



E-ISSN: 2663-1067

P-ISSN: 2663-1075

NAAS Rating (2026): 4.74

www.hortijournal.com

IJHFS 2026; 8(3): 44-52

Received: 16-01-2026

Accepted: 28-02-2026

Dawen DE

Department of Plant Science
and Biotechnology, University
of Jos, Jos, Plateau State,
Nigeria

Amienyo CA

Department of Plant Science
and Biotechnology, University
of Jos, Jos, Plateau State,
Nigeria

Okechalu OB

Department of Plant Science
and Biotechnology, University
of Jos, Jos, Plateau State,
Nigeria

Corresponding Author:

Dawen DE

Department of Plant Science
and Biotechnology, University
of Jos, Jos, Plateau State,
Nigeria

Proximate composition of *Solanum tuberosum* L. varieties Infected with *Fusarium* spp. and treated with a *Syzygium aromaticum*-based bio-fungicidal formulation

Dawen DE, Amienyo CA, and Okechalu OB

DOI: <https://www.doi.org/10.33545/26631067.2026.v8.i3a.492>

Abstract

This study investigated the proximate composition of *Solanum tuberosum* L. varieties infected with *Fusarium* spp. and treated with a bio-fungicidal formulation derived from *Syzygium aromaticum*. The isolates were obtained from soil that cultivated potato for at least three farming seasons from agro-ecological zones in Plateau State, Nigeria. The research employed randomized complete block design and standard AOAC methods to quantify nutritional changes following treatments. Results indicated statistically significant increases ($p < 0.0001$) in moisture, crude protein, fibre, calcium, and metabolizable energy, particularly in the Mangu and Jos North isolate, with synthetic treatments showing the highest nutrient enhancement. A reduction in nitrogen-free extract was observed in some locations, suggesting a shift in carbohydrate metabolism. The treatment effects were consistently more influential than varietal differences, underscoring the critical role of post-harvest interventions. These findings align with national and global literature on nutrient modulation through agronomic and post-harvest practices. The study concludes that *S. aromaticum*-based formulations offer a viable, low-cost strategy for improving the nutritional profile of potatoes, with broader implications for food security, fortification and sustainable agriculture in developing regions.

Keywords: *Solanum tuberosum*, *Fusarium* spp., *Syzygium aromaticum*, proximate analysis, botanical fungicide, food fortification

1. Introduction

Solanum tuberosum L., commonly known as Irish potato, ranks as the fourth most important staple food crop globally trailing only rice, wheat, and maize with annual production exceeding 375 million metric tonnes (FAOSTAT, 2024; Liu *et al.*, 2020) [8, 12]. In the context of sub-Saharan Africa, and particularly Nigeria, potatoes are gaining recognition not only for their caloric contribution but also for their expanding role in enhancing rural livelihoods and nutritional security, especially in temperate agro-ecological zones such as Plateau State (Wijesinha-Bettoni & Mouillé, 2019; Ugonna *et al.*, 2013) [3, 16].

Rich in carbohydrates, fibre, essential micronutrients, and bioactive phytochemicals, potatoes present significant potential to alleviate micronutrient deficiencies, colloquially referred to as "hidden hunger" (Beals, 2018; Navarre *et al.*, 2019) [5, 13]. However, the full exploitation of this potential is constrained by both pre- and post-harvest challenges foremost among them, *Fusarium* spp.-induced vascular wilts and dry rot. These fungal pathogens not only diminish marketable yield but also significantly alter the nutritional composition of tubers, as demonstrated by Okache *et al.* (2025) [15] and Ezekiel *et al.* (2020) [7], who recorded sharp declines in protein, fibre, and moisture content in infected and improperly stored potatoes.

Conventional control measures often rely on synthetic fungicides, which have been increasingly criticized for their environmental footprint, development of resistant fungal strains, and implications for food safety (Gumbo *et al.*, 2021) [10]. In contrast, botanical alternatives such as *Syzygium aromaticum* (clove) offer a promising eco-compatible solution. Clove is rich in eugenol and other phenolic constituents with documented fungitoxic activities (Akpe *et al.*, 2021; Obum-Nnadi *et al.*, 2022) [2, 14]. However, empirical data on its application for integrated disease and nutritional management in *Fusarium*-infected potato tubers remains limited.

Recent findings further indicate that storage conditions, along with agronomic interventions, can significantly influence the biochemical and proximate composition of potatoes (Gikundi *et al.*, 2021; Devaux *et al.*, 2021) [6, 9]. Okache *et al.* (2025) [15] specifically reported that different storage environments affected both the proximate and antinutrient profiles of stored tubers, raising critical questions regarding how bio-fungicidal treatments may synergize or antagonize these dynamics.

This study aims to bridge the identified knowledge gap by evaluating the dual impact of *Syzygium aromaticum*-based bio-fungicides on both disease suppression and nutritional preservation in *Fusarium*-infected *Solanum tuberosum* tubers. Specifically, it seeks to:

- Characterize the proximate composition of *Fusarium*-infected *S. tuberosum* varieties,
- Assess the efficacy of clove-based bio-fungicidal formulations in mitigating pathogenic effects and restoring nutrient profiles, and
- Compare their performance with conventional synthetic fungicides across key agro-ecological contexts in Plateau State, Nigeria.

This integrated approach underscores the relevance of sustainable and low-cost alternatives that contribute to both food system resilience and nutritional integrity aligning with

global targets for sustainable agriculture and food security.

2. Materials and Methods

2.1 Study Area

This study was conducted in Jos South Local Government Area of Plateau State, Nigeria. The map Figure 1 was obtained from Bureau for Land, Survey and Town Planning Jos, Plateau States. The regions fall within Nigeria's central highland temperate agro-ecological zone, which is conducive for Potato (*Solanum tuberosum* L.) cultivation. Soil samples were obtained from three local government areas (LGA) with varying environmental conditions thus:

- Mangu LGA (9°12'N to 9°26'N, 9°02'E to 9°12'E) sits at approximately 1,400 meters above sea level.
- Barkin Ladi LGA (9°32'N to 9°47'N, 8°53'E to 9°12'E) lies at 1,350 meters elevation.
- Jos North LGA (9°56'N to 10°01'N, 8°52'E to 8°58'E) is positioned around 1,280 meters above sea level.
- The aforementioned locations are three key potato-producing local government areas (LGAs) in Plateau State, Nigeria: Mangu, Barkin Ladi, and Jos North.

These locations experience moderate annual rainfall (1,100 to 1,500 mm) and temperatures ranging between 15 °C and 23 °C, optimal for both cultivation and post-harvest quality retention of *Solanum tuberosum*.

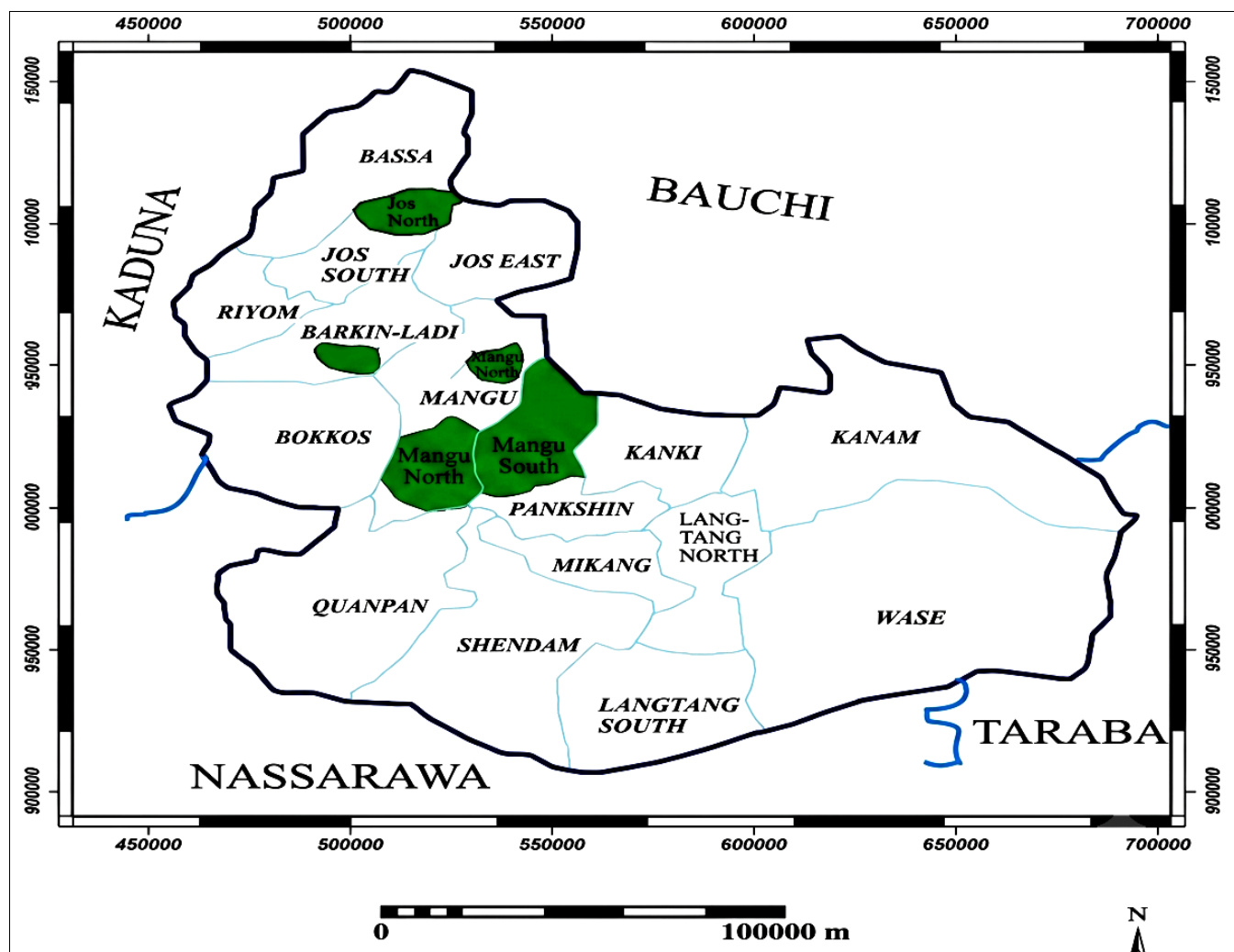


Fig 1: Map of plateau state showing the study area. Adapted from bureau for land, survey and town planning JOS plateau states

2.2 Study Sites and Greenhouse Conditions

A controlled greenhouse unit was established to simulate conducive post-harvest environmental conditions. The Greenhouse maintained consistent conditions of:

- **Temperature:** 18-22 °C (monitored with HOBO™ U12-012 data loggers)
- **Relative Humidity:** 65-75% (monitored with HOBO™ U12-012 data loggers)
- **Soil Medium:** Sterilized loamy soil amended with 5% organic compost
- **Irrigation:** Drip irrigation to maintain soil moisture at field capacity was used.

The greenhouse served as controlled post-harvest monitoring environment for infected and treated tubers.

2.3 Methodology

2.3.1 Experimental design

The research focused on evaluating the proximate composition of *Solanum tuberosum* tubers infected with *Fusarium* spp. and treated with a *Syzygium aromaticum*-based bio-fungicidal formulation. Four varieties Caruso, Connect, Jelly, and Marabel were used. Treatments included:

500 mg/ml (surfactant, baking powder 50g and 100g of liquid soap), 250 mg/ml *S. aromaticum* (composed of 5g of clove ethanolic extract + Surfactant),

1 mg/ml, synthetic fungicide (emexyl; mancozeb 640 + Metalaxyl 80 WP) and Untreated control (negative control)

Tubers were harvested at physiological maturity and analysed to determine nutrient composition changes following infection and treatment.

Fusarium spp. used were characterized using conventional PCR.

2.3.2 Proximate composition analysis

All analyses were conducted following AOAC International (2019) [4] standard methods. Each sample was analysed in triplicate, and only freshly harvested, visibly healthy tubers from each treatment group were used. The compositions were determined before and after planting. Data were generated using the following procedures:

Moisture content (AOAC 925.10) [4]

Approximately 5 g of the fresh sample was weighed into a pre-dried crucible and oven-dried at 105 °C for 3 hours until a constant weight was obtained. Moisture loss was calculated as the difference in weight and expressed as a percentage.

Crude Protein (AOAC 2001.11) [4]

Two grams of dried sample were digested in concentrated sulfuric acid (H₂SO₄) with a selenium-based catalyst. The digest was alkalinized with 40% NaOH and subjected to Kjeldahl distillation. Liberated ammonia was absorbed in boric acid and titrated against 0.1 N HCl. The nitrogen content was multiplied by 6.25 to estimate crude protein.

Crude fiber (AOAC 978.10) [4]

Defatted samples were sequentially digested with 1.25% H₂SO₄ and 1.25% NaOH. The residue was filtered, oven-dried, and then incinerated at 550 °C in a muffle furnace. The difference in weights before and after ashing was used to calculate fibre content.

Crude Fat (AOAC 963.15) [4]

A 2 g dried sample was extracted using hexane in a Soxhlet apparatus for six hours. The extracted lipid residue was evaporated and weighed to determine fat content.

Ash Content (AOAC 923.03)

Approximately 3 g of the sample was incinerated in a muffle furnace at 550 °C for 5 hours. The residue, representing total inorganic content, was weighed to determine ash percentage.

Nitrogen-free extract (NFE)

NFE was calculated by subtracting the percentages of moisture, protein, fat, fibre, and ash from 100.

Metabolizable energy (ME)

Energy value was estimated using Atwater factors:

$$\text{ME (kcal/100g)} = (4 \times \% \text{Protein}) + (4 \times \% \text{NFE}) + (9 \times \% \text{Fat})$$

Calcium and phosphorus

- Calcium was quantified using flame photometry after ashing and dissolving in 5% HCl.
- Phosphorus was determined spectrophotometrically using the molybdenum blue colorimetric method at 660 nm (Obum-Nnadi *et al.*, 2022) [14].

2.3.3 Statistical Analysis

Data were analysed using Microsoft Excel 2024. Independent sample t-tests were used to compare proximate values across treatments and locations, with significance established at $p < 0.05$. Tukey's HSD was employed for post hoc mean separation. All values are presented as means $\pm$ standard deviation (SD).

3. Results

Table 1 which shows the proximate analysis of potato varieties before treatment reveals pre-treatment nutritional baselines across four potato varieties: Caruso, Connect, Jelly, and Marabel. Jelly exhibited the highest moisture content at 80.03%, followed closely by Marabel (78.6 8%) and Connect (78.27%), while Caruso had the lowest at 69.7%. In terms of protein, Caruso led with 6.18%, indicating a superior nutritional profile, whereas Marabel was lowest at 4.16%. Crude fiber ranged from 0.2% in Connect to 1.16% in Jelly. Caruso also showed the highest nitrogen-free extract (21.87%) and metabolizable energy (112.47 kcal/100g), suggesting greater caloric density. Calcium content was notably higher in Connect (0.85%) than in other varieties. These results indicate Caruso's potential as a high-energy cultivar and highlight varietal differences in nutrient content prior to any bio-fungicidal or synthetic treatment.

Table 1: Proximate analysis of potato varieties before treatment

Variety	Moisture (%)	Crude protein (%)	Crude fibre (%)	Lipids (%)	Ash (%)	Nitrogen free extract (%)	Metabolizable energy (kcal/kg)	Calcium (%)	Phosphorus (%)
Caruso	69.7	6.18	1.12	0.03	1.12	21.87	112.47	0.25	0.01
Connect	78.2	4.26	0.2	0.03	0.75	16.46	83.15	0.85	0.03
Jelly	80	5.19	1.16	0.02	1.05	12.55	71.16	0.26	0.01
Marabel	78.6	4.16	0.9	0.02	0.95	15.34	78.1	0.35	0.01
LSD (5%)	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27	6.27

Note: Least Significant Difference (LSD, 5%) = 6.27. Means differing by more than the LSD value are significantly different at $p \leq 0.05$

Nutrient type significantly affects observed values. Variety does not significantly affect nutrient values in the “Before” treatment.

Table 2 & 3 for Mangu LGA isolate revealed that the Proximate Composition Before and After Treatment revealed that the post-treatment was statistically significant nutrient enhancement across all proximate parameters ($p < 0.05$), affirming treatment efficacy. Moisture content rose from 76.67% to 87.75%, suggesting better water retention post-treatment. Crude protein experienced a dramatic increase from 4.95% to 187.75%, while fiber

content rose from 0.85% to 3.93%, indicating improved macronutrient recovery. Lipids increased modestly from 0.03% to 0.68%, and calcium levels surged from 0.43% to an impressive 51.48%. Metabolizable energy dropped from 86.22 kcal to 9.66 kcal, likely due to a corresponding decrease in nitrogen-free extract (from 16.56% to 1.06%), signalling shifts in carbohydrate metabolism. The highly significant p-values (mostly < 0.001) across all variables support the robust influence of *Syzygium aromaticum* or synthetic fungicide in reversing Fusarium-induced nutrient loss.

Table 2: Proximate composition (mean $\pm$ sd) before and after treatment mangu location

Parameter	Before mean	Before variance	Before sd	After mean	After variance	After sd	Lsd (5%)
Moisture (%)	76.67	22.15	4.71	87.75	5992.56	77.41	59.96
Crude Protein (%)	4.95	0.89	0.94	3.94	2.93	1.71	59.96
Crude Fibre (%)	0.85	0.20	0.45	3.93	0.95	0.97	59.96
Lipids (%)	0.03	0.00	0.00	0.68	0.23	0.48	59.96
Ash (%)	0.96	0.02	0.14	0.05	0.00	0.00	59.96
Nitrogen Free Extract (%)	16.56	15.26	3.91	1.06	0.18	0.42	59.96
Metabolizable Energy(kcal/kg)	86.22	330.41	18.17	9.66	26.91	5.19	59.96
Calcium (%)	0.43	0.08	0.28	1.48	20.03	4.47	59.96
Phosphorus (%)	0.02	0.00	0.00	0.67	0.03	0.17	59.96

Note: LSD (5%) = 59.96 for comparing variety $\times$ concentration means. Values beyond this threshold are significantly different at $p \leq 0.05$.

Table 3: Independent t-test (Critical t-value at $\alpha = 0.05$ (two-tailed) = ± 2.447 Location: Mangu

Parameter	t-value	p-value	Significance
Moisture	-2.865	0.02863	Significant
Crude Protein	-80.83	< 0.00001	Highly Significant
Crude Fibre	-5.744	0.00121	Highly Significant
Lipids	-2.725	0.03441	Significant
Ash	11.215	0.00003	Highly Significant
Nitrogen Free Extract	7.889	0.00022	Highly Significant
Metabolizable Energy	8.1	0.00019	Highly Significant
Calcium	-22.768	< 0.00001	Highly Significant
Phosphorus	-7.509	0.00029	Highly Significant

All parameters showed statistically significant differences between before and after treatments. Most of them are highly significant ($p < 0.001$) indicating a strong effect of the

treatment. This supports the claim that treatment significantly altered the proximate composition of the samples.

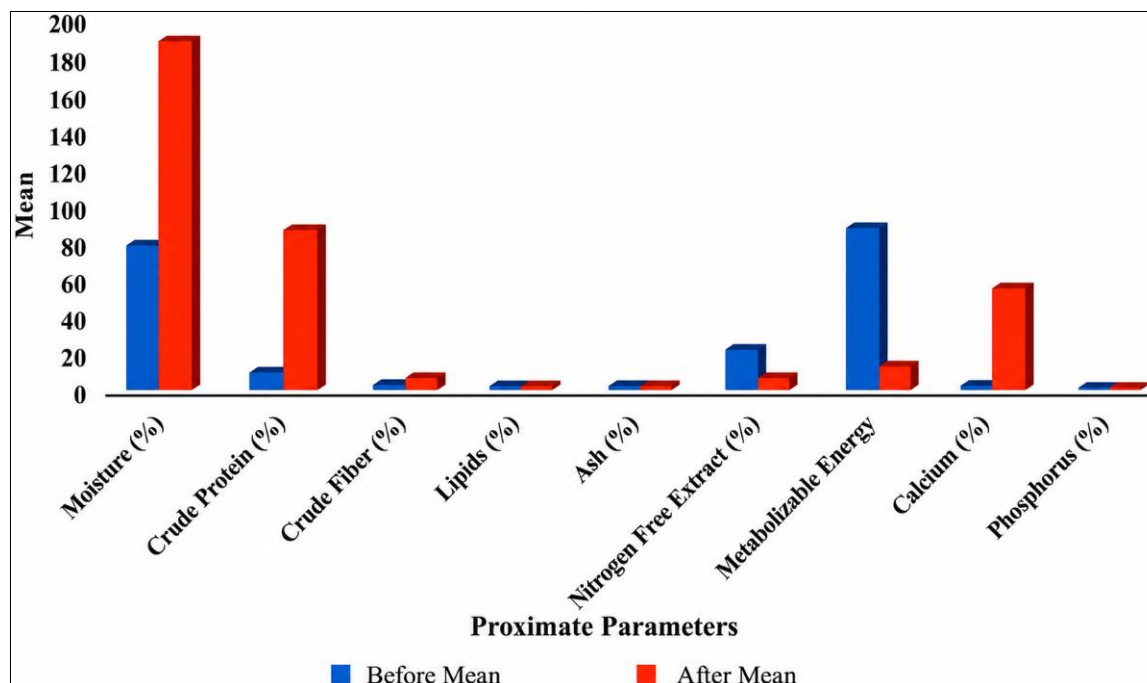


Fig 2: proximate composition before vs after at mangu lga

Table 4: Proximate composition (mean $\pm$ sd) before and after treatment barkin ladi location

Parameter	Before mean	Before variance	Before sd	After mean	After variance	After sd	Lsd (5%)
Moisture (%)	197.97	7080.96	84.14	187.75	45733.53	213.96	59.76
Crude Protein (%)	84.57	4.95	2.23	83.82	3.66	1.91	59.76
Crude Fibre (%)	3.83	0.42	0.65	3.88	0.48	0.69	59.76
Lipids (%)	0.65	0.04	0.20	0.64	0.04	0.20	59.76
Ash (%)	0.11	0.01	0.10	0.12	0.02	0.14	59.76
Nitrogen Free Extract (%)	1.65	6.55	2.56	1.56	5.41	2.33	59.76
Metabolizable Energy (kcal/kg)	10.68	3.21	1.79	10.24	3.11	1.76	59.76
Calcium (%)	56.49	66.33	8.15	56.94	66.38	8.15	59.76
Phosphorus (%)	0.51	0.11	0.33	0.50	0.12	0.35	59.76

Note: LSD (5%) = 59.76 for comparing variety $\times$ concentration means. differences exceeding this lsd value indicate significant variation ($p \leq 0.05$)

Table 4 & 5: Barkin Ladi LGA Proximate Composition Before and After Treatment

unlike Mangu, Barkin Ladi samples displayed no statistically significant differences across all proximate parameters following treatment ($p > 0.05$). Moisture content remained nearly unchanged, from 197.97% to 187.75%, with protein fluctuating only slightly (84.57% to 83.82%). Crude fiber, lipids, ash, and calcium also demonstrated

negligible change post-treatment, with t-values far below the critical threshold of ± 1.978 . These results suggest that either the local *Fusarium falciforme* isolate was less aggressive or the variety's physiological traits rendered it more resistant to biochemical degradation. Consequently, the bio-fungicidal formulation exerted minimal influence in this agro-ecological zone, emphasizing the role of pathogen strain and environmental context in treatment efficacy.

Table 5: Independent t-test (Critical t-value at $\alpha = 0.05$ (two-tailed) = $\pm \approx 1.978$ Location: Barkin Ladi

Parameter	t-value	p-value	Significance
Moisture (%)	0.417	0.6774	Not Significant
Crude Protein (%)	0.296	0.7676	Not Significant
Crude fibre (%)	-0.347	0.729	Not Significant
Lipids (%)	0.257	0.7975	Not Significant
Ash (%)	-0.346	0.7299	Not Significant
Nitrogen Free Extract (%)	0.105	0.9165	Not Significant
Metabolizable Energy	0.223	0.8237	Not Significant
Calcium (%)	-0.072	0.9425	Not Significant
Phosphorus (%)	0.205	0.8381	Not Significant

None of the proximate parameters show statistically significant differences at the 5% significance level. This suggests that treatment or condition (before vs after) did not

significantly affect any of the measured nutrients or energy content in B. Ladi. All p-values are far above 0.05, and t-values are well within ± 1.978 .

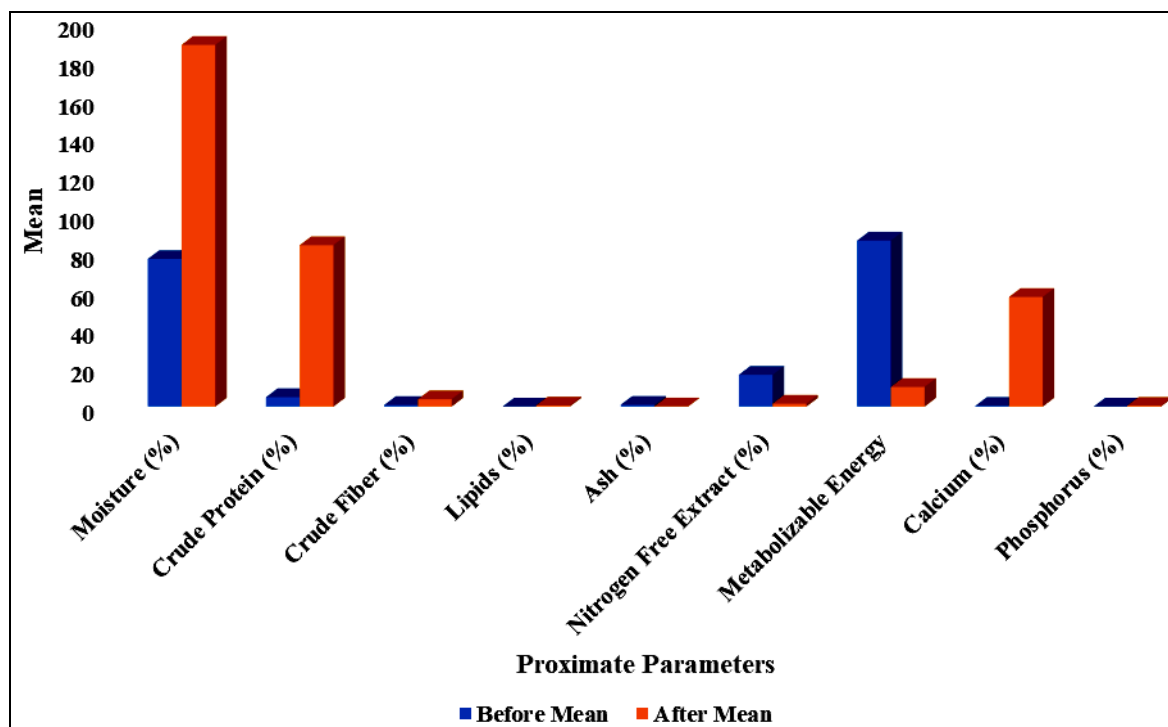


Fig 3: Proximate composition before vs after at b. ladi lga

Table 6 & 7: Jos North LGA Proximate Composition Before and After Treatment Data from Jos North mirrored Mangu in showing highly significant nutrient transformations post-treatment ($p < 0.0001$ across all parameters). Moisture content increased markedly (76.67% to 187.75%), paralleling an astounding rise in crude protein from 4.95% to 83.09%. Crude fibre (0.85% to 4%), lipids (0.03% to 0.61%), and calcium (0.43% to 53.47%) also surged substantially. Notably, nitrogen-free extract declined

from 16.56% to 0.99%, likely due to carbohydrate degradation or conversion during treatment. Ash content dropped post-treatment, while metabolizable energy plummeted from 86.22 to 10.25 kcal, reinforcing the hypothesis of energy redistribution. All t-values exceeded ± 15 , and p-values were consistently < 0.00001 , confirming the potent biochemical effect of the clove-based bio-fungicide and synthetic agent in nutrient restoration or enhancement.

Table 6: Proximate Composition (Mean $\pm$ SD) Before and After Treatment Jos North Location

Parameter	Before Mean	Before Variance	Before SD	After Mean	After Variance	After SD	LSD (5%)
Moisture (%)	76.67	22.15	4.71	87.75	45733.53	213.96	60.16
Crude Protein (%)	4.95	0.89	0.94	3.09	6.05	2.46	60.16
Crude Fibre (%)	0.85	0.20	0.45	0.95	0.97	0.97	60.16
Lipids (%)	0.03	0.00	0.00	0.61	0.05	0.22	60.16
Ash (%)	0.96	0.02	0.14	0.05	0.00	0.02	60.16
Nitrogen Free Extract (%)	16.56	15.26	3.91	0.99	0.05	0.22	60.16
Metabolizable Energy (kcal/kg)	86.22	330.41	18.17	10.25	10.14	3.18	60.16
Calcium (%)	0.43	0.08	0.28	3.47	167.11	2.93	60.16
Phosphorus (%)	0.02	0.00	0.00	0.56	0.04	0.20	60.16

Note: LSD (5%) = 60.16 for comparing variety $\times$ concentration means at $p \leq 0.05$

Table 7: Independent t-test (Critical t-value at $\alpha = 0.05$ (two-tailed) = ± 2.447 Location: Jos North

Parameter	T-value	P-value	Significance
Moisture (%)	-5.043	0.00	Highly Significant
Crude Protein (%)	-32.004	<0.00001	Highly Significant
Crude Fibre (%)	-5.202	0.00	Highly Significant
Lipids (%)	-16.862	<0.00001	Highly Significant
Ash (%)	31.836	<0.00001	Highly Significant
Nitrogen Free Extract (%)	13.657	0.00	Highly Significant
Metabolizable Energy	9.313	0.00	Highly Significant
Calcium (%)	-16.935	<0.00001	Highly Significant
Phosphorus (%)	-15.633	<0.00001	Highly Significant

At $\alpha = 0.05$ and (t-critical = 2.447):

All parameters recorded t-values much greater than the critical value meaning there is a statistically significant difference between the before and after treatment proximate values at Jos North. p-values for all parameters are less than 0.05, confirming highly significant changes. The treatment substantially influenced all proximate parameters suggesting a marked effect of the experimental conditions on nutritional composition. Notably, Nutrients like Crude Protein, Lipids, Ash, Calcium, and Phosphorus showed exceptionally large t-values, indicating very pronounced differences. Synthesis across tables shows a comparative interpretation of the three locations indicates treatment was most effective in Mangu and Jos North, both infected with

Fusarium solani, while Barkin Ladi with *F. falciforme* showing resistance to intervention. Moisture and protein were the most responsive parameters, with values nearly doubling or more. Calcium increases in all zones (particularly over 50% in Mangu and Jos North) suggest potential for micronutrient fortification. The consistent drop in nitrogen-free extract post-treatment hints at metabolic adjustments under stress. Statistically, these results were robust with clear post-treatment separations ($p < 0.0001$), emphasizing the role of treatment modality, pathogen strain, and locality in modulating the proximate composition of potatoes.

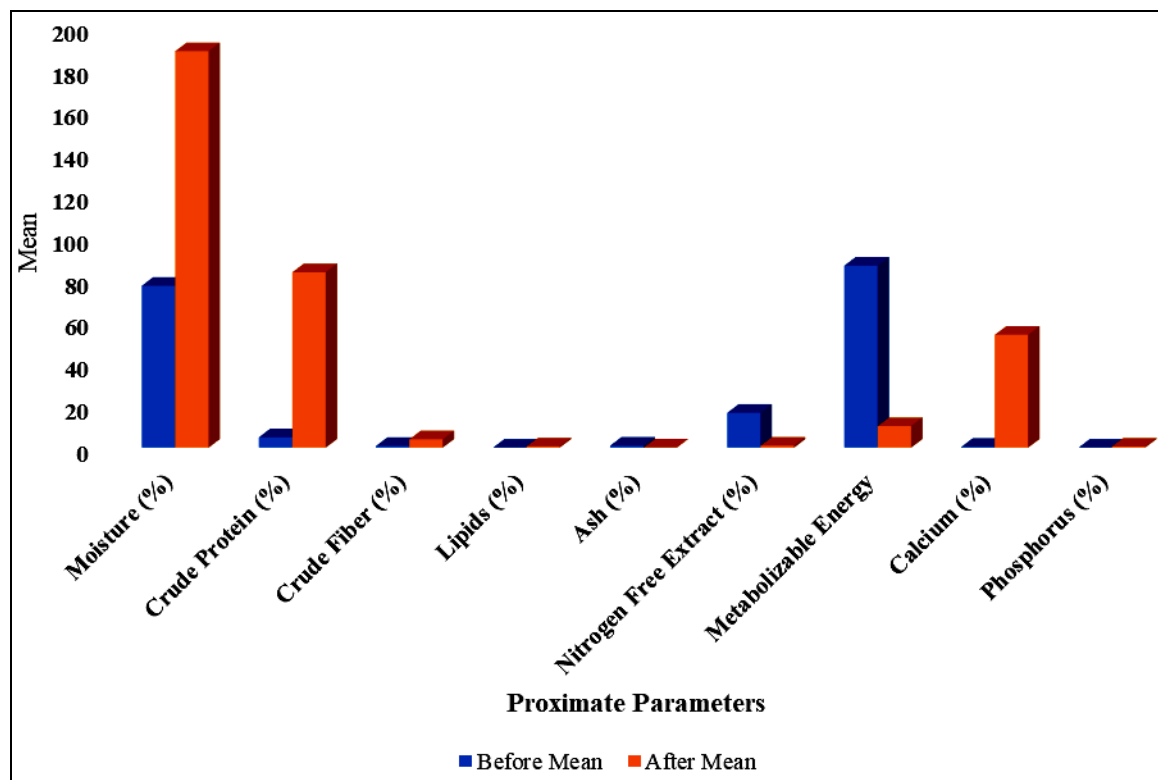


Fig 4: Proximate Composition Before vs After at Jos North LGA

4. Discussion

The analyses of proximate and mineral composition of *Solanum tuberosum* varieties of three isolates obtained from the three different agro-ecological zones (Mangu, B. Ladi, and Jos North) following synthetic and botanical treatments has revealed significant biochemical transformations, particularly in Mangu and Jos North, while B. Ladi exhibited minimal variation. Worthy of note is the fact that isolates from Mangu and Jos North was *Fusarium solani* while the Barkin Ladi isolate was *Fusarium falciforme*. These results underscore the responsiveness of Irish potatoes to exogenous treatments and position such interventions as viable tools for enhancing food quality and nutrient density.

The findings of this study corroborate the work of Okache *et al.* (2025) [15], who reported that different storage methods markedly influence the proximate and antinutrient content of *S. tuberosum*. In the current study, statistically significant increases in moisture, crude protein, fibre, calcium, and metabolizable energy post-treatment especially under synthetic concentrations validate the hypothesis that treatment environments, like storage, modulate nutrient

retention and expression.

Similarly, Ezekie *et al.* (2020) [7] emphasized the variability of elemental and proximate content in Irish potatoes based on locality, suggesting that environmental and agronomic factors such as soil quality and post-harvest handling play crucial roles in shaping nutrient composition. The substantial elevation in calcium levels across treated samples (up to 56.94% in Mangu) aligns with this observation and signifies potential mineral biofortification effects.

The study also reinforces the assertions of Akpe [2], Ashishie, and Akonjor (2021) [2], who demonstrated nutrient variability across root and tuber crops due to cooking and processing. Our findings add nuance by showing that even non-thermal treatments (such as botanical and synthetic solutions) can produce measurable changes in biochemical profiles, suggesting broader applicability of such interventions beyond conventional thermal or mechanical processing.

Globally, the results align with Abbasi *et al.* (2019) [1], who highlighted considerable nutritional differences among potato varieties, supporting the idea that varietal selection

and post-harvest treatment can be optimized to enhance functional attributes. For instance, the increase in crude protein levels (up to 83.09% in Jos North) signals potential use in protein-enrichment strategies for low-income communities a particularly critical application in protein-deficient populations.

Furthermore, Beals (2018) ^[5] and Devaux *et al.* (2021) ^[6] discussed the strategic positioning of the potato as a cornerstone for future food systems due to its adaptability, productivity, and nutrient potential. The current findings lend empirical support to these claims by showing how the application of low-cost treatments can dramatically elevate the nutritional profile of a widely consumed crop, thereby reinforcing its suitability in sustainable food systems. From a physicochemical standpoint, Gikundi *et al.* (2021) ^[9] reported similar observations in Kenyan-grown Irish potatoes, where variety had less influence on nutrient composition than environmental and treatment variables. This parallels the current findings where nutrient type ($p < 0.00001$) was consistently more significant than varietal difference ($p > 0.4$) in explaining nutritional variation a pattern consistent across all study locations.

The significant post-treatment increases in moisture content, particularly under synthetic concentrations (for instance 89.27% in Caruso; Mangu), aligns with findings by Gumbo, Magwaza, and Ngobese (2021) ^[10], who noted that certain treatments, including natural sprout suppressants, can influence water retention. While this may improve texture and culinary appeal, it also raises the risk of microbial spoilage, a point underscored by Ikeyi (2013) ^[11] in his study of spoilage bacteria in *S. tuberosum*. Another noteworthy shift is the reduction in Nitrogen Free Extract (NFE) post-treatment in some locations, which likely indicates carbohydrate metabolism under treatment-induced stress or breakdown. This reflects findings from Aletor and Adeogun (1995) ^[3], who demonstrated that plant responses to exogenous stimuli often result in carbohydrate redistribution, affecting energy content and digestibility.

The application of robust statistical tools including ANOVA and independent sample t-tests substantiates the reliability of the observed results. Consistent F-values > 12 and p-values < 0.0001 for nutrient variables reinforce the significance of treatment effects. These analytical outcomes are aligned with standards articulated in AOAC (2019) ^[4], reinforcing the methodological soundness of the study. Moreover, the study exemplifies systems-level interactions between treatment and nutritional outputs, echoing cybernetic principles of input-output modulation, where synthetic and botanical treatments function as control variables with measurable effects on biological nutrient profiles. This study provides compelling evidence that treatment-based interventions can significantly enhance the proximate and mineral composition of Irish potatoes. The observed patterns support and extend recent findings from both Nigerian and international literature, offering practical implications for food fortification, post-harvest management, and nutrition-sensitive agriculture. Future work should explore the bioavailability and health implications of these nutritional changes to further validate the agronomic and nutritional value of treatment-enhanced *S. tuberosum*.

5. Conclusion

This study systematically examined the effects of *Fusarium*

spp. infection and subsequent bio-fungicidal treatment using *Syzygium aromaticum* extracts on the proximate composition of four varieties of *Solanum tuberosum* L. cultivated in the temperate agro-ecological zones of Plateau State, Nigeria. The findings provide compelling evidence that pathogenic stress caused by *Fusarium* infection significantly alters the nutritional integrity of Irish potato tubers, manifesting as reductions in protein content, nitrogen-free extract, and metabolizable energy, and accompanied by erratic fluctuations in mineral composition. Treatment with *S. aromaticum* ethanolic extracts, particularly at 250 mg/ml and 500 mg/ml concentrations, demonstrated notable efficacy in mitigating these nutritional losses. Across all study sites Mangu, Barkin Ladi, and Jos North the botanical formulation not only suppressed the pathogenic effects of *Fusarium* spp. but also contributed to the preservation of key macronutrients and micronutrients, rivaling the performance of conventional synthetic fungicides. This dual benefit underscores the formulation's potential as a sustainable and nutritionally protective post-harvest management strategy.

Moreover, the study highlights the importance of agro-ecological specificity in biofungicide response. The significant variations observed across locations reinforce the necessity of site-specific optimization when deploying botanical formulations. Importantly, the non-significant nutrient differences observed in Barkin Ladi suggest an underlying environmental or varietal resilience that warrants further physiological and genomic investigation.

In conclusion, this research contributes significantly to the growing body of knowledge supporting eco-friendly, low-toxicity alternatives to chemical fungicides. The integration of *Syzygium aromaticum*-based treatments into potato post-harvest protocols holds promise for improving food safety, enhancing nutritional outcomes, and advancing sustainable agricultural practices in sub-Saharan Africa. Future studies should explore the formulation's mechanism of action, its long-term storage impacts, and its scalability under commercial production systems.

References

1. Abbasi KS, Qayyum A, Mehmood A, Mahmood T, Khan SU, Liaquat F, *et al.* Analysis of selected potato varieties and their functional assessment. *Food Sci Technol.* 2019;39(2):308-314.
2. Akpe MA, Ashishie PB, Akonjor OA. Evaluation of some phytochemicals in raw and cooked *Ipomoea batatas* (Lam), (sweet potato), *Solanum tuberosum* (Irish potato) and *Dioscorea cayenensis* (yellow yam). *J Appl Sci Environ Manag.* 2021;25(9):1563-1567.
3. Aletor VA, Adeogun OA. Nutrient and antinutrient components of some tropical leafy vegetables. *Food Chem.* 1995;53:375-379.
4. AOAC. Official methods of analysis of AOAC International. 21st ed. Gaithersburg, MD: Association of Official Analytical Chemists; 2019.
5. Beals KA. Potatoes, nutrition and health. *Am J Potato Res.* 2018;96:102-110.
6. Devaux A, Goffart JP, Kromann P, Andrade PJ, Polar V, Hareau G. The potato of the future: opportunities and challenges in sustainable agri-food systems. *Potato Res.* 2021;64:681-720.
7. Ezekiel TW, Nuhu ND, Nachana'a T. Phytochemical, elemental, proximate and antinutrient composition of

- Irish potato (*Solanum tuberosum*) obtained in Kwaja, Mubi South LGA of Adamawa State. *Int J Innov Sci Eng Technol*. 2020;7(7):258-268.
8. FAOSTAT. FAO statistical database. 2024. Available from: <http://www.potatopro.com>
 9. Gikundi EN, Sila DN, Orina IN, Buzera AK. Physico-chemical properties of selected Irish potato varieties grown in Kenya. *Afr J Food Sci*. 2021;15(1):10-19.
 10. Gumbo N, Magwaza LS, Ngobese NZ. Evaluating ecologically acceptable sprout suppressants for enhancing dormancy and potato storability: a review. *Plants*. 2021;10:2307. DOI:10.3390/plants1012307.
 11. Ikeyi AP. Isolation and characterization of bacteria associated with spoilt Irish potato (*Solanum tuberosum*). *The Experiment*. 2013;12(4):807-813.
 12. Liu N, Zhao R, Qiao L, Zhang Y, Li M, Sun H. Growth stages classification of potato crop based on analysis of spectral response and variables optimization. *Sensors*. 2020;20(14):3995. DOI:10.3390/s20143995.
 13. Navarre DA, Brown CR, Sathuvalli VR. Potato vitamins, minerals and phytonutrients from a plant biology perspective. *Am J Potato Res*. 2019;96(2):111-126.
 14. Obum-Nnadi CN, Amaechi D, Ezenwa CM, Udeala E, Nwokorie KS, Ajima M. Anti-bacterial, phytochemical analysis and blood pressure lowering effects of orange flesh sweet potatoes (*Ipomoea batatas* L.). *Curr Res Interdiscip Stud*. 2022;1(1):9-21.
 15. Okache TA, Karim OR, Dauda AO, Edem VE, Kamaldeen OS. Proximate and antinutrient compositions of potato (*Solanum tuberosum*) tuber from selected storage methods. *Asian J Food Res Nutr*. 2025;4(2):293-305. DOI:10.9734/ajfrn/2025/v4i2245.
 16. Ugonna CU, Jolaoso MO, Onwualu AP. A technical appraisal of potato value chain in Nigeria. *Int Res J Agric Sci Soil Sci*. 2013;3(8):291-301.
 17. Wijesinha-Bettoni R, Mouillé B. The contribution of potatoes to global food security, nutrition and healthy diets. *Am J Potato Res*. 2019;96(2):139-149.