: 25.9%). Axis 1 is strongly correlated with proteins and water, opposing treatments rich in these components to those characterized by low carbohydrate content. Axis 2 is mainly associated with ash content, reflecting an opposition between mineral richness and other biochemical parameters. The projection of treatments shows some differentiation: treatment T1 (red circle) is more associated with ash, indicating better mineral richness; treatment T2 (green triangle) is positioned more on the carbohydrate side, confirming its energetic superiority already revealed by descriptive analysis (Figures 3 and 4); finally, treatment T3 (blue square) is closer to proteins and water.

The correlation matrix (Figure 6) reveals generally weak relationships between the nutritional parameters of the tubers. A moderate positive correlation was observed between water content and proteins (r = 0.39), suggesting that samples richer in water also tend to contain more protein. Other relationships remained very weak, even negative, such as between fibers and ash (r = -0.13) or between fibers and carbohydrates (r = -0.13), indicating an absence of significant association. Overall, the variables seemed to behave independently, confirming that each parameter contributes specifically to the biochemical variability of the studied yams.

Interaction between the Biochemical Composition of Harvested Yam Tubers and Nematode Parasitic Density

The Principal Component Analysis (PCA) (Figure 7) illustrates the relationship between agroecological zones (AEZ), applied treatments, biochemical variables such as water, fiber, ash, protein, and carbohydrate content, and nematode density on the tubers.

The main axis 1 (Dim1), explaining 53.5% of the variance, clearly opposes treatments characterized by high nematode density (notably II_T2 and II_T3 located on the right) and those with low or almost no nematode presence (such as I_T1, I_T3 and III_T1 on the left). This axis therefore reflects the major effect of the 'nematode density' variable in structuring the data.

The secondary axis 2 (Dim2), representing 17% of the variance, mainly differentiates the nutritional components of the tubers. In particular, it opposes variables related to water, proteins, and carbohydrates located in the upper part of the graph, to mineral and fibrous factors (ash and fiber) located at the bottom left. Thus, this axis reflects a diversity in nutritional quality depending on the different agroecological zones.

The vectors representing parasitic variables (Nematode_J0, J60, J120, J180) are closely aligned and oriented towards the right, indicating a strong positive correlation between densities measured at different times.

The 'Carbohydrate' vector also points to the right, in proximity to heavily infested treatments (II_T2, II_T3), indicating a positive correlation between nematode density and tuber carbohydrate content. In contrast, 'Water' and 'Protein' are grouped in the upper left zone, associated with lightly infested treatments (III_T3), underscoring that lower nematode levels correspond to increased water and protein content.

Figure.3 Variation in the biochemical composition of yams according to AEZ and treatments

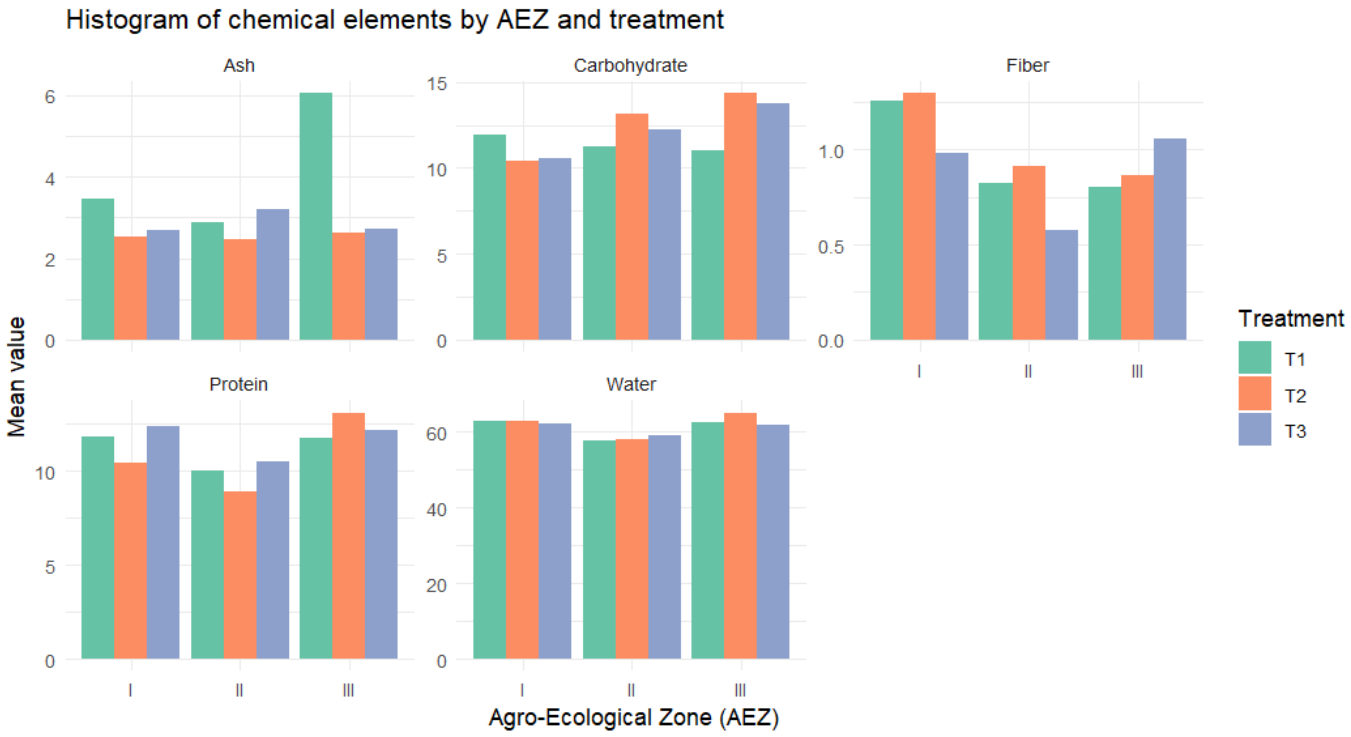


Figure.4 Variation in the biochemical composition of yams according to treatments

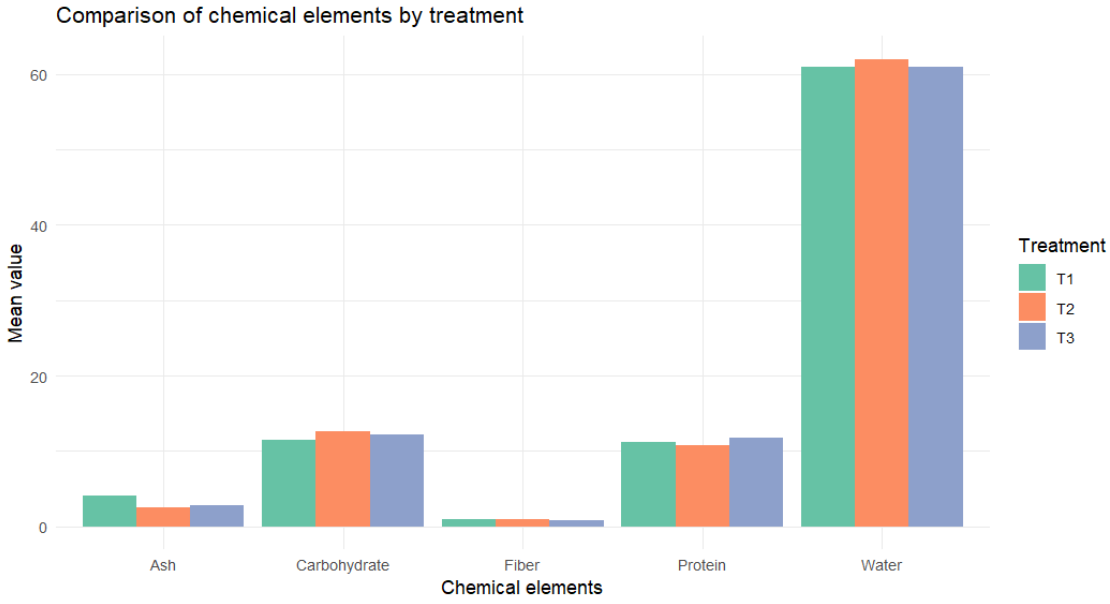


Figure.5 Principal Component Analysis (PCA) of the biochemical composition of yam tubers according to treatments

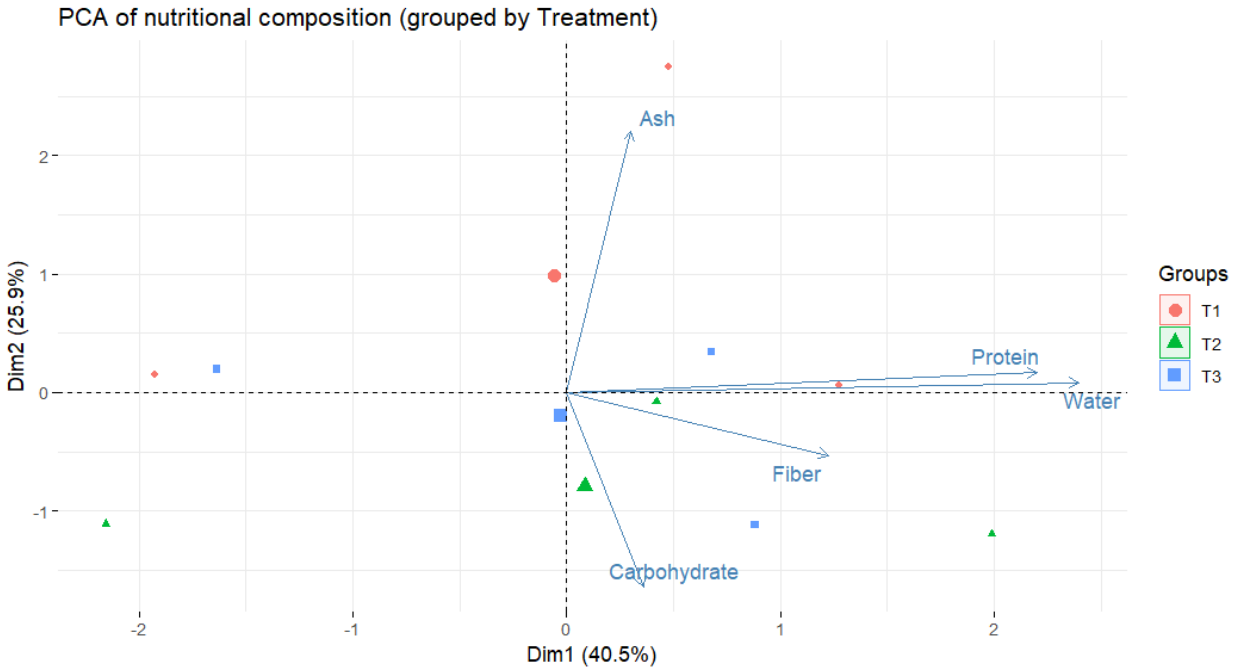


Figure.6 Correlation matrix of the different biochemical components of yam tubers

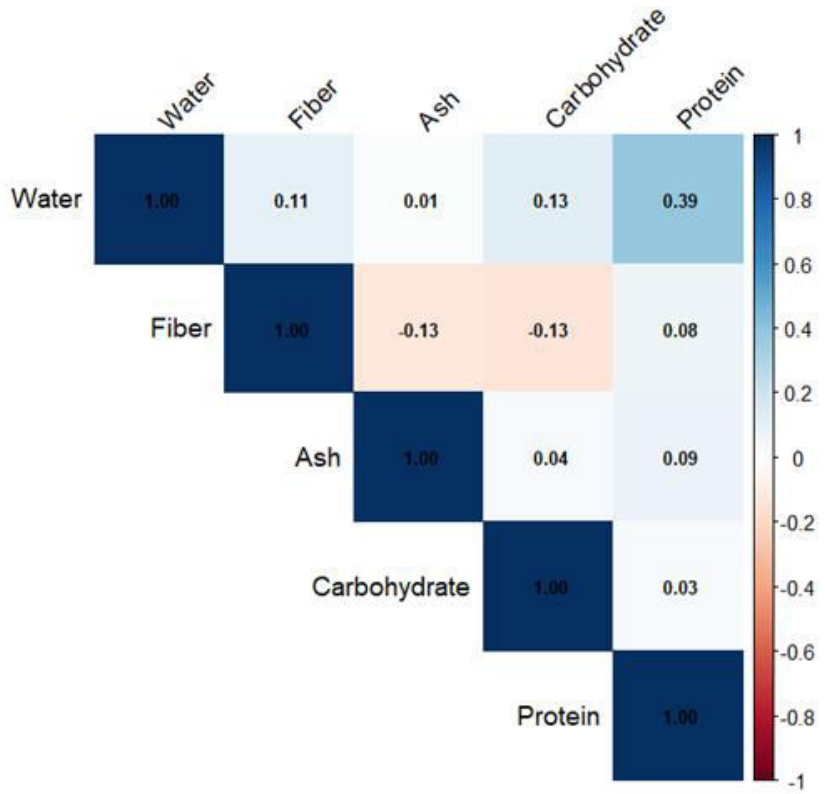
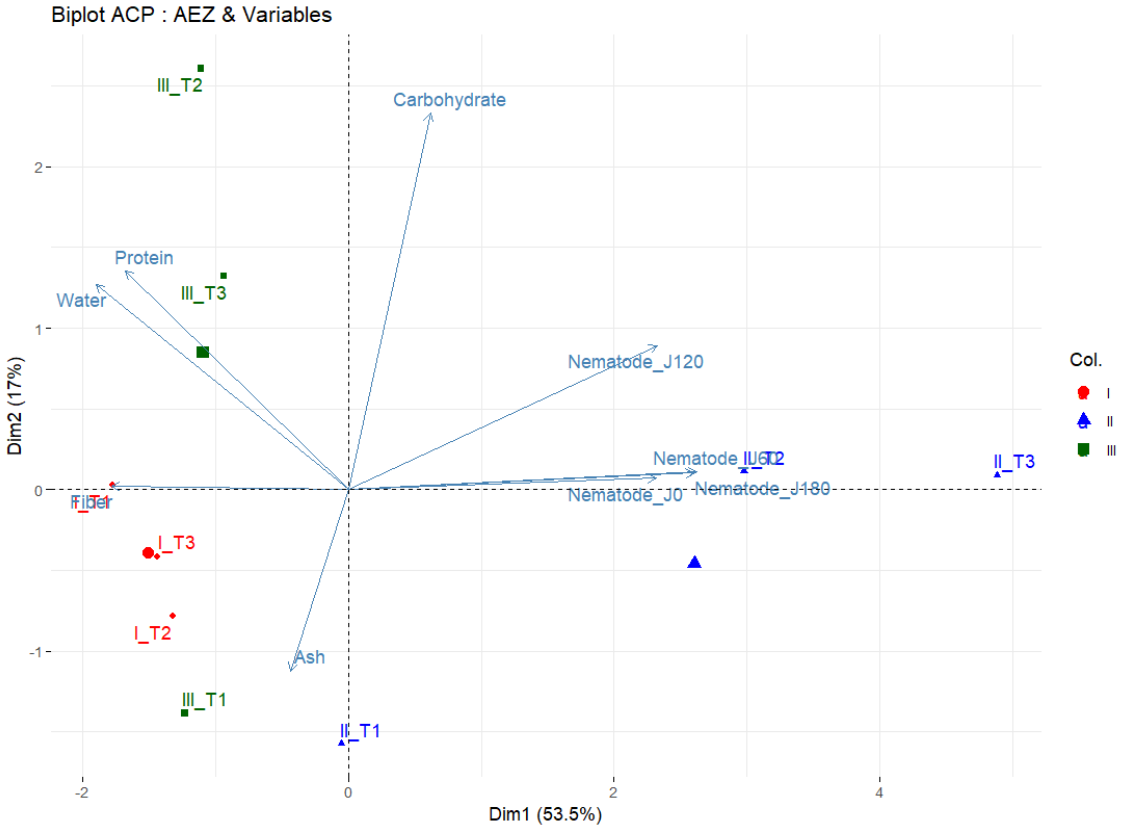


Figure.7 PCA of the biochemical composition of yam tubers in relation to nematode density



The 'Ash' and 'Fiber' components are located at the bottom left, opposite carbohydrates and nematodes, and appear linked to some treatments from zone AEZ I (I_T2, I_T3).

Regarding the distribution of treatments by agroecological zone, those from AEZ II (blue) show the highest nematode densities as well as a concomitant increase in carbohydrates, while treatments from AEZ III (green) are associated with better nutritional quality in proteins and water despite moderate to low infestation. Treatments from zone AEZ I (red) are distinguished by a dominance of fibers and minerals with low correlation to nematodes.

Among the treatments, II_T3 stands out as the most heavily infested and enriched in carbohydrates, while III_T3 presents a more balanced profile with high protein and water content and few nematodes. Treatment I_T3 itself shows particular nutritional interest due to its richness in fibers and ash, despite a weak association with nematode presence.

The free water content of a food is a critical parameter that strongly influences its stability, conservation, and susceptibility to microbial spoilage (Khan and Karim, 2017; Mathlouthi, 2001; Wang *et al.,* 2018). The more free water a food contains, the more vulnerable it is to microorganism growth and degradation of its organoleptic qualities (Khan and Karim, 2017; Mathlouthi, 2001; Slade *et al.,* 1991; Wang *et al.,* 2018). In this study, the highest water contents were observed in samples from agroecological zone III, located in the south of Togo and benefiting from two rainy seasons. Conversely, the contrary results recorded in zone AEZ II could be explained by reduced rainfall with a short rainy season disturbed by drought episodes (Adewi *et al.,* 2010). Furthermore, the water content of plant products is determined by a complex combination of genetic, environmental, and technical factors. Variety, climate, soil science (pedology) (Medyouni *et al.,* 2021; Ievinsh, 2023), and post-harvest storage methods all play a major role in the variation of water content (Gane, 1950; Ievinsh, 2023).

Dietary fibers promote intestinal transit, regulate metabolism and satiety, and help prevent various chronic diseases (Papathanasopoulos and Camilleri, 2010; He *et al.,* 2022; Tian *et al.,* 2023). The dietary fiber contents in this study varied from 0.41% to 1.94%, with higher values in yams treated with abamectin and relative controls compared to previous work on raw yams (Tchiègang and Ngueto, 2009). The dietary fiber content of yams (*Dioscorea* spp.) varies considerably depending on the varieties, whether cultivated or wild (Bhandari *et al.,* 2003; McAnuff *et al.,* 2005; Abara *et al.,* 2011; Dufie *et al.,* 2013; Sahoo *et al.,* 2023). In *Dioscorea alata* (water yam), it ranges between 4.1% and 11% depending on the (Dufie *et al.,* 2013), while some local accessions present crude fiber contents between 6.7% and 11.6% (Bhandari *et al.,* 2003; Padhan and Panda, 2020). Wild yams often tend to have higher fiber content than cultivated varieties (McAnuff *et al.,* 2005; Padhan and Panda, 2020). This variability is mainly linked to factors such as genetic origin, growing conditions, geographical location, and harvest time (Bekele and Bekele, 2018; Sahoo *et al.,* 2023).

Proteins support cellular structure and renewal, mediate nutrient transport, provide amino acids, regulate hormonal and enzymatic functions, ensure immune protection, and control energy metabolism (Bitocchi *et al.,* 2017; Li and Hoppe, 2023; Sahytjn, 1949). The levels observed in this study fall within the range documented by (Aruna *et al.,* 2017), who report crude protein levels between 6% and 15%, suggesting a notable nutritional contribution of tubers in a vegetarian diet (Guéguen *et al.,* 2016).

Yams are an important source of carbohydrates, mainly in the form of starch. Depending on the species and varieties, their total carbohydrate content generally varies from 62.6% to 79.4% on a dry matter basis, for both wild and cultivated species (Yalindua *et al.,* 2021; Sahoo *et al.,* 2023). For example, purple yam flour contains about 79.4% carbohydrates, while white yam flour contains 73.41% (Yalindua *et al.,* 2021). In contrast, in high-water-content yams (*D. alata*), the carbohydrate content on a fresh weight basis is much lower, oscillating between 17.10% and 29.37% depending on local accessions (Fauziah *et al.,* 2020). In the present study, the observed levels were between 8.49% and 15.49%, values lower than those previously reported, which could be attributed to varietal differences (Otegbayo *et al.,* 2017; Shao *et al.,* 2020; Sahoo *et al.,* 2023), agroecological conditions (Otegbayo *et al.,* 2017; Sahoo *et al.,* 2023), and the physiological stage of the tubers at harvest time (Zou *et al.,* 2020).

The mineral fraction, measured by ash content, fluctuated between 2.02% and 9.45%, within a range close to that reported by (Tchiègang and Ngueto, 2009). This mineral richness gives yams an interesting nutritive potential (Coursey, 1967).

The interaction between pedoclimatic conditions (Epping and Laibach, 2020; Padhan and Panda, 2020; Yang *et al.,* 2023) and cultural practices (Fathima *et al.,* 2020; Matsumoto *et al.,* 2021; Elbasiouny *et al.,* 2022) exerts a significant influence on the nutritional quality of yam tubers, particularly on fibers and minerals. Water content, relatively stable between 60% and 65% regardless of treatments, seems more determined by intrinsic factors such as genotype and local conditions (Oyetunji and Afolayan, 2007; Kihara *et al.,* 2024). The results highlight contrasting effects of the treatments: T1 promotes ash accumulation, T2 improves carbohydrate and protein contents, while T3 is associated with a punctual increase in fibers, notably in zone AEZ III, confirming the observations of (Dansi *et al.,* 2013).

Furthermore, multivariate analysis revealed a marked correlation between the dynamics of nematode populations and the biochemical quality of tubers, illustrating the deleterious effect of these parasites on the physiology and nutritional composition of yams (Claudius-Cole, 2021; D. L. Coyne *et al.,* 2006). The results indicate that fiber and ash contents are higher in zone AEZ I, characterized by low parasitic pressure. Conversely, in zones where nematode pressure is higher, infestations lead to an accumulation of carbohydrates, but at the expense of proteins and water content. This imbalance is explained by the fact that nematode attacks directly degrade the nutritional quality of yam tubers by causing dry rot and tissue disorganization, which reduces their edible fraction and their content of starch, proteins, and essential micronutrients (D. L. Coyne *et al.,* 2006; Abdulsalam *et al.,* 2021; Claudius-Cole, 2021). Moreover, the loss of mass and quality that occurs during storage of infested tubers further accentuates the decrease in their available nutritional value for consumption or sale. The physiological stress induced by these parasites also alters the plant's metabolism, affecting the synthesis and storage of nutrients, particularly proteins and minerals (Abdulsalam *et al.,* 2021; Claudius-Cole, 2021; Espère *et al.,* 2024). In this context, zone AEZ II appears the most vulnerable to

infestations, while zone AEZ III manages to maintain better nutritional quality.

Finally, the "Wrap and Plant" technology, applied without insecticide (T2), proves particularly promising for improving nutritional quality, notably by increasing protein and carbohydrate contents. This approach illustrates the interest of integrating cultural innovations adapted to local contexts into a strategy for sustainable yam crop management.

In Conclusion, it appears that the treatments applied to yam tubers differently influence their biochemical composition depending on agroecological zones and pedoclimatic conditions. Water content, relatively stable, confirms the importance of intrinsic factors such as genotype and local environment in regulating this parameter. Fibers, proteins, carbohydrates, and minerals show significant variations linked to variety, cultural practices, and the level of nematode infestation. The "Wrap and Plant" approach without the use of insecticides proves particularly promising, as it combines a beneficial effect on nutritional quality with better environmental sustainability. It thus constitutes an innovative alternative to strengthen the resilience of production systems in the face of parasitic and climatic pressures. Ultimately, this study highlights that improving the biochemical quality of yams relies on integrated management combining varietal choice, adapted cultural practices, and reasoned control of nematodes. These results open perspectives for recommending innovative strategies, both ecological and economically viable, in favor of sustainable yam production in Togo and West Africa.

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Author Contributions

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

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