THE FEDERAL UNIVERSITY OF TECHNOLOGY AKURE, NIGERIA

NUTRACEUTICALS AND FUNCTIONAL FOODS: NATURE'S ANSWER TO THE TRILOGY OF MAN

INAUGURAL LECTURE SERIES 209



Delivered By

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B.Tech., M.Tech. (Akure)., PhD. (Akure-Florence)

Professor of Food Biochemistry & Functional Foods

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PROTOCOL

The Vice-Chancellor,

Deputy Vice-Chancellor (Academic),

Deputy Vice-Chancellor (Development),

The Registrar,

Other Principal Officers of the University,

Deans, Directors and Heads of Departments,

My Lords Spiritual and Temporal,

Distinguished Guests and Friends of the University,

Ladies and Gentlemen of the Press,

Distinguished Ladies and Gentlemen,

Great FUTARIANS.

PREAMBLE

It is with great delight and honour that I stand before this distinguished congregation on this auspicious occasion of the presentation of the 209th Inaugural Lecture of this great citadel of learning. This is the 9th Inaugural Lecture from the Department of Biochemistry following those of my esteemed

predecessors: Prof. T. L. Olawoye (18/01/2000; Series 20), Prof. A. A. Akindahunsi (08/12/2009; Series 56), Prof. G. Oboh (04/04/2017; Series 85), Prof. M. T. Olaleye (07/03/2023; Series 150); Prof. A.C Akinmoladun (19/08/2023;Series 159); Prof. E.O. Ibukun (13/03/2025; Series 178), Prof. F.M. Olajuyigbe (06/05/2025; Series 180); and Prof. A. O. Kolawole (13/01/2026; Series 190). I am thankful to the Omniscient One for making this day a reality. I appreciate Him for the setbacks and successes that dot my academic landscape and for His overriding control in my academic career. I say "unto the King eternal, immortal, invisible, the only wise God, honor and glory, forever and ever. Amen."

MY ACADEMIC ODYSSEY

As I stand before you today, I am humbled to share my academic journey- a testament to God's faithfulness and providence.

Madam Vice Chancellor, to the glory of God, I confess that if, years ago, someone had prophesied that I would become a Professor, I would have laughed like Sarah in the Bible- not because the calling is unworthy (it remains a noble status the world over, even though our political elites have done much to tarnish it in Nigeria's eyes), but because I doubted I had what it took. Like Sarah's laughter in Genesis 18:12, mine was borne of disbelief, not joy. Glory be to God, His word still came to pass.

My academic journey began at Local School Management Board (LSMB), Ijagbo, Kwara State, where I excelled while living with my parents. A compulsory transfer then took me to a local school in Omu-Aran, Kwara State, for Primaries 2 and 3, where I lived with my grandmother. God bless our grandparents- especially the unlettered ones, who loved us easily but, forgetting that "faith without works is dead" (James 2:17). Our parents and

grandparents that are not lettered always believe in God, that He will let us know our book, as often said, and leave our discipline entirely to God. In Omu-Aran, I was, frankly, a hopeless student - a "super Olodo."

At the instance of my mother, a solicited transfer then moved me to another Local School Management Board in Afon, Kwara State, for Primaries 4 to 6, where I lived with my "Dad"- a disciplinarian and former teacher who also drilled me academically and also inculcated into me that the world was full of evil. He was not wrong, though his lessons, not anchored in scripture, left their own scars.

My academics soon improved dramatically in primary school, earning me a place at Government High School, Ilorin, Kwara State, for my secondary education. But in my fourth year, disaster struck: I lost confidence in my abilities and failed my Mock Examination ahead of WASCE. Providentially, my Physics teacher, Dr. (Alhaji) Y.Y. Oloriegbe- who also worked in the same school with my "Dad" - visited us at home and heard my fears. He urged me to trust the foundation I had already built and sit the final exam in faith. I took his advice, quietly continuing to tutor classmates (who never suspected my own struggle) as my own revision. God did not disappoint: I passed with six credits and two passes.

Still lacking confidence, I chose the College of Education, Ilorin, over university, hoping to build up to a degree later. I was denied admission- a mystery to this day. That rejection, however, reignited my resolve. I refused to settle for less, sat the necessary subjects in external GCE, wrote JAMB, and was admitted to study Biochemistry at the Federal University of Technology, Akure (FUTA)- Nigeria's finest university of technology. Fearing failure, I even sought for a backup admission to study Agricultural Economics at FUNAAB, while I was in Year One

in case I failed in FUTA- a fear that, thankfully, never materialized.

Poor family finances during the military era later threatened to end my education. I returned from my parents in despair during one of my visits, but my friends and classmates; Messrs Kunle Shitta and Wale Akande stepped in, supporting me from 200 to 400 Level, until my father's gratuity carried me through to a strong finish in my final year.

Prof. J.O. Ajele first invited me into academia after completing my degree, but I resisted- teaching seemed unrewarding then. I eventually joined FUTA as a Graduate Assistant in 2000, three years after the NYSC program. There, Prof. A.A. Akindahunsi mentored and guided me, and I rose through the ranks to be conferred a full Professor of Food Biohemistry and Functional Foods in December 2020 by Prof. J.A. Fuwape, backdated to October 1, 2019. Prof. Fuwape personally delivered the news by phone while I was thousands of kilometers from home, telling me it would speed my recovery- and it did.

I remain deeply grateful to God and to our Vice Chancellor, Professor Adenike Temidayo Oladiji, FAS, for appointing me Director of Quality Assurance Management Unit, a post I held for two consecutive terms of four years- another chapter of divine providence.

Looking back, I am, without question, a product of God's grace and mercy. If God has been calling you toward the next stage of my destiny and you have delayed, I ask you to heed that call today.

Madam Vice Chancellor,distinguished ladies and gentlemen- this is my journey.

Nutraceuticals and Functional Foods: Nature's Answer to the Trilogy of Man

Nutraceuticals and functional foods support physical, emotional, and mental well-being.

Overview of Nutraceuticals and Functional Foods

Functional foods and nutraceuticals offer health benefits beyond basic nutrition, preventing chronic diseases like diabetes and cardiovascular disorders by modulating metabolic pathways. Functional foods (e.g., oats, nuts, yogurt) contain bioactive compounds in natural forms, while nutraceuticals are concentrated extracts in capsules or pills. Key examples include omega-3s, probiotics, vitamin D, curcumin, ashwagandha, magnesium, and B vitamins.

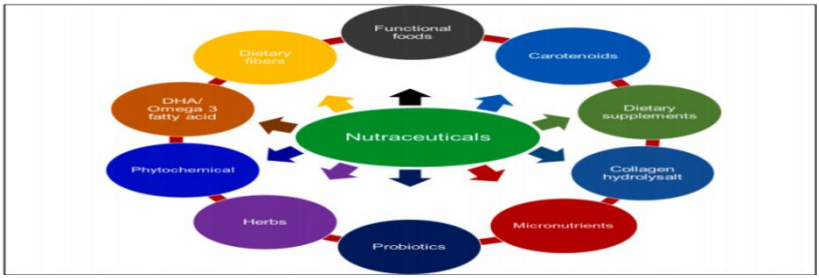


Figure 1: Classification of Nutraceutical

Functional foods provide health benefits beyond basic nutrition (Hammoudi Halat *et al*., 2023), including fatty fish, berries, and fermented foods. Their design increasingly utilizes food side-streams for sustainability (Cena & Calder, 2020).



Figure 2: Classification of Functional Foods

Rising non-communicable diseases (NCDs) like cardiovascular disease, diabetes, obesity, and cancer—driven by poor diet—have shifted nutrition science toward prevention through functional foods (Alongi and Anese, 2021).

Recognized by EFSA, FDA, and WHO, functional foods include whole foods (fruits, vegetables, grains) and modified items rich in fibers and phytochemicals (Granato *et al*., 2020). Processed variants overlap with encapsulated nutraceuticals like fish oil.

By actively promoting health, these products represent a paradigm shift in nutritional science (Harford *et al*., 2011).

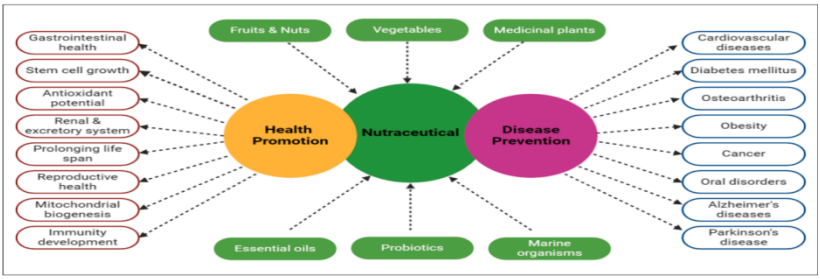


Figure 3: Role of nutraceuticals in disease prevention and health promotion.

The Trilogy of Well-Being

Human health relies on an interconnected balance of physical, emotional, and mental wellness.

Physical Health: The body's operational functionality without disease.

Functional Foods and Nutraceutical for Physical Well-being.

Key foods and supplements supporting physical health are outlined below:

Table 1: Functional Foods and Nutraceuticals for Physical Well-being.

Category	Item	Benefit
	Ginger	Soothes muscles and reduces pain
	Berries (blueberries, raspberries)	Antioxidant-rich
Heart Health	Omega-3s (salmon, walnuts)	Lowers triglycerides
	Olive oil	Good fats for heart health
	Legumes (lentils, chickpeas)	Fibre and protein boost
Energy and Immunity	Probiotics (yogurt, kefir)	Gut health and immunity
	Leafy greens (spinach, kale)	Vitamins and minerals
	Nuts and seeds (almonds, chia seeds)	Healthy fats and protein
Other Nutraceuticals	Vitamin D	Bone health and immune function
	Magnesium	Muscle function and relaxation
	CoQ10	Energy production and antioxidant support

Functional Foods and Nutraceutical for Emotional Well-being

Emotional Health: Involves stress management, emotional expression, and social connection.

Table 2: Functional Foods and Nutraceuticals for Emotional Well-being

Category	Item	Benefit
Mood Lifters	Dark chocolate (flavonoids)	Uplifts mood and reduces stress
	Fermented foods (kimchi, sauerkraut)	Gut-brain connection
	Omega-3s (salmon, walnuts)	Supports brain health
Stress Relief	Adaptogens (ashwagandha, ginseng)	Calms and balances
	Leafy greens (spinach, kale)	Vitamins and minerals for mood support
	B vitamins (salmon, eggs)	Energy and mood regulation
Serotonin Boosters	Tryptophan-rich foods (turkey, bananas)	Serotonin precursor
	Complex carbs (oats, quinoa)	Stabilizes mood

	Probiotics (yogurt, kefir)	Gut health and mood ~~link~~lifters
Other Nutraceuticals	Magnesium	Relaxation and stress reduction
	Vitamin D	Mood regulation and seasonal affective disorder
	GABA	Calming and anxiety reduction

Functional Foods and Nutraceuticals for Mental Well-being

Mental Health: Encompasses cognitive function, emotional regulation, and psychological state.



Figure 4: Interrelationship Between Spiritual, Physical, Emotional and Mental Well-Being



Figure 5: Interrelationship Between Anxiety and Depression

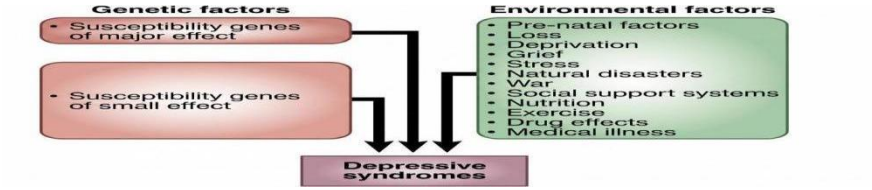


Figure 6: Schematic Representation of The Causes of Depression In Humans

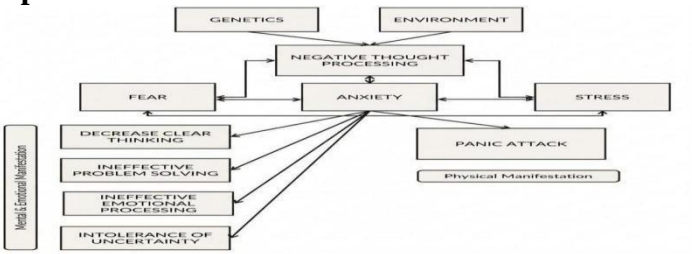


Figure 7: Schematic Representation of Causes of Anxiety In Human

Interconnected health examples:

- Chronic stress (emotional) can lead to hypertension (physical) and anxiety (mental).
- Poor sleep (physical) can impact mood (emotional) and cognitive function (mental).
- Social isolation (emotional) can increase risk of depression (mental) and cardiovascular disease (physical).

Table 3: Functional Foods and Nutraceuticals for Mental Well-being

Category	Item	Benefit
Cognitive Support	Omega-3s (salmon, walnuts)	Brain health and focus
	Dark chocolate (flavonoids)	Improves blood flow to the brain

	Leafy greens (spinach, kale)	Antioxidants and vitamins
Memory and Focus	Bacopa monnieri	Herbal support for memory
	Ginkgo biloba	Improves concentration and memory
	Berries (blueberries, strawberries)	Antioxidant-rich for brain health
Mood and Calm	Adaptogens (ashwagandha, rhodiola)	Stress relief and balance
	GABA	Calming and anxiety reduction
	Magnesium	Relaxation and sleep support
Key Nutraceuticals	Vitamin B complex	Energy and cognitive function
	Acetyl-L-carnitine (ALCAR)	Supports brain health
	Phosphatidylserine	Memory and cognitive support

Phytochemicals

Phytochemicals are secondary plant metabolites serving defense functions against stressors (Olaleye *et al*., 2010). They offer therapeutic benefits against cancer, diabetes, and cardiovascular diseases. Major classes include polyphenols, alkaloids, and terpenoids, with flavonoids enhancing cognitive function and cerebral blood flow.

Harnessing Antioxidants and Polyphenols in Nutraceuticals and Functional Foods for Health

Antioxidants counteract oxidative stress from free radicals, preventing chronic conditions (Cornelli, 2009). Dietary antioxidants neutralize radicals, suppress their formation, and repair cellular damage, lowering risks for age-related disorders like Parkinson's (Rijk *et al*., 1997; Ferrari, 2001).

Polyphenols—comprising tannins, lignans, phenolic acids, flavonoids, and stilbenes—are abundant plant antioxidants providing anti-inflammatory, anticancer, and anti-aging benefits (Liu *et al*., 2024; Del Rio *et al*., 2013).

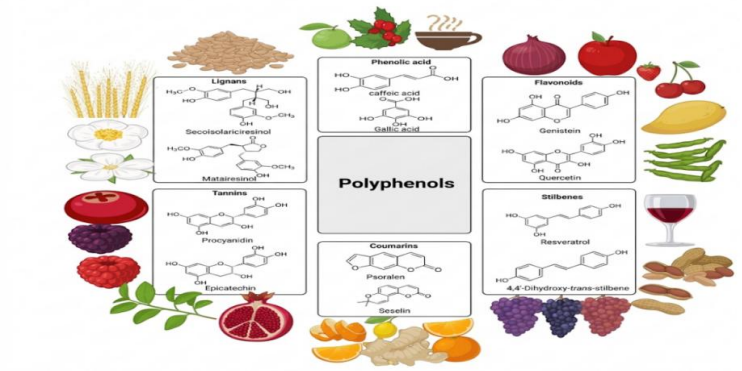


Figure 8: Chemical structures of principal polyphenol subclasses (lignans, phenolic acids, flavonoids, tannins, coumarins, and stilbenes) alongside their respective plant-based food sources exemplifying dietary consumption.

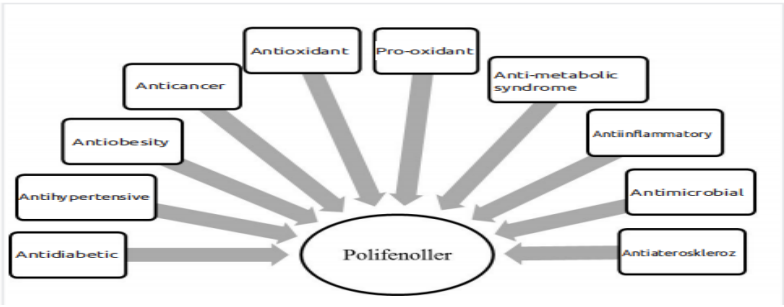


Figure 9: Biological activity of polyphenols

At low doses, polyphenols exert antioxidant effects that mitigate diseases like cancer. However, high doses may act as pro-oxidants, inducing cytotoxicity and apoptosis in cancer cells for therapeutic application.

RESEARCH CONTRIBUTIONS

My modest research contributions to knowledge of functional foods/nutraceuticals in particular, and humanity in general, span evaluation of antioxidant properties of tropical/medicinal plants, assessment of *in vitro* gastrointestinal digestion on the antioxidant potentials of tropical foods, evaluation of bioactive compounds, essentially polyphenols in tropical foods and medicinal plants, and hepatoprotective, antidiabetic, antidepressants, anxiolytics, neuroprotective potential of tropical foods and medicinal plants.

Madam Vice Chancellor, my research contributions to knowledge are highlighted as follows: (1) Antioxidant potentials of tropical foods and medicinal plants (2) Assessment of the effects of *in vitro* gastrointestinal digestion on the antioxidant potentials of tropical foods (3) HPLC-DAD-MS quali-quantitative estimation of phenolics and other bioactive compounds in tropical foods and medicinal plants (4) Assessment of tropical foods as functional foods and nutraceuticals (5) Evaluation of tropical foods in the management of depression, anxiety and insomnia

ANTIOXIDANT POTENTIALS OF TROPICAL FOODS AND MEDICINAL PLANTS

Vegetables and fruits are central to disease prevention, largely due to antioxidants such as ascorbic acid, tocopherols, carotenoids, and phenolic compounds (Rice-Evans *et al*., 1995). In Nigeria, indigenous leafy vegetables form a vital part of the diet, offering phytochemicals that strengthen defenses against

oxidative stress and chronic disorders. Madam Vice Chancellor, studies have examined the antioxidant properties of tropical vegetables using diverse assays. Akindahunsi and **Salawu** (2005), analyzed 14 leafy vegetables for free radical scavenging, reducing power, total phenols, vitamin C, and phytic acid, confirming their rich antioxidant potential. **Salawu** *et al.* (2008), also evaluated *Vernonia amygdalina*, *Manihot utilissima*, *Ocimum gratissimum*, and *Corchorus olitorius* using DPPH assay, showing dose-dependent and concentration-specific activities. Across these investigations, Nigerian leafy vegetables consistently demonstrated strong antioxidant capacity, attributable to phenolic compounds, vitamins, and phytates. Their ability to scavenge radicals, reduce oxidative stress, and inhibit LDL oxidation underscores their nutritional and therapeutic relevance in managing cancer, cardiovascular, and degenerative diseases (Akindahunsi and **Salawu,** 2005; **Salawu** *et al.* 2008; **Salawu**, *et al*., 2012).

Vegetables, cereals, and legumes are vital dietary sources of antioxidants, protecting against oxidative stress and chronic diseases. Madam Vice Chancellor, the Nigerian indigenous crops, rich in phenolic compounds, vitamins, and flavonoids, have been extensively studied for their ability to scavenge free radicals, reduce oxidative damage, and inhibit lipid oxidation. Sorghum (white, red), teff (white, brown), and cowpea (*Betchuana white, black-eyed pea*) were analyzed for cell wall-bound phenolics. Whole grains consistently exhibited higher phenolic, flavonoid content, and stronger antioxidant indices than cell wall extracts. Across these studies, Nigerian vegetables and cereals, demonstrated significant antioxidant potential (**Salawu *et al*., 2013; Salawu *et al*., 2014; Salawu *et al*., 2015)**.

Nigerian crops and plant-based foods-often underutilized-have been shown to contain rich phenolic and flavonoid compounds

that enhance radical scavenging, reducing power, and lipid oxidation inhibition. Madam Vice Chancellor, the sweet orange peels (ripe and unripe) were analyzed for radical scavenging activity, reducing power, and phytochemical content. Ripe peels exhibited stronger antioxidant activity due to higher flavonoid and phenolic levels. Pearl millet–tiger nut biscuits retained significant antioxidant properties, with flour blends and biscuits showing high total phenolic content and ABTS radical scavenging activity, confirming their value as functional foods. Moringa leaves**,** Licorice root, and their composite tea infusions were tested for phenolic and flavonoid content, reducing power, and hydroxyl radical scavenging activities. Moringa and blends consistently outperformed Licorice, highlighting their therapeutic potential. Across these studies, ripe orange peels, PM–TN biscuits, and Moringa-based teas demonstrated strong antioxidant capacity, linked to phenolic and flavonoid richness. Their ability to scavenge radicals, reduce oxidative stress, and inhibit lipid oxidation, as reported together with my research collaborators, underscores their nutritional and therapeutic relevance. These indigenous foods and functional blends represent affordable, natural strategies for preventing oxidative stress-related disorders (Omooba *et al*., 2015[a]; Omoba, *et al*., 2015[b]; **Salawu** *et al*., 2019).

Spices, vegetables, and medicinal plants are not only staples of Nigerian diets but also potent sources of antioxidants that protect against oxidative stress and chronic diseases. Their phenolic and flavonoid compounds contribute to radical scavenging activity, reducing power, and anti-inflammatory effects, validating both nutritional and folkloric relevance. Madam Vice Chancellor, spices**:** *Ocimum basilicum*, *Xylopia aethiopica*, and *Piper guineensis* were analyzed for phenolic content, flavonoids, and radical scavenging activities (DPPH, ABTS, NO). *Xylopia aethiopica* showed the highest activity, confirming its

cardiovascular protective potential. Leafy vegetables**:** *Celosia argentea* and *Gongronema latifolium* (blanched/unblanched) were tested *in vivo* using rats on high-fat diets. They enhanced antioxidant enzymes (GSH, GPX, SOD, CAT) and reduced lipid peroxidation, with unblanched Celosia and blanched Gongronema most effective. Medicinal plant: Together, Nigerian spices, vegetables, and medicinal plants demonstrate strong antioxidant and anti-inflammatory properties. Their ability to scavenge radicals, boost antioxidant enzymes, and inhibit oxidative damage, as reported together with my research collaborators, underscores their therapeutic and nutritional importance in preventing cardiovascular, metabolic, and degenerative diseases (Omoba, *et al*.[a,b], 2015; Adegbenro, *et al*., 2021).

Table 4: Antioxidant Indices of Some Green Leafy Vegetables

Vegetable species	Free radical scavenger (%)	Reducing power	Total phenol (%)	Phytic acid (mg/100 g)	Vitamin C (mg/100 g)
Basella alba	88.9	0.16	0.65	282	461
Hibiscus esculentus	55.6	0.19	0.75	451	554
Crassocephalum crepidioides	88.9	0.24	0.40	508	692
Ocimum gratissimum	11.1	0.24	0.55	564	692
Vernonia amygdalina	55.6	0.23	0.63	282	554
Solanum macrocarpon	77.8	0.60	0.83	56	400
Structium sparjanophora	22.2	0.62	0.92	282	667
Celosia argentea	90.2	0.62	0.94	451	285
Talinum triangulare	88.9	0.60	0.32	677	400
Corchorus olitorius	44.5	0.62	0.85	226	340
Piper guineese	90.1	0.30	0.71	169	500
Amaranthus caudatus	88.9	0.64	0.91	451	400
Manihot utilissima	90.2	0.64	0.90	282	500
Xanthosoma mafaffa	99.5	0.62	0.48	508	500

Data are mean SD values (n 5).

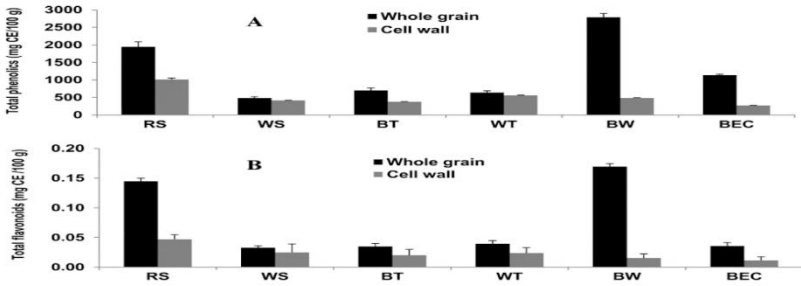


Figure 10: (A) Total Phenolics And (B) Total Flavonoids Of Whole Grain Flour and Cell Wall Preparations Of Cereals And Legumes Error Bars Represent Standard Deviations. Graph Bars With The Same Letters Are Not Significantly Different ($p < 0.05$). BEC, Black-Eyed Cowpea; BW, Betchuana White Cowpea; BT, Brown Teff; RS, Red Sorghum; WS, White Sorghum; WT, White Teff.

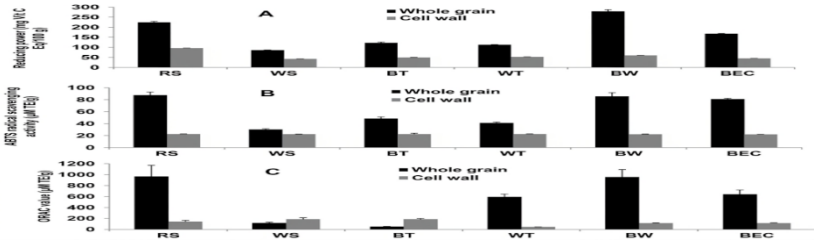


Figure. 11: (a) Reducing Power, (b) ABTS Radical-Scavenging Activity and (c) Oxygen Radical Absorption Capacity (ORAC) Values Of Whole Grain Flour And Cell Wall Preparations Of Cereals And Legumes Error Bars Represent Standard Deviations. Graph Bars With The Same Letters Are Not Significantly Different ($p < 0.05$). BEC, Black-Eyed Cowpea; BW, Betchuana White Cowpea; BT, Brown Teff; RS, Red Sorghum; WS, White Sorghum; WT, White Teff.

Table 5. Antioxidant properties of unripe and ripe orange peel powder.

Antioxidant Properties	Unripe	Ripe
Total phenol content (mgGAE/g)	5.27 ± 0.03^{b}	9.40 ± 0.01^{a}
Total flavonoid content (mgQE/g)	3.30 ± 0.30^{b}	4.20 ± 0.02^{a}
ABTS scavenging ability (mmol/TEAC g)	14.68 ± 0.01^{b}	16.89 ± 0.02^{a}
FRAP (mg/GAE100 g)	70.69 ± 0.01^{b}	91.38 ± 0.01^{a}

Values represent means ± standard deviation of triplicate ($n = 3$). Values with different alphabet along the same row (for the same antioxidant properties) are significantly different ($p > 0.05$)

Table 6. EC50 (mg/mL) of ripe and unripe orange peel on different antioxidant parameters

Antioxidant Parameters	Unripe	Ripe
DPPH	2.71 ± 0.03^{a}	2.23 ± 0.03^{b}
OH	0.67 ± 0.02^{a}	0.57 ± 0.03^{b}
Fe^{2+} Chelation	0.57 ± 0.02^{a}	0.49 ± 0.01^{b}
Malondialdehyde (MDA)	0.63 ± 0.06^{a}	0.50 ± 0.01^{b}

Values represent means ± standard deviation of triplicate (n = 3). Values with the different alphabet along the same row (for the same parameter) are significantly different (p > 0.05).

Table 7. Effects of TN flour inclusion to PM flour on the total phenolic content, radical cation ABTS scavenging capacity of PM–TN flour and biscuits

Samples	Total phenolic - Flours (mgGAE/g)	Total phenolic - Biscuits (mgGAE/g)	ABTS - Flours (µmolTEAC/g)	ABTS - Biscuits (µmolTEAC/g)
A	2.65 ± 0.01^{fA}	1.20 ± 0.01^{gB}	26.7 ± 0.01^{fB}	28.5 ± 0.00^{gA}
B	2.75 ± 0.03^{eA}	1.26 ± 0.03^{dB}	27.5 ± 0.01^{eB}	30.8 ± 0.01^{eA}
C	2.78 ± 0.02^{eA}	1.36 ± 0.01^{eB}	27.8 ± 0.01^{eB}	31.7 ± 0.02^{eA}
D	2.97 ± 0.01^{dA}	1.98 ± 0.01^{dB}	27.9 ± 0.01^{dB}	32.5 ± 0.03^{dA}
E	3.17 ± 0.02^{cA}	2.88 ± 0.03^{cB}	29.2 ± 0.00^{cB}	35.2 ± 0.03^{cA}
F	4.79 ± 0.02^{bA}	3.13 ± 0.07^{bB}	31.0 ± 0.01^{bB}	35.7 ± 0.01^{bA}
G	4.95 ± 0.01^{aA}	3.42 ± 0.01^{aB}	36.4 ± 0.03^{aB}	38.6 ± 0.01^{aA}

Notes: a Values are means of triplicates results ± SD; b values with different small letters (a-g) in the same column is significantly different at $p \leq 0.05$; c values with different capital letters (A-B) on the same row is significantly different at $p \leq 0.05$; keys: A PM15: TN 85; B PM20:TN80; C PM25: TN75; DPM30: TN 70; E PM35:TN 65; F PM40: TN60; G PM45:TN55

Table 8: Antioxidant indices of *M. oleifera, G. glabra* and their composite blends

Sample	TPC (mg TAE/g)	TFC (mg QE/g)	Reducing power (mg AAE/g)	% OH scavenging ability
M	97.08 ± 1.84^{b}	77.11 ± 2.54^{b}	32.79 ± 0.10^{b}	61.55 ± 1.28^{b}
LR	81.66 ± 3.22^{a}	70.34 ± 1.20^{a}	19.00 ± 0.55^{a}	52.05 ± 3.49^{a}
M+LR	97.87 ± 2.84^{b}	82.47 ± 3.52^{bc}	32.85 ± 1.00^{b}	60.90 ± 4.21^{b}

Values represent mean±standard deviation of triplicate experiments. Values with different superscripts in the same column differ significantly (p<0.05) M, *Moringa oleifera*; LR, licorice root; M+LR, moringa leaf+licorice root; TAE, tannic acid equivalent; QE, quercetin equivalent; AAE, ascorbic acid equivalent

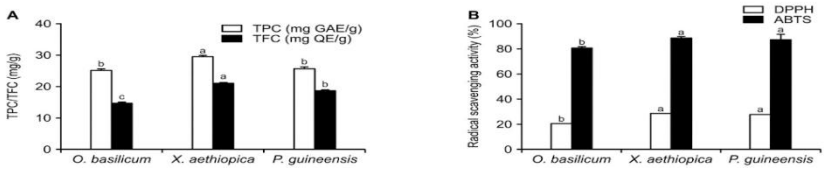


Figure 12: (A) Total Phenolic Content (TPC) And Total Flavonoid Content (TFC) and (B) 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) and 2,2'-Azinobis(3-Ethylbenzothiazoline-6-Sulphonic Acid) (ABTS) Radical Scavenging Activities of Methanolic Extract of *Ocimum basilicum*, *Xylopia aethiopica*, and *Piper guineensis*. Values With Different Letters (a-c) Are Significantly Different At *P*<0.05. GAE, Gallic Acid Equivalents; QE, Quercetin Equivalents.

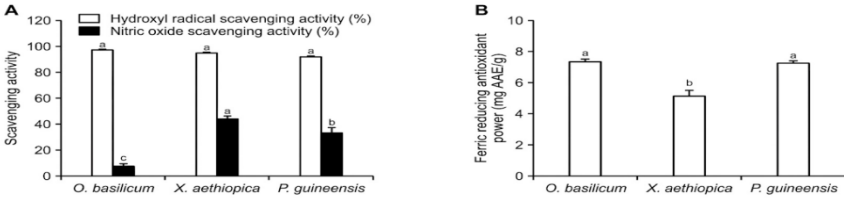


Figure 13 (A) Hydroxyl Radical And Nitric Oxide Scavenging Activities and (B) ferric Reducing Antioxidant Power Of Methanolic Extract of *Ocimum basilicum*, *Xylopia aethiopica*, and *Piper guineensis*. Values With Different Letters (a-c) Are Significantly Different At *P*<0.05.

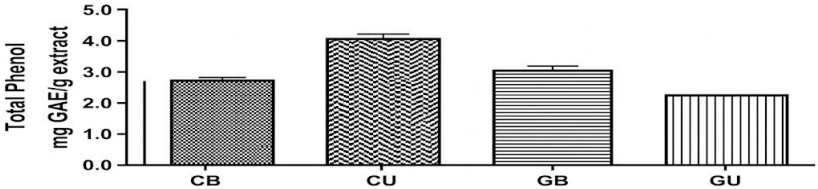


Figure 14: The Total Phenolic Content (Mg Tannic Acid Equivalent/g Of Sample) Of Blanched And Unblanched *G. Latifolium* And *C. Argentea*. Values Are Given As Mean ± SE Of Independent Experiments Performed In Triplicate. *CB* Blanched *Celosia argentea, CU* Unblanched *Celosia argentea, GB* Blanched *Gongronema latifolium, GU* Unblanched *Gongronema latifolium*

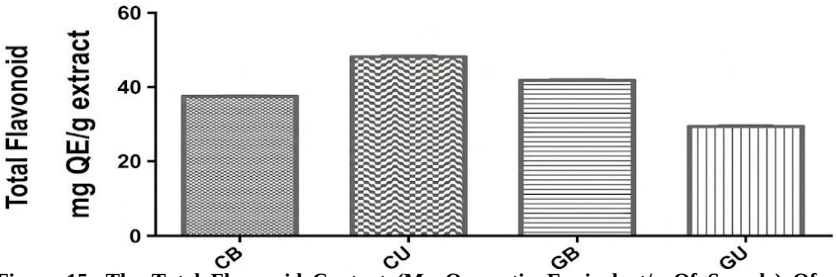


Figure 15: The Total Flavonoid Content (Mg Quercetin Equivalent/g Of Sample) Of Blanched And Unblanched *G. Latifolium* And *C. Argentea*. Values Are Given As Mean ±Se Of Independent Experiments Performed In Triplicate. *CB* Blanched *Celosia argentea, CU* Unblanched *Celosia argentea, GB* Blanched *Gongronema latifolium, GU* Unblanched *Gongronema latifolium*

Table 9: Effects of *G. Latifolium* and *C. Argentea* on *In Vivo* Antioxidant Enzyme Activities In High Fat Diet-Induced Hyperlipidemic Rats

	GSH (mmol/mg protein)	GPX (mmol/GSH consumed/mg protein)	SOD (U/mg protein)	LPO (µM MDA/mg protein)	Catalase
CD	24.34±3.14	56.58±0.58	3.25±0.18	10.97±0.96	33.10±1.24
HFD	5.40±0.33$^{\#\#\#\#}$	23.02±0.76$^{\#\#\#\#}$	1.60±0.15$^{\#\#\#\#}$	25.59±1.13$^{\#\#\#\#}$	17.27±1.24$^{\#\#\#\#}$
HFD+AT (5 mg/kg)	25.68±2.73****	52.89±1.47****	3.36±0.19****	9.41±0.27****	38.40±1.51****
HFD+CB (5%)	8.79±0.64**	28.43±1.05****	1.65±0.29	23.94±0.65*	22.89±1.44*
HFD+CB (10%)	13.83±0.31****	39.21±0.36****	2.46±0.39**	15.62±0.47****	27.26±1.24*
HFD+CB (15%)	22.99±0.68****	51.61±0.55****	3.22±0.15****	11.12±0.12****	31.04±1.55****
HFD+CU (5%)	8.88±0.38**	36.99±2.33****	1.86±0.00	23.55±0.10**	24.96±1.23
HFD+CU (10%)	14.04±0.39****	43.40±0.38****	2.53±0.19****	14.22±0.86****	28.64±1.58****
HFD+CU (15%)	23.11±0.19****	55.14±0.95****	3.55±0.18****	9.87±0.57****	33.95±1.61****
HFD+GB (5%)	8.01±0.11	34.02±0.52****	1.73±0.43	23.68±1.06**	23.70±1.63
HFD+GB (10%)	12.93±0.81****	40.09±1.07****	2.51±0.18****	14.24±0.99****	27.35±1.63****
HFD+GB (15%)	22.86±0.18****	51.06±0.91****	3.45±0.42****	10.64±0.39****	31.94±1.70****
HFD+GU (5%)	7.16±0.41	29.20±1.34****	1.71±0.00	24.61±0.33	20.32±1.21
HFD+GU (10%)	12.74±0.76****	37.65±1.07****	2.47±0.25***	16.07±0.20****	25.97±1.31****
HFD+GU (15%)	21.61±0.85****	50.00±0.38****	3.32±0.31*** *	11.52±0.16*** *	30.71±1.05*** *

Results Are Expressed As Mean±SD (n=5) *CD* control diet, *HFD* high fat diet, *CB* blanched *Celosia argentea, CU* unblanched *Celosia argentea, GB* blanched *Gongronema latifolium*,

***GU* unblanched *Gongronema latifolium* #### p<0.0001 vs HFD, *p<0.05 **p<0.01, ***p<0.001, ****p<0.0001 vs CB, CU, GB, GU**

ASSESSMENT OF THE EFFECTS OF *IN VITRO* GASTROINTESTINAL DIGESTION ON THE ANTIOXIDANT POTENTIALS AND CHEMICAL COMPOSITIONS OF TROPICAL FOODS

Antioxidants play vital roles in plant-based foods, but their biological effects depend on how they are released during digestion. Conventional solvent-based extraction methods often misrepresent their true activity in the gastrointestinal tract (Bhatt and Patel, 2013). The *in vitro* digestion method provides a more reliable measure of bio-availability, assessing the nutrients liberated during digestion and available for absorption (Chandrasekara and Shahidi, 2012). This approach is cost-effective compared to human or animal studies and has been widely applied to evaluate diverse food systems. Notably, several studies, as reported together with my research collaborators (Omoba, *et al*., 2015[a]; **Salawu,** 2016; **Salawu** *et al*., 2017, **Salawu** *et al*., 2018., **Salawu** *et al*., 2019., **Salawu** *et al*., 2020), have demonstrated the actual antioxidant activities of tropical foods following simulated gastrointestinal digestion, underscoring the importance of digestion-based assessments in understanding antioxidant functionality.

The bio-availability of antioxidants in foods depends on their release during digestion, which differs from solvent-based extraction. Madam Vice Chancellor, the simulated gastrointestinal digestion models provide a more accurate measure of antioxidant activity, as they mimic nutrient liberation during digestion. Studies on tropical foods-including pearl millet–tiger nut biscuits, and bitter yam-consistently show that enzymatic digestion yields higher antioxidant values than chemical extraction. In PM–TN biscuits, enzymatic digestion produced superior phenolic release and radical scavenging

activity compared to aqueous or ethanolic extracts. Similarly, bitter yam varieties revealed enhanced phenolic and flavonoid release, with improved DPPH, ABTS, and NO scavenging indices after digestion. Collectively, these findings, as reported together with my research collaborators, validate gastrointestinal digestion models as the most reliable approach for assessing antioxidant bio-availability and highlight the functional food potential of underutilized tropical crops (Bhatt & Patel, 2013; Chandrasekara & Shahidi, 2012; Omoba, *et al*, 2015[a]; **Salawu** *et al.,* 2017).

The bio-availability of antioxidants and minerals in foods is best assessed through simulated gastrointestinal digestion, which more accurately reflects nutrient release than solvent-based extraction. Madam Vice Chancellor, studies on diverse tropical crops—*Basella rubra* (Malabar spinach)**,** *Phaseolus lunatus* **(**Lima beans) and *Lycopersicum esculentum* (Tomato)- demonstrate this principle. In *B. rubra*, essential minerals and antioxidant molecules became more bio-accessible after digestion, though raw samples retained higher values than blanched ones. Lima beans showed progressive increases in phenolic, flavonoid, and amino acid release across oral, gastric, and intestinal phases of digestion, with cooked beans outperforming raw in antioxidant activity. Tomato fruits and pastes revealed superior phenolic content, flavonoid release, radical scavenging, and enzyme activities after digestion compared to ethanolic extracts, with ripe tomato ranking highest. Collectively, these findings confirm that gastrointestinal digestion enhances the liberation of bio-active compounds, validating its use in evaluating functional food potential of tropical vegetables and legumes (**Salawu** *et al*., 2018; **Salawu** *et al*., 2019; **Salawu** *et al*., 2020).

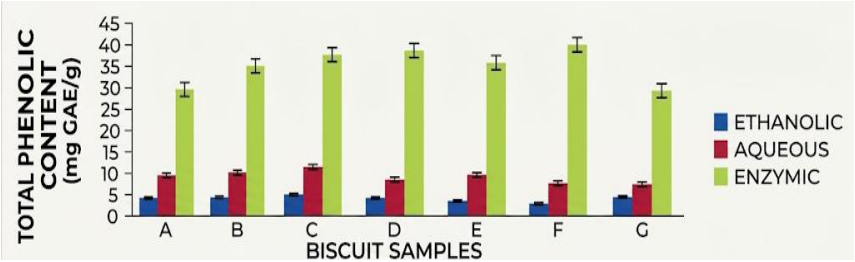


Figure 16: TPC, Expressed as GAEs, as Determined from Biscuit Matrix (100 g) using Ethanolic Extraction, Aqueous Extraction and after Simulated Gastrointestinal Digestion. Data Shown Represent Means SD (*n*=3 Independent Experiments). A PM15: TN 85; B PM20:TN80; C PM25: TN75; D PM30: TN 70; E PM35:TN 65; F PM40: TN60; G PM45:TN55

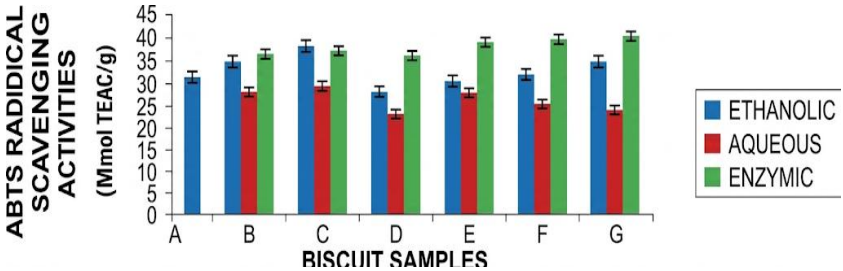


Figure 17:. Radical Scavenging Activity Assessed By The ABTS test, expressed as molTEAC/g As Determined From Biscuit Matrix (100 g) Using Ethanolic Extraction, Aqueous Extraction And After Simulated Gastrointestinal Digestion. Data Shown Represent Means SD (*n* =3 Independent Experiments). A PM15: TN 85; B PM20:TN80; C PM25: TN75; D PM30: TN 70; E PM35:TN 65; F PM40: TN60; G PM45:TN55

Table 10. $ABTS^{\cdot+}$, $DPPH^{\cdot}$, $NO^{\cdot}$, and $OH^{\cdot}$ scavenging ability of *in vitro* Enzyme Digested raw and cooked bitter yam extracts

Sample	White bitter yam - Raw	White bitter yam - Cooked	Yellow bitter yam - Raw	Yellow bitter yam - Cooked
ABTS scavenging ability (µM TE/g dry sample)				
AME	$1{,}414.00 \pm 7.25^{h}$	$1{,}272.67 \pm 9.45^{g}$	$1{,}142.67 \pm 19.63^{f}$	810.67 ± 5.77^{e}
ED	$2{,}190.63 \pm 6.25^{i}$	$2{,}223.96 \pm 4.77^{j}$	$2{,}190.63 \pm 6.2^{i}$	$2{,}219.79 \pm 1.80^{j}$
UC	417.67 ± 3.61^{d}	312.25 ± 4.25^{b}	374.50 ± 3.13^{c}	285.11 ± 3.13^{a}
DPPH scavenging ability (µM TE/g dry sample)				
AME	677.95 ± 3.08^{h}	172.31 ± 0.78^{b}	245.13 ± 1.11^{c}	99.49 ± 0.47^{a}
ED	$1{,}134.66 \pm 0.62^{k}$	$1{,}209.06 \pm 0.73^{l}$	556.09 ± 0.82^{f}	644.23 ± 1.30^{g}
UC	945.51 ± 0.41^{j}	870.19 ± 0.48^{i}	500.00 ± 0.17^{e}	471.15 ± 0.46^{d}

Sample	White bitter yam - Raw	White bitter yam - Cooked	Yellow bitter yam - Raw	Yellow bitter yam - Cooked
% NO scavenging ability				
AME	58.15 ± 0.01^{c}	46.54 ± 0.01^{b}	44.32 ± 0.01^{ab}	41.11 ± 0.00^{a}
ED	82.01 ± 0.23^{f}	84.75 ± 0.08^{g}	82.01 ± 0.02^{f}	84.27 ± 0.01^{g}
UC	82.78 ± 0.22^{f}	75.55 ± 0.26^{d}	79.88 ± 0.09^{de}	79.43 ± 0.24^{de}
% OH scavenging ability (0.005 mg/mL)				
AME	74.68 ± 0.07^{g}	86.54 ± 0.01^{h}	87.06 ± 0.01^{h}	89.00 ± 0.01^{hi}
ED	20.53 ± 0.01^{ab}	36.55 ± 0.21^{d}	19.13 ± 0.06^{a}	27.18 ± 0.23^{c}
UC	37.71 ± 0.27^{d}	44.64 ± 0.26^{e}	49.35 ± 0.25^{ef}	48.11 ± 0.24^{ef}

Values represent mean ± SD of triplicate experiments. Values in the same properties followed by different letters (a-l) are significantly different (P<0.05). ABTS$^{\cdot+}$, 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) radical cation; DPPH$^{\cdot}$, 2,2-diphenyl-1-picrylhydrazyl radical; NO$^{\cdot}$, nitric oxide radical; OH$^{\cdot}$, hydroxyl radical; TE, Trolox equivalent; AME, aqueous-methanolic extract; ED, enzyme digested; UC, undigested control.

Table 11. Mineral composition (mg/100 g) of *in vitro* digested raw and blanched Basella rubra

Sample	Mg	Zn	Fe	Na	K	Ca	P
ROC	6.98±0.06^{e}	4.81±0.35^{d}	3.68±0.47^{de}	181.45±20.16^{ab}	5,036.29±4.03^{f}	1,514.11±2.02^{cd}	4.28±0.25^{a}
ROD	5.33±0.07^{bc}	3.66±0.33^{b}	5.17±0.01^{a}	203.63±2.02^{ab}	4,036.29±4.03^{d}	1,209.68±9.80^{b}	3.18±0.05^{c}
BOC	6.47±0.46^{d}	3.13±0.06^{a}	3.59±0.18^{d}	886.09±1.01^{c}	5,515.12±7.06^{h}	1,915.32±9.10^{f}	3.58±0.05^{d}
BOD	4.82±0.28^{ab}	2.92±0.05^{a}	4.13±0.07^{f}	128.02±5.04^{a}	3,215.73±30.24^{a}	1,814.52±2.78^{e}	3.78±0.05^{e}
RGC	7.56±0.35^{f}	4.59±0.04^{d}	2.98±0.20^{c}	203.51±3.10^{ab}	5,061.98±103.31^{f}	1,033.06±7.70^{a}	2.01±0.05^{a}
RGD	5.51±0.11^{c}	4.61±0.04^{d}	3.40±0.23^{d}	231.40±4.13^{b}	5,309.92±61.98^{g}	1,446.28±8.40^{c}	1.96±0.10^{a}
BGC	5.62±0.10^{c}	5.47±0.18^{e}	1.96±0.02^{ab}	123.97±6.70^{a}	4,130.17±4.13^{e}	2,027.89±4.10^{g}	9.30±0.10^{i}
BGD	4.37±0.05^{a}	4.73±0.02^{d}	1.78±0.14^{a}	125.00±1.03^{a}	6,243.81±2.07^{i}	1,756.20±103.31^{e}	5.89±0.10^{h}
RIC	9.21±0.74^{g}	3.99±0.09^{c}	4.32±0.27^{f}	5,615.38±179.50^{g}	6,333.33±128.21^{i}	1,794.87±9.30^{e}	4.04±0.06^{f}
RID	5.29±0.04^{bc}	6.36±0.15^{f}	4.23±0.07^{f}	5,128.21±2.56^{f}	3,726.92±3.85^{c}	2,307.69±7.50^{h}	2.44±0.13^{b}
BIC	8.86±0.04^{g}	3.63±0.17^{b}	2.21±0.15^{b}	3,623.08±2.56^{d}	3,410.26±5.13^{b}	2,365.38±7.40^{h}	7.95±0.13^{i}
BID	8.97±0.05^{g}	5.31±0.25^{e}	4.02±0.14^{ef}	4,128.21±25.64^{e}	3,769.23±25.64^{c}	1,565.38±8.30^{d}	2.05±0.13^{a}

Values in the same column followed by different letters (a-j) are significantly different (P<0.05). ROC, raw oral control; ROD, raw oral digest; BOC, blanched oral control; BOD, blanched oral digest; RGC, raw oral control; RGD, raw gastric digest; BGC, blanched gastric digest; BGD, blanched gastric digest; RIC, raw intestinal control; RID, raw intestinal digest; BIC, blanched intestinal control; BID, blanched intestinal digest.

Table 12: Antioxidant indices of raw and blanched *Basella rubra* at different phases of *in vitro* digestion

Sample	*B. rubra* raw	*B. rubra* blanched
Total phenolic content (mg tannic acid equivalent/g dry weight)		
Oral	79.48 ± 0.82^{a}	108.71 ± 3.85^{b}
Gastric	386.71 ± 4.50^{b}	80.02 ± 0.47^{a}
Intestinal	553.56 ± 5.83^{c}	553.56 ± 5.83^{c}

Sample	*B. rubra* raw	*B. rubra* blanched
Total flavonoid content (mg quercetin equivalent/g dry weight)		
Oral	302.15 ± 0.00^{b}	264.78 ± 0.49^{b}
Gastric	260.29 ± 0.15^{a}	250.80 ± 0.74^{a}
Intestinal	518.88 ± 1.21^{c}	488.33 ± 0.68^{c}
Ferric reducing antioxidant power (mg ascorbic acid equivalent/g dry weight)		
Oral	5.27 ± 0.02^{a}	4.95 ± 0.02^{a}
Gastric	5.70 ± 0.01^{b}	5.19 ± 0.00^{b}
Intestinal	8.15 ± 0.01^{c}	8.14 ± 0.01^{c}
Total antioxidant activity (mg Trolox equivalent/g dry weight)		
Oral	3,087.84 ± 2.00^{a}	3,106.34 ± 2.00^{a}
Gastric	3,274.47 ± 0.00^{ab}	3,253.83 ± 2.10^{ab}
Intestinal	5,043.16 ± 0.00^{d}	4,815.03 ± 6.48^{c}

Values represent mean ±SD of triplicate experiment. Values in the same column followed by different letters (a-c) are significantly different (P<0.05).

Table 13: The Amino Acid Profile of Raw and Cooked *in vitro* Enzyme Digested and Undigested Lima Beans (mg/kg)

Amino Acid	RP	ORD	OGRD	TDR	CP	ODC	OGCD	TCD
Glycine	310±32.4^{f}	0.083±0.002^{a}	0.15±0.03^{c}	290±19.2^{e}	330±19.4^{h}	0.14±0.02^{b}	0.29±0.03^{d}	320±34.2^{g}
Alanine	290±12.5^{f}	0.096±0.004^{a}	0.15±0.05^{c}	270±15.1^{e}	320±17.2^{h}	0.11±0.04^{b}	0.23±0.05^{d}	310±12.5^{g}
Serine	500±21.2^{g}	0.10±0.05^{a}	0.23±0.04^{c}	440±21.3^{e}	520±22.3^{h}	0.17±0.04^{b}	0.46±0.03^{d}	490±43.3^{f}
Proline	120±14.3^{f}	0.012±0.006^{a}	0.037±0.02^{c}	82±4.1^{e}	120±11.4^{g}	0.029±0.001^{b}	0.059±0.002^{d}	87±6.4^{gf}
Valine	500±21.5^{f}	0.15±0.03^{a}	0.24±0.05^{c}	460±21.3^{e}	510±17.4^{g}	0.21±0.03^{b}	0.27±0.04^{d}	500±24.3^{f}
Threonine	340±13.3^{g}	0.12±0.04^{a}	0.21±0.01^{c}	320±14.2^{e}	350±15.2^{h}	0.18±0.02^{b}	0.24±0.03^{d}	330±31.3^{f}
Isoleucine	410±14.1^{f}	0.14±0.02^{a}	0.19±0.03^{c}	400±15.3^{e}	500±21.3^{h}	0.16±0.06^{b}	0.23±0.06^{d}	480±32.4^{g}
Leucine	600±15.2^{f}	0.17±0.03^{a}	0.23±0.01^{c}	570±20.4^{e}	650±31.4^{h}	0.19±0.06^{b}	0.26±0.05^{d}	640±18.4^{g}
Aspartate	850±23.6^{g}	0.35±0.01^{a}	0.44±0.04^{c}	710±18.1^{e}	870±28.5^{h}	0.39±0.03^{b}	0.50±0.07^{d}	780±33.5^{f}
Lysine	520±21.3^{g}	0.17±0.05^{a}	0.19±0.03^{c}	410±12.3^{e}	570±21.4^{h}	0.19±0.07^{b}	0.22±0.04^{d}	500±41.2^{f}
Methionine	75±4.7^{f}	0.014±0.003^{a}	0.015±0.006^{ab}	73±4.1^{e}	79±5.5^{g}	0.015±0.001^{ab}	0.15±0.03^{c}	70±8.5^{d}
Glutamate	960±15.6^{f}	0.38±0.04^{a}	0.42±0.03^{c}	940±1.4^{e}	1000±29.7^{h}	0.40±0.05^{b}	0.53±0.02^{d}	930±27.3^{g}
Phenylalanine	420±17.3^{g}	0.15±0.03^{a}	0.22±0.04^{c}	370±21.4^{e}	440±12.3^{h}	0.17±0.03^{b}	0.25±0.04^{d}	400±33.4^{f}
Histidine	270±12.4^{f}	0.25±0.02^{a}	0.31±0.03^{c}	250±14.2^{e}	280±21.4^{g}	0.29±0.02^{b}	0.36±0.06^{d}	250±14.5^{e}
Arginine	400±25.3^{e}	0.13±0.04^{a}	0.17±0.05^{c}	400±13.6^{e}	530±25.2^{h}	0.15±0.01^{b}	0.22±0.03^{d}	470±23.4^{g}
Tyrosine	250±1.3^{g}	0.055±0.003^{a}	0.26±0.03^{c}	230±10.2^{e}	240±22.4^{h}	0.08±0.001^{b}	0.32±0.06^{d}	210±19.4^{f}
Tryptophan	94±7.5^{g}	0.11±0.02^{a}	0.17±0.01^{c}	73±5.1^{e}	110±9.7^{h}	0.12±0.03^{ab}	0.18±0.03^{cd}	82±3.7^{f}
Cysteine	100±9.7^{g}	0.034±0.005^{a}	0.13±0.03^{c}	80±4.3^{e}	100±8.5^{g}	0.047±0.002^{b}	0.14±0.01^{cd}	99±2.9^{f}

Abbreviations: RP = Raw dried and powdered; ORD = Oral raw digested; OGRD = Oral and gastric raw digested; TDR = Total digested raw; CP = Cooked dried and powdered; ODC = Oral cooked digested; OGDC = Oral and gastric cooked digested; TCD = Total cooked digested. Values are given as mean ± SE of independent experiments performed in triplicate. Values are given as mean ± SE of independent experiments performed in triplicate. Values with different superscripts in the same row differ significantly (P<0.05)

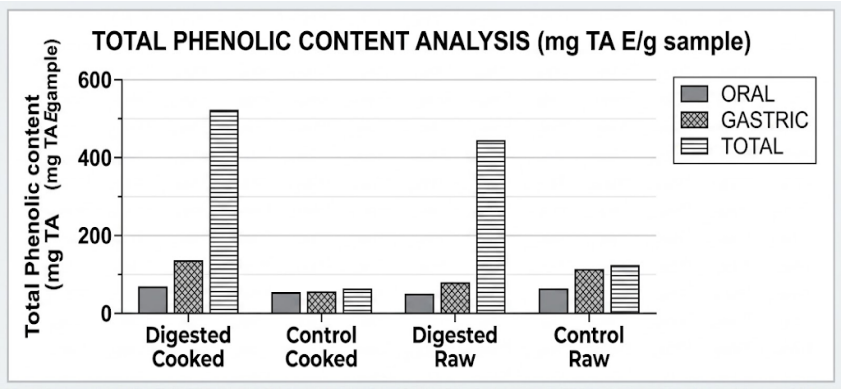


Figure 18: Total Phenolic Content Of P. Lunatus Extract. The Results Are Expressed As Milligrams of Tannic Acid Equivalent (mg TA) per 100 g of dry weight sample. Values are given as mean ± SE of independent experiments performed in triplicate. TA= Tannic Acid; Oral= Oral digestion; Gastric= Gastric digestion; Total=Total intestinal digestion

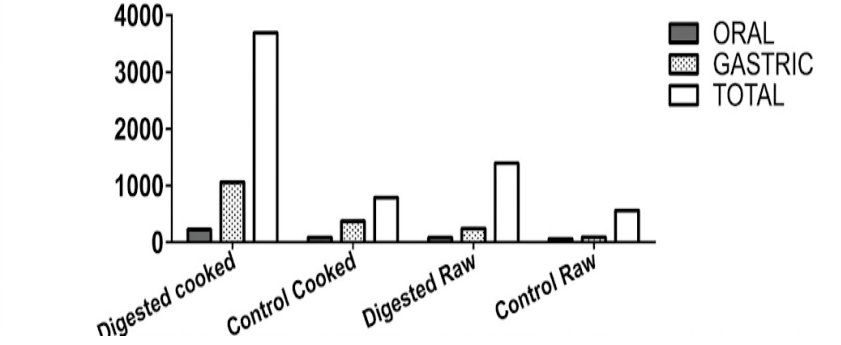


Figure 21: Total Flavonoid Content Of *P. Lunatus* Extract Expressed As Mg of Quercetin Equivalents (QE) per 100 g of dry weight of the sample. Values are given as mean ± SE of independent experiments performed in triplicate. Oral= Oral digestion; Gastric= Gastric digestion; Total=Total intestinal digestion

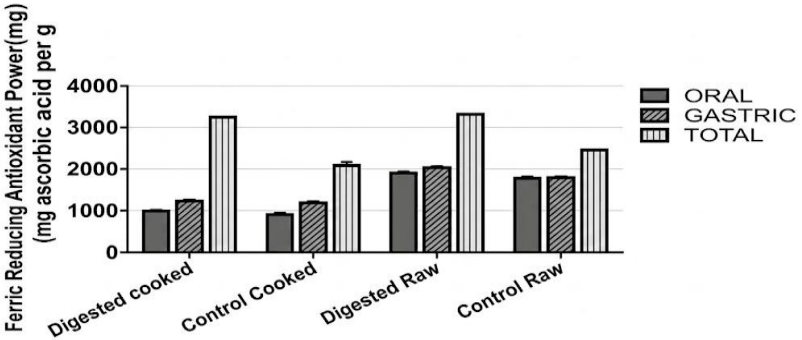


Figure 19: Ferric Reducing Antioxidant Power of *P. lunatus* Extract Expressed As Milligrams Ascorbic Acid Equivalent Per 100 g of Dry Weight Sample. Values are given as mean ± SE of independent experiments performed in triplicate. AA= Ascorbic Acid; Oral= Oral digestion; Gastric= Gastric digestion; Total=Total intestinal digestion

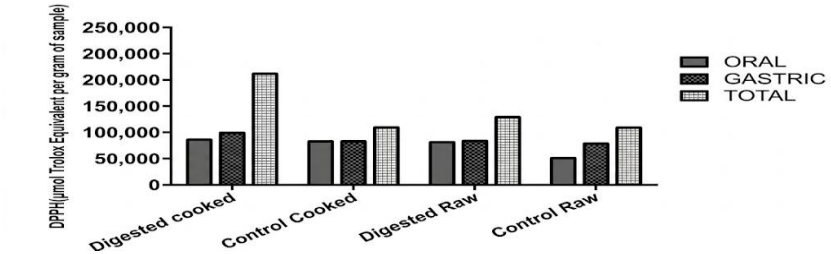


Figure 20: DPPH Radical Scavenging Activity of P. Lunatus Extract Expressed As ➪ mole Trolox Equivalents Per 100 g Of Dry Weight of The Sample. Values are given as mean ± SE of independent experiments performed in triplicate. Oral= Oral digestion; Gastric= Gastric digestion; Total=Total intestinal digestion

Table 14: Antioxidant Indices of tomato fruit (ripe and unripe) and paste (*paste 2* and *paste 1)*

Sample	TPC (mg GAE/g)	TFC (mg QE/g)	FRAP (mg AAE/g)	DPPH (µmol TE/g)	ABTS (µmol TE/g)	NO (% Inhibition)	OH (% Inhibition)
RT	35.59±0.09^{d}	21.25±1.01^{c}	11.98±0.01^{d}	50.03±0.40^{d}	89.86±0.00^{c}	58.67±0.60^{c}	18.11±0.90^{d}
UT	14.91±0.05^{a}	10.01±0.35^{a}	01.70±0.01^{a}	34.14±0.20^{a}	83.40±0.40^{a}	48.36±0.60^{a}	0.47±0.18^{a}
P1	29.99±0.03^{b}	10.62±0.62^{a}	07.40±0.00^{b}	37.04±0.35^{b}	87.64±0.60^{b}	49.24±0.11^{a}	10.57±2.09^{c}
P2	30.28±0.05^{c}	18.06±0.30^{b}	11.40±0.21^{d}	42.13±0.12^{c}	89.38±0.60^{c}	53.48±0.00^{b}	10.60±0.09^{c}
DRT	61.08±0.30^{fg}	50.86±0.41^{g}	19.89±0.009^{g}	71.90±0.63^{g}	95.49±0.14^{c}	69.06±0.51^{f}	35.71±0.18^{g}
DUT	38.97±0.55^{c}	25.06±0.00^{d}	10.36±0.00^{c}	50.75±0.81^{d}	89.86±0.14^{c}	60.75±0.17^{d}	06.99±0.73^{b}
DP1	56.02±0.05^{f}	29.47±0.66^{e}	12.86±0.02^{e}	63.34±0.37^{e}	93.75±0.00^{d}	64.67±0.37^{e}	26.87±0.73^{e}
DP2	60.36±0.35^{fg}	43.95±0.66^{f}	18.70±0.01^{f}	65.06±0.27^{f}	94.86±0.60^{d}	67.55±0.06^{f}	32.43±0.91^{f}

Values represent mean ± standard deviation of triplicate experiments. Values with different superscripts in the same column differ significantly (p<0.05). Abbreviations: RT= Ripe Tomatoes; UT= Unripe Tomatoes; P1= Paste 1 Tomatoes; P2= Paste 2 Tomatoes; DRT= Digested Ripe Tomatoes; DUT= Digested Unripe Tomatoes; DPT= Digested Paste 2 Tomatoes; DGT= Digested Paste 1 Tomatoes; GAE=Gallic Acid Equivalent; QE=Quercetin Equivalent; AAE=Ascorbic Acid Equivalent; TE=Trolox equivalents.

Table 15: Effect of ethanolic extract and *in vitro* digested samples of tomato fruit and paste on antioxidant enzyme activities

Samples	GSH (U/mL)	GPX (U/mL)	SOD (U/mL)	CATALASE (U/mL)
RT	8.54 ± 0.65^{c}	14.6 ± 0.18^{e}	3.14 ± 0.02^{c}	2.49 ± 0.09^{c}
UT	5.39 ± 0.26^{a}	1.68 ± 0.11^{a}	0.68 ± 0.13^{a}	1.10 ± 0.02^{a}
P1	6.43 ± 0.16^{b}	2.83 ± 0.9^{b}	1.64 ± 0.03^{b}	1.57 ± 0.11^{b}
P2	6.03 ± 0.08^{b}	8.38 ± 0.06^{d}	3.12 ± 0.04^{c}	2.15 ± 0.47^{b}
DRT	10.68 ± 0.50^{e}	34.3 ± 0.02^{h}	6.04 ± 0.02^{e}	5.15 ± 0.14^{d}
DUT	5.78 ± 0.65^{a}	6.62 ± 1.98^{c}	1.46 ± 0.10^{b}	1.11 ± 0.01^{a}
DP1	9.24 ± 0.17^{d}	17.30 ± 0.75^{f}	3.27 ± 0.00^{c}	2.61 ± 0.23^{b}
DP2	9.94 ± 0.13^{d}	22.87 ± 0.08^{g}	4.06 ± 0.02^{d}	2.67 ± 0.25^{b}

Values represent mean ±standard deviation of triplicate experiments. Values with different superscripts in the same column differ significantly (p<0.05) Abbreviation: RT= Ripe Tomatoes; UT= Unripe Tomatoes; P1= Paste 1 Tomatoes; P2= Paste 2 Tomatoes; DRT= Digested Tomatoes; DUT= Digested Unripe Tomatoes; DP2= Digested Paste 2 Ripe Tomatoes; DP1= Digested Paste 1 Tomatoes; GSH= Glutathion; PX=Glutathion peroxidase; SOD=Superoxide dismutase.

HPLC-DAD-MS QUALI-QUANTITATIVE ESTIMATION OF PHENOLIC AND OTHER BIOACTIVE COMPOUNDS IN TROPICAL FOODS AND NATURAL PRODUCTS.

Polyphenols are naturally occurring, water-soluble plant compounds with molecular weights ranging from 500 to 4000 Da. Found abundantly in fruits, vegetables, cereals, and beverages, they represent a diverse group of over 8,000 identified compounds (Quideau *et al*., 2011). Their structural diversity underpins a wide range of biological activities, including anti-inflammatory, anticancer, antimicrobial, and anti-aging effects (Ganesan and Xu, 2017; Karav *et al*., 2015). Consequently, polyphenols have shown significant potential in

managing diseases such as cancer, as well as neurological, cardiovascular, and metabolic disorders (Ganesan and Xu, 2017; Del Rio *et al*., 2013). The phenolic composition of tropical foods and natural products as reported together with my research collaborators, has been extensively documented in several studies (**Salawu** *et al*., 2008; 2009; 2013; 2014; Omoba, *et al*., 2015; **Salawu** *et al*., 2016; Badejo *et al*., 2017; **Salawu** *et al*., 2019; Omoba, *et al*., 2019; Akande, *et a*l., 2022), providing valuable insights into their nutritional and therapeutic relevance.

Tropical vegetables, cereals, and legumes are rich in phenolic compounds such as flavonoids and cinnamoyl derivatives, which underpin their health-promoting potential. Madam Vice Chancellor, we use HPLC/DAD/MS characterization, studies to analyze phenolic profiles in *Ocimum gratissimum, Vernonia amygdalina, Corchorus olitorius, Manihot utilissima,*sorghum, teff, and cowpea**.** Results revealed diverse compounds: up to 17 phenolics in V. amygdalina, in decoction, novel compounds like cichoric acid in O. gratissimum and amentoflavone in M. utilissima, and catechin, quercetin, and hydroxycinnamic acids in sorghum, teff, and cowpea. Decoction stability tests showed most phenolics remained intact after boiling, with blanching broths retaining significant metabolites. Whole grains displayed richer flavonoid profiles than cell wall fractions, emphasizing the nutritional value of pericarp and seed coat layers. Collectively, these findings confirm that tropical vegetables and grains are reservoirs of stable, bioactive phenolics, supporting their use as functional foods with substantial health benefits (**Salawu** *et al*., 2008; **Salawu** *et al*., 2009; **Salawu** *et al*., 2013; **Salawu** *et al*., 2014).

Phenolic compounds, particularly flavonoids and phenolic acids, are key bioactive molecules with strong antioxidant potential, making tropical crops and plant-based foods valuable for

functional nutrition. Madam Vice Chancellor, we use HPLC/DAD/MS analysis, studies, characterized phenolic profiles in citrus peels and seeds, acha–tigernut beverages, and lima beans**.** Orange peels contained abundant flavonoids such as quercitrin, rutin, and quercetin, with ripe peel showing superior antioxidant activity. Beverages from acha–tigernut blends were rich in phenolic acids and flavonoids, dominated by quercetin. Lima beans contained gallic acid, catechin, caffeic acid, rutin, quercitrin, quercetin, kaempferol, and apigenin, with cooking moderately reducing several compounds but leaving caffeic acid and quercetin more abundant in raw beans. Collectively, these findings, as reported together with my research collaborators confirm that citrus by-products, legumes, and plant-based beverages are sustainable sources of stable phenolics, supporting their use as functional foods with antioxidant and health-promoting benefits (**Salawu** *et al*., 2016; Badejo *et al*., 2017; **Salawu** *et al*., 2019).

Spices and medicinal plants are rich in phenolic compounds that underpin antioxidant, cardioprotective, and neuroprotective activities. Madam Vice Chancellor,using HPLC-DAD/MS and ^{1}H NMR, studies to profile phenolics in *Ocimum basilicum* (OB), *Xylopia aethiopica* (XA), *Piper guineensis* (PG), and *Anogeissus leiocarpus* stem bark**.** Methanolic extracts of OB, XA, and PG revealed diverse phenolic acids and flavonoids including gallic, chlorogenic, caffeic, rosmarinic, rutin, quercitrin, quercetin, isoquercitrin, kaempferol, capsaicin, and dihydrocapsaicin, with quercetin dominant in OB, rutin/quercitrin in XA, and isoquercitrin in PG. A. leiocarpus decoction yielded 59 compounds-43 ellagitannins and 16 triterpenoids-highlighting roburin, vescalin, and castalin as novel detections. These findings as reported together with my research collaborators, confirm that tropical spices and medicinal plants are reservoirs of stable bioactive molecules with nutritional, pharmaceutical,

and therapeutic relevance, supporting their use in functional foods and natural medicine (Omoba, *et al*., 2019; Akande, *et al*., 2022; Micheli *et al*., 2023., Trumbeckaite *et al*., 2006; Kanashiro *et al*., 2009; Javed *et al*., 2012; Wang *et al*., 2011).

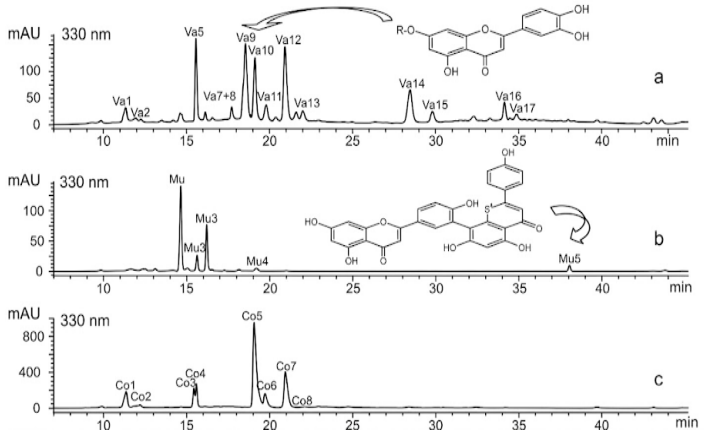


Figure 21: Chromatographic profiles at 330 nm of the hydro alcoholic extracts: (a) Vernonia amygdalina; (b) Manihot utilissima Pohl.; (c) Corchorus olitorius L. at 330 nm. The profiles were obtained with the Synergi max column and elution method 1.

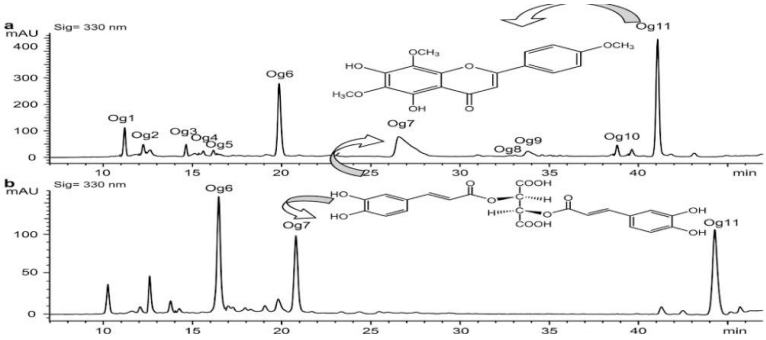


Figure 22: Chromatographic profile at 330 nm of Og hydroalcoholic extract with: (a) Synergi max column and elution method 1. (b) Polaris-ether column and elution method 2.

Table 16: List of the identified compounds of Four Tropical Vegetables by HPLC/DAD and HPLC/ESI/MS

Peak no.	Compounds	R_t (min)	λ_{max} (nm)	$[M-H]^-$	Fragment ions	References
(a) *Vernonia amygdalina* L. (Va)						
Va 1	Caffeoyl quinic acid	11.4	330	353	191	
Va 2	Chlorogenic acid	12.0	330	353	191	
Va 3	Rutin	14.6	256/564	609	301	Std.
Va 4	Luteolin 7-O-rut.	14.7	264/348	593	285	
Va 5	Luteolin 7-O-rut.	15.6	264/348	447	285	Std.
Va 6	Luteolin 4'-O-rut.	15.1	260/336	593	285	Sakakibara et al (2003)
Va 7 + 8	Flavonoid + caffeoyl dec.	17.7	–	–	–	
Va 8	Luteolin-7-O-glucur.[a]	18.6	254/348	461	285	Sakakibara et al (2003)
Va 10	1,5-Dicaffeoyl-quinic ac.	19.1	328	461	333,191	
Va 11	Dicaffeoyl-quinic ac.	19.7	328	515	335, 191, 173	
Va 12	Dicaffeoyl-quinic ac.	20.9	328	515	333; 191, 179	
Va 13	Apigenin 6-O or 7-O-glucur.	2.0	264/384	445	269	
Va 14	Luteolin	28.5	264/348	285	–	Std.
Va 15	Flavonoid[b]	29.8	284/334	547	299; 295	
Va 16	Flavonoid[b]	34.2	336	663	269	
Va 17	Flavonoid[b]	34.9	270/336	663	531; 299	
(b) *Manihot utilissima* Pohl (Mu)						
Mu 1	Rutin	14.6	356	609	300	Std.
Mu 2	Kaempferol 4'-O-rut.	15.6	260/348	593	285	
Mu 3	Kaempferol 3-O-rut.	16.2	260/348	593	285	Std.
Mu 4	Ferulic acid	19.2	336	193	179; 195	Std.
Mu 5	Amentoflavone	38.1	268/388	337		Std.

Peak no.	Compounds	Rt (min)	λ_{max} (nm)	$[M-H]^-$	Fragment ions	References	mg/g dw (SD)
(c) *Corchorus olitorius* L. (Co)							
Co 1	Caffeoyl quinic derivative	11.3	320	729	375, 353, 191, 179	1.0 (0.03)	
Co 2	Chlorogenic acid	12.0	326	353	301	Std.	0.19 (0.01)
Co 3	Hyperoside	15.4	256/358	463	301	Std.	2.47 (0.15)
Co 4	Isoquerctitin	15.6	256/358	463	301	Std.	2.53 (0.19)
Co 5	1,5-dicaffeoyl-quinic ac.[a]	16.1	328	515	353; 191; 179; 161		8.89 (0.49)
Co 6	Dicaffeoyl quinic ac.	19.7	326	515	353; 179; 161		
Co 7	Dicaffeoyl derivative	20.7	328	515	353; 161		3.2 (0.19)
Co 8	Quercetin derivative	25.1	354	533	505; 301		

Peak no.	Compounds	Rt (min)	λ_{max} (nm)	$[M-H]^-$	Fragment ions	References
(d) *Ocimum gratissimum* L. (Og)						
Og 1	Vicenin-2	11.2	270; 336	593	387	Grayer et al. (2002)
Og 2	Caffeic acid	12.3	330	179	135	Std.
Og 3	Rutin	14.6	256; 356	609	301	Std.
Og 4	Luteolin 7-O-gluc.	15.6	260; 348	447	285	
Og 5	Raempferol 3-O-rut.	18.2	Impure	593	285	Std.
Og 6	Rosmarinic acid	19.9	330	359	197, 161, 135	Std.
Og 7	Cicholic acid	26.4	330	473	311, 179, 161, 149, 195	Std.
Og 8	Caffeoyl dec.	33.8	330	–	–	
Og 9	Cirsiliol	34.3	273; 344	329		Grayer et al. (2002)
Og 10	Cirsimaritin[e]	38.8	276, 334	313	297	
Og 11	Nevadensin[e]	48.1	284; 332	343	313, 299	Grayer et al. (2001)

Abbreviations: rut. = rutinoside; glucur. = glucuronide; ac. = acid; glu. = glucoside; der. = derivative: dw = dried weight of the leaves. A). Coelution with a dicaffeoyl-quinic ac. derivative. B). Peaks showing similar UV–vis spectra. C). Coelututed with a quercetin glicoside. D). The ethanol extract from the leaves of rosemary leaves was used to confirm the identification by comparison of Rt, UV and MS spectra (Giaccherini *et al*., 2007). e The structure was confirmed by NMR experiment on isolated compounds and by comparison with literature (Grayer et al., 2001).

Table 17: Quantitative Estimates of phenolic compounds for Va, Mu and Og extracts.

	Compound	mg/g dried weight	
		EtOH/H_2O extract (mean ± SD)	Hot water extrac (mean ± SD)
Va 1	Caffeoyl quinic acid	0.122 ± 0.017	0.189 ± 0.037
Va 2	Chlorogenic acid	0.029 ± 0.001	0.169 ± 0.028
Va-x +y	Caffeoyl quinic acids	Traces	0.322 ± 0.137
Va 3	Rutin	0.157 ± 0.012	nd
Va 5	Luteolin 7-O-glu.	0.359 ± 0.004	0.345 ± 0.028
Va 6	Luteolin 4′-O-rut.	0.025 ± 0.003	nd
Va 7	Flavonoid	0.094 ± 0.004	nd
Va z	Caffeoyl der.	0.208 ± 0.023	nd
Va 9	Luteolin 7-O-glucur.	0.471 ± 0.021	0.919 ± 0.083
Va 10	1,5-Dicaffeoyl quinic acid	0.409 ± 0.006	0.227 ± 0.077
Va 11	Dicaffeoyl quinic acid	0.144 ± 0.001	0.32 ± 0.116
Va 12	Dicaffeoyl quinic acid	0.638 ± 0.009	0.224 ± 0.081
Va 13	Apigenin-O-glucur.	0.082 ± 0.015	0.124 ± 0.01
Va 14	Luteolin	0.425 ± 0.005	0.131 ± 0.012
Va 15–17	Others flavonoids	0.182 ± 0.004	nd
Mu 1	Rutin	15.44 ± 1.85	5.765 ± 0.065
Mu 2	Kaempferol 4′-O-rut.	2.21 ± 0.19	0.861 ± 0.021
Mu 3	Kaempferol 3-O-rut.	6.66 ± 0.50	2.3 ± 0.08
Mu 4	Ferulic acid	Traces	0.49 ± 0.07
Mu 5	Amentoflavone	0.97 ± 0.03	nd
Og 1	Vicenin-2	0.65 ± 0.04	0.706 ± 0.004
Og 2	Caffeic acid	0.25 ± 0.05	0.595 ± 0.017
Og 3	Rutin	0.39 ± 0.02	0.204 ± 0.024
Og 4	Kaempferol 4′-O-rut.	0.04 ± 0.01	nd
Og 6	Rosmarinic acid	1.92 ± 0.1	0.714 ± 0.126
Og 7	Cichoric acid	2.55 ± 0.14	1.75 ± 0.09
Og 10	Cirsimaritin	0.18 ± 0.01	nd
Og 11	Nevadensin	2.73 ± 0.09	0.18 ± 0.016

The data are a mean of three extracts from the same lot and the compounds are progressively numbered within each plant. Abbreviation; Va: Vernonia amygdalina; Mu: Manihot utilissima; Og: Ocimum gratissimm; Co: Cochorus olitorious

Table 18: Phenolic compounds in processed and unprocessed leaves of *Corchorus Olitorius*.

Compounds of *Corchorus olitorius*	Raw	Blanched
Co1 - caffeoyl quinic derivative	14.8 ± 0.4	2.8 ± 0.03
Co2 - chlorogenic acid	0.2 ± 0.02	0.07 ± 0.00
Co3+4 - hyperoside+isoquercitrin	2.1 ± 0.06	0.3 ± 0.004
Co5 1,5-dicaffeoyl quinic acid	23.2 ± 0.6	2.0 ± 0.03
Co6 - dicaffeoyl quinic acid	0.1 ± 0.004	0.002 ± 0.002
Co7 - dicaffeoyl derivative	1.7 ± 0.03	0.5 ± 0.004
Co8 - quercetin derivative	0.1 ± 0.009	nd

All the data are a mean of three different determinations and are expressed as mg/g (SD) dried leaves.

Table 19: Phenolic compounds in processed and unprocessed leaves of *Vernonia amygdalina*

Compounds of *Vernonia amygdalina*	Raw	Blanched	Abrasion
Va1+2 - caffeoyl quinic and chlorogenic acids	2.3 ± 0.3	0.4 ± 0.02	0.5 ± 0.04
Va4 - rutin	0.2 ± 0.04	nd	nd
Va5 - luteolin 7-O-glu	2.7 ± 0.3	0.3 ± 0.02	0.4 ± 0.02
Va7 - flavonoid	0.3 ± 0.03	0.1 ± 0.009	0.005 ± 0.006
Va9 - luteolin 7-O-glucuronide	4.9 ± 0.5	0.7 ± 0.02	0.7 ± 0.04
Va10 - 1,5 dicaffeoyl quinic acid	23.47 ± 3.0	1.4 ± 0.2	6.9 ± 1.5
Va11 - dicaffeoyl quinic acid	2.6 ± 0.1	0.3 ± 0.02	0.5 ± 0.08
Va12 - dicaffeoyl quinic acid	2.5 ± 0.4	0.4 ± 0.03	1.3 ± 0.5
Va13 - apigenin-O-glucuronide	0.7 ± 0.02	0.4 ± 0.02	0.2 ± 0.02
Va14 - luteolin	0.2 ± 0.03	0.1 ± 0.01	0.6 ± 0.06
Va15 - flavonoid	0.1 ± 0.02	0.1 ± 0.01	0.02 ± 0.004
Va16 - flavonoid	0.09 ± 0.01	0.04 ± 0.004	0.3 ± 0.01
Va17 - flavonoid	0.06 ± 0.01	0.1 ± 0.001	0.0015 ± 0.0

All the data are a mean of three different determinations and are expressed as mg/g (SD) dried leaves. Abbreviation; Va: Vernonia amygdalina

Table 20: Phenolic compounds in processed and unprocessed leaves of *Manihot utilissima*

Compounds of *Manihot utilissima*	Raw	Blanched
Mu1 - rutin	5.1 ± 0.2	5.8 ± 1.0
Mu2 - kaempferol 4'-O-rut	0.7 ± 0.05	0.8 ± 0.2
Mu3 - kaempferol 3'-O-rut	2.5 ± 0.1	2.8 ± 0.5
Mu5 - amentoflavone	0.9 ± 0.008	1.1 ± 0.2

All the data are a mean of three different determinations and are expressed as mg/g (SD) dried leaves.

Table 21: Phenolic compounds in processed and unprocessed leaves of *Ocimum gratssimum*

Compounds of *Ocimum gratissimum*	Raw	Blanched	Abrasion
Og1 - vicenin-2	1.5 ± 0.002	1.0 ± 0.06	0.9 ± 0.06
Og2 - caffeic acid	0.5 ± 0.01	0.5 ± 0.03	0.3 ± 0.007
Og3 - rutin	0.2 ± 0.003	0.1 ± 0.001	0.02 ± 0.001

Og4 - luteolin-7-O-glucoside	0.3 ± 0.01	0.2 ± 0.02	nd
Og5 - kaempferol 3'-O-rutinoside	0.04 ± 0.006	0.03 ± 0.0	nd
Og6 - rosmarinic acid	6.1 ± 0.6	29.8 ± 1.7	1.0 ± 0.2
Og10 - cirsimaritin	0.7 ± 0.05	0.6 ± 0.01	0.5 ± 0.02
Og11 - nevadensin	5.8 ± 0.4	5.0 ± 0.3	4.6 ± 0.2

All the data are a mean of three different determinations and are expressed as mg/g (SD) dried leaves. Abbreviation; Og: Ocimum gratissimum

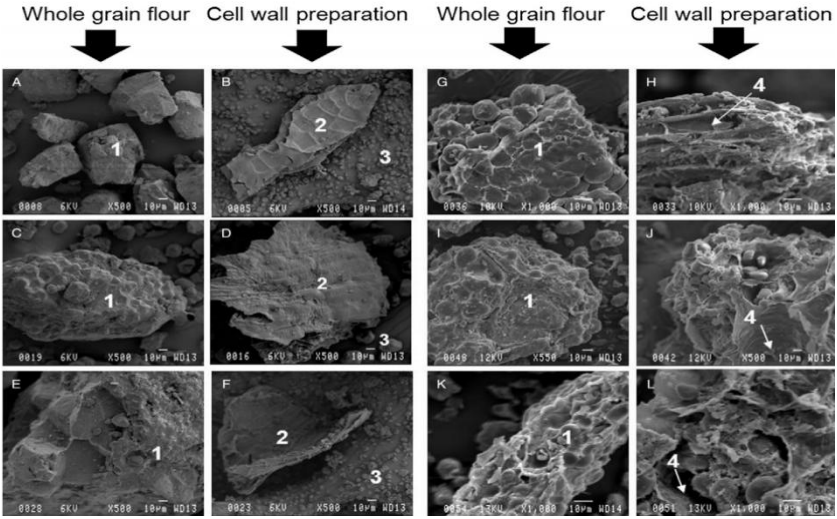


Figure 23: The Scanning Electron Micrographs of The Whole Grain Flours (A, C, E, G, I and K) and Cell Wall Preparations (B, D, F, H, J and L) of Brown Teff (A, B); White Sorghum (C, D); White Teff (E, F); Red Sorghum(G, H); Black-Eyed Cowpea (I, J); Betchuana White Cowpea (K, L) ; 1, chunks of material; 2, cell wall fragment; 3, remnants of starch granules and protein bodies; 4, material with empty cells (indicated with arrows)

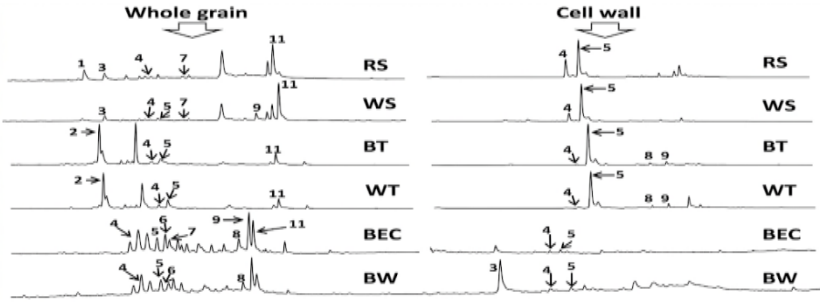


Figure 25: High-Performance Liquid Chromatography Chromatograms of Extracts from Whole Grain Flours and Cell Wall Preparations of Selected Cereals and Legumes. BEC, black-eyed cowpea; BW, Betchuana white cowpea; BT, brown teff; RS, red sorghum; WS, white sorghum; WT, white teff. 1, catechin; 2, *p*-hydroxybenzoic acid; 3, caffeic acid; 4, *p*-coumaric acid; 5, ferulic acid; 6, taxifolin; 7, naringenin; 8, quercetin; 9, luteolin; 10, cinnamic acid; 11, apigenin. Chromatograms for sorghum and teff samples are given at 280 nm and chromatograms for cowpea samples are given at 330 nm.

Table 22: Phenolic Acid and Flavonoid Contents (Mg/100 g) of Extracts from Whole Grain Flour and Cell Wall Preparations of Selected Cereals and Legumes

Compound	RS	WS	BT	WT	BEC	BW
Whole grain extracts						
Caffeic acid	2.43 ± 0.39	ND	ND	ND	ND	ND
p-coumaric acid	0.72 ± 0.06	0.40 ± 0.03	1.56 ± 0.37	0.87 ± 0.10	7.89 ± 0.31	4.87 ± 0.08
Ferulic acid	Trace	0.89 ± 0.17	5.38 ± 0.17	2.52 ± 0.40	6.10 ± 1.01	2.12 ± 0.41
Catechin	23.63 ± 4.94	ND	ND	ND	ND	ND
Naringenin	0.99 ± 0.28	0.68 ± 0.09	ND	ND	3.61 ± 0.81	ND
Apigenin	14.34 ± 0.62	28.92 ± 4.83	ND	3.14 ± 0.38	9.53 ± 0.81	2.11 ± 0.12
Luteolin	ND	9.91 ± 2.04	ND	ND	4.03 ± 0.95	ND
p-Hydroxybenzoic acid	ND	ND	59.75 ± 3.03	34.44 ± 2.37	ND	ND
Quercetin	ND	ND	ND	ND	30.72 ± 3.28	4.54 ± 0.73
Taxifolin	ND	ND	ND	ND	5.21 ± 0.58	4.54 ± 0.40
Cinnamic acid	ND	ND	ND	ND	ND	2.43 ± 0.18
Cell wall extracts						
p-Coumaric acid	23.59 ± 0.57	15.18 ± 2.50	1.17 ± 0.00	0.69 ± 0.07	0.15 ± 0.03	0.50 ± 0.01
Ferulic acid	128.94 ± 0.76	37.87 ± 5.33	14.16 ± 0.18	39.40 ± 0.76	1.39 ± 0.11	0.45 ± 0.05
Catechin	ND	ND	ND	ND	trace	33.60 ± 4.21
Naringenin	ND	ND	ND	ND	ND	ND
Apigenin	ND	ND	ND	trace	ND	ND
Luteolin	ND	ND	5.17 ± 0.64	3.24 ± 0.15	ND	ND
p-Hydroxybenzoic acid	ND	ND	Trace	Trace	ND	ND
Quercetin	ND	ND	1.50 ± 0.02	24.51 ± 2.92	ND	ND

Compound	RS	WS	BT	WT	BEC	BW
Taxifolin	ND	ND	ND	ND	ND	ND
Cinnamic acid	ND	ND	ND	ND	ND	Trace

All the data are a mean of three different determinations and are expressed as mg/g ± SD

Table 23: Phenolic acids and flavonoids composition of orange peel powder (ripe and unripe) extracts.

Compounds	Unripe Orange Peel (mg/g)	Ripe Orange Peel (mg/g)
Catechin	$5.91 \pm 0.03^{c,B}$	$12.49 \pm 0.01^{c,A}$
Caffeic acid	$3.45 \pm 0.01^{d,A}$	$3.57 \pm 0.02^{e,A}$
Naringin	$3.58 \pm 0.02^{d,B}$	$5.71 \pm 0.02^{d,A}$
Epicatechin	$3.21 \pm 0.01^{d,B}$	$6.08 \pm 0.01^{d,A}$
Rutin	$18.65 \pm 0.03^{a,A}$	$17.93 \pm 0.03^{b,B}$
Quercitrin	$18.77 \pm 0.01^{a,B}$	$22.61 \pm 0.01^{a,A}$
Quercetin	$10.39 \pm 0.01^{b,B}$	$14.03 \pm 0.02^{b,A}$
Kaempferol	$5.86 \pm 0.02^{c,A}$	$3.76 \pm 0.03^{e,B}$
Luteolin	$3.19 \pm 0.03^{d,B}$	$5.83 \pm 0.01^{d,A}$

Results are expressed as mean ± standard deviations (SD) of three determinations. Values with different alphabets along the same column (lowercase letters) are significantly different by Tukey test ($p < 0.05$). Values with different alphabets along the same row (capital letters) are significantly different ($p < 0.05$) by one-way analysis of variance (ANOVA).

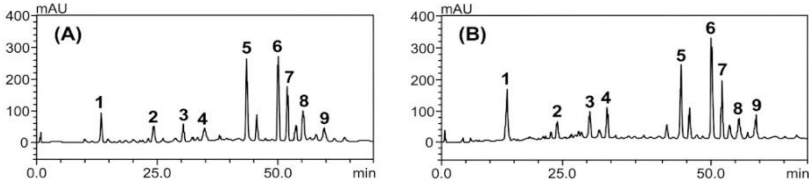


Figure 26: Representative high performance liquid chromatography profile of unripe orange peel powder (A) and ripe orange peel powder (B). Catechin (peak 1), caffeic acid (peak 2), naringin (peak 3), epicatechin (peak 4), rutin (peak 5), quercitrin (peak 6), quercetin (peak 7) kaempferol (peak 8) and luteolin (peak 9).

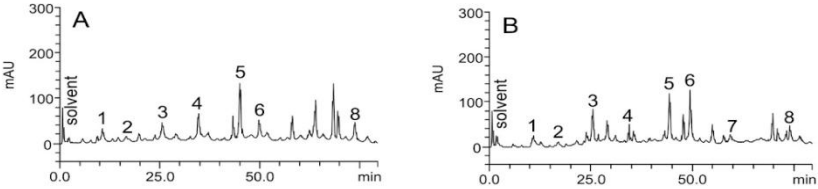


Figure 27: Representative high performance liquid chromatography profile of Lima bean raw (A) and cooked (B) extracts. Gallic acid (peak 1), catechin (peak 2), caffeic acid (peak

3), rutin (peak 4), quercitrin (peak 5), quercetin (peak 6), kaempferol (peak 7) and apigenin (peak 8)

Table 24: Phenolic and flavonoid composition of Lima Bean extracts

Compounds	Raw Lima beans mg/g	Cooked Lima beans mg/g
Gallic acid	1.96 ± 0.02^{a}	1.82 ± 0.01^{a}
Catechin	0.83 ± 0.01^{b}	0.73 ± 0.01^{b}
Caffeic acid	2.08 ± 0.04^{a}	2.95 ± 0.04^{c}
Rutin	2.61 ± 0.03^{d}	1.74 ± 0.03^{a}
Quercitrin	5.73 ± 0.01^{e}	5.68 ± 0.01^{d}
Quercetin	2.11 ± 0.02^{a}	5.73 ± 0.02^{d}
Kaempferol	-	0.81 ± 0.03^{b}
Apigenin	2.09 ± 0.01^{a}	1.79 ± 0.02^{a}

Results are expressed as mean ± standard deviations (n = 3). Averages followed by different letters differ by Tukey test at p < 0.05. LOD= Limit of detection, LOQ= Limit of qualification. Minus sign indicates percentage increase after processing

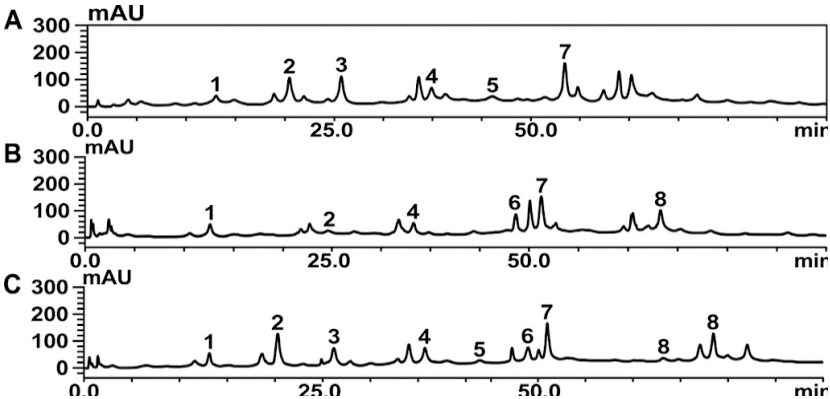


Figure 38: Representatives of high performance liquid chromatography profile of acha-ginger beverage (a), tigernut-ginger beverage (b) and acha–tigernut–ginger beverages (c). Gallic acid (peak *1*), chlorogenic acid (peak *2*), caffeic acid (peak *3*), ellagic acid (peak *4*), rutin (peak *5*), quercitrin (peak *6*), quercetin (peak *7*) and kaempferol (peak *8*)

Table 25: Phenolic and flavonoid contents (mg/g) of acha– tigernut–ginger beverages

Compounds	ACG	TNG	ATG1	ATG2	ATG3
Gallic acid	0.59 ± 0.01^{d}	0.97 ± 0.05^{b}	1.15 ± 0.02^{a}	0.67 ± 0.03^{c}	1.09 ± 0.01^{b}

Compounds	ACG	TNG	ATG1	ATG2	ATG3
Chlorogenic acid	1.87 ± 0.04[b]	0.28 ± 0.03[d]	2.01 ± 0.01[a]	1.63 ± 0.02[c]	1.68 ± 0.03[c]
Caffeic acid	1.96 ± 0.07[a]	ND	1.23 ± 0.07[c]	1.79 ± 0.07[b]	1.71 ± 0.07[b]
Ellagic acid	1.03 ± 0.03[b]	1.03 ± 0.01[b]	1.28 ± 0.02[a]	0.72 ± 0.05[c]	1.15 ± 0.02[a]
Rutin	0.64 ± 0.01[a]	ND	0.34 ± 0.05[b]	0.64 ± 0.01[a]	ND
Quercitrin	ND	1.53 ± 0.07[b]	1.29 ± 0.07[c]	1.58 ± 0.07[b]	2.03 ± 0.07[a]
Quercetin	3.05 ± 0.01[b]	2.98 ± 0.07[b]	3.14 ± 0.03[a]	3.16 ± 0.07[a]	2.94 ± 0.05[b]
Kaempferol	ND	1.62 ± 0.04[a]	0.25 ± 0.03[b]	0.23 ± 0.04[b]	0.28 ± 0.03[b]

Values are Mean±SEM (n=3). Values with the same superscript within a column are not significantly different (P<0.05). ACH, 100% malted acha+ginger extracts; TNG, 100% tigernut+ginger extracts; ATG1, 75% malted acha+25% tigernut+ginger extracts; ATG2, 50% malted acha+50% tigernut+ginger extracts; ATG3, 25% malted acha+75% tigernut+ginger extracts *ND* not detected

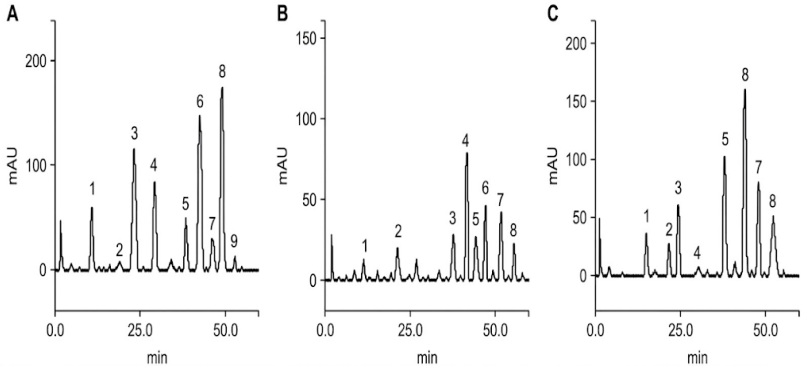


Figure 29: Representative high performance liquid chromatography profiles. (A) Extract of Ocimum basilicum: peak 1, gallic acid; peak 2, chlorogenic acid; peak 3, caffeic acid; peak 4, rosmarinic acid; peak 5, rutin; peak 6, isoquercitrin; peak 7, quercitrin; peak 8, quercetin; peak 9, kaempferol. (B) Extract of Piper guineensis: peak 1, gallic acid; peak 2, chlorogenic acid; peak 3, rutin; peak 4, isoquercitrin; peak 5, quercitrin; peak 6, quercetin; peak 7, dihydrocapsaicin; peak 8, capsaicin. (C) Extract of Xylopia aethiopica: peak 1, xylopic acid; peak 2, chlorogenic acid; peak 3, caffeic acid; peak 4, ellagic acid; peak 5, rutin; peak 6, quercitrin; peak 7, quercetin; peak 8, kaempferol.

Table 26: Phenolic composition of methanolic extracts of three spices from Nigeria

Compounds	*Ocimum basilicum* (mg/g)	*Xylopia aethiopica* (mg/g)	*Piper guineensis* (mg/g)
Gallic acid	26.75 ± 0.02[a]	ND	8.53 ± 0.01[b]
Chlorogenic acid	4.19 ± 0.03[c]	11.50 ± 0.03[b]	13.91 ± 0.02[a]
Caffeic acid	51.30 ± 0.01[a]	23.61 ± 0.02[b]	ND

Compounds	*Ocimum basilicum* (mg/g)	*Xylopia aethiopica* (mg/g)	*Piper guineensis* (mg/g)
Rosmarinic acid	40.65 ± 0.01	ND	ND
Xylopic acid	ND	12.93 ± 0.01	ND
Ellagic acid	ND	1.78 ± 0.02	ND
Rutin	25.93 ± 0.03^{b}	54.93 ± 0.01^{a}	20.47 ± 0.02^{c}
Isoquercitrin	78.24 ± 0.02^{a}	ND	46.70 ± 0.01^{b}
Quercitrin	22.18 ± 0.02^{b}	78.35 ± 0.01^{a}	19.85 ± 0.03^{c}
Quercetin	92.31 ± 0.01^{a}	39.42 ± 0.03^{b}	24.13 ± 0.01^{c}
Kaempferol	4.50 ± 0.01^{b}	25.81 ± 0.01^{a}	ND
Dihydrocapsaicin	ND	ND	23.82 ± 0.03
Capsaicin	ND	ND	13.50 ± 0.01

Results are expressed as mean ± standard deviations (n = 3). Averages followed by different letters differ by Tukey test at p < 0.05. LOD= Limit of detection, LOQ= Limit of qualification. Minus sign indicates percentage increase after processing

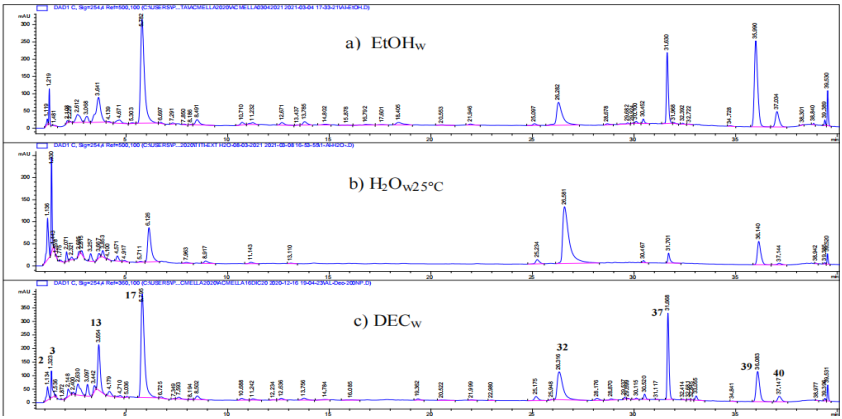


Figure 30: Chromatographic profiles at 254 nm of (a) hydroalcoholic extract (EtOHw); (b) water extract at room temperature (H2Ow25◦ C) (c) decoction (DECw) of *Anogeissus leiocarpus.* 2) Vescalin, 3) Castalin, 13) Vescalagin, 17) Castalagin, 32) Ellagic acid, 37) Dimethyl-ellagic acid pentoside isomer 3, 39) Dehydrated tergallic acid C-glucoside isomer1.

Table 27 : a). Phenolic Compounds b). Triterpenoids and Saponins Detected in Stem Bark of *Anogeissus leicarpus* DC and Tentatively Identified by their MS Spectra According to the Literature

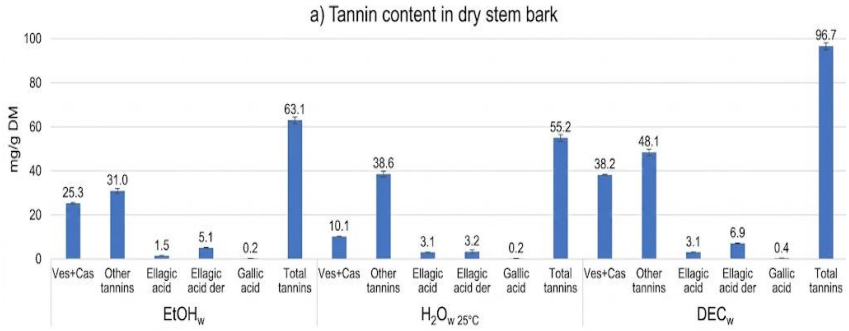
a) Phenolic Compounds

a) Phenolic compounds

N°	Rt (min)	Compound	[M−H]⁻	[2 M−H]⁻	[M−2H]²⁻	Fragment ions	References
1	1.1	Quinic acid	191	383		–	Orlando et al., 2019
2	1.2	Vescalin	631			481, 331, 301	Comandini et al. 2014
3	1.3	Castalin	631	1263		481, 331, 301	Comandini et al. 2014
4	1.7	HHDP-glucose	481			331	Campo et al., 2016; **Orlando et al., 2019
5	1.9	Monogalloyl-glucose	331			313, 271, 169	Campo et al., 2016; **Orlando et al., 2019
6	2.1	Gallic acid §	169			–	
7	2.3	Pedunculagin	783			481, 301, 169	Campo et al. 2016; Rauha et al. 2001
8	2.3	Roburin B	1981		990	1065, 781, 532, 331, 169	Campo et al. 2016; Rasines-Perea et al. 2019; Sanz et al. 2010
9	2.5	Roburin A/D	1849		924	1065, 990, 924, 915, 616, 301	Rasines-Perea et al. 2019; Sanz et al. 2010
10	2.7	Roburin E	1065		532	990, 924, 781, 301	Rasines-Perea et al. 2019; Sanz et al. 2010
11	3.1	Roburin E isomer 1	1065		532	924, 633, 301	Rasines-Perea et al. 2019; Sanz et al. 2010
12	3.4	Roburin E isomer 2	1065		532	924, 615, 301	Rasines-Perea et al. 2019; Sanz et al. 2010
13	3.7	Vescalagin	933	1867	466	915, 615, 301	Comandini et al. 2014
14	4.1	β-1-*O*-ethylvescalagin	961		480	933, 924, 915, 466, 313, 301	Rasines-Perea et al. 2019
15	4.2	Roburin E or Grandinin	1065		532	925, 717, 466, 301	Comandini et al. 2014
16	5.0	Roburin E or Grandinin	1065		532	466, 301	Rasines-Perea et al. 2019
17	5.8	Castalagin	933	1867	466	301	Comandini et al. 2014
18	6.9	Castalagin isomer	933		466		Comandini et al. 2014; Sanz et al. 2010
19	7.9	Methyl-β-1-*O*-ethylvescalagin	975		487	610, 541, 301	
19a	7.9	Castalagin isomer 1	933		466	610, 541, 301	
19b	7.9	Castalagin isomer 2	905		452	610, 541, 301	
20	8.8	Guajavin B or Eugenigrandinin A	1221		610	915, 457	Reis et al. 2019
21	11.1	Acutissimin	1205		602	915, 457	Rasines-Perea et al. 2019; Reis et al. 2019; Sanz et al. 2010
22	11.6	Punicalagin isomer	1083		541		** Orlando et al., 2019
23	13.1	Di-HHDP-galloyl-glucose, or casuarictin/potentillin	935		467	527, 301	Fernandes et al. 2011; Fracassetti et al. 2013; Teixeira et al. 2015
24	14.4	(casuarictin / potentillin)	935		467	301	Fernandes et al. 2011; Fracassetti et al. 2013; Teixeira et al. 2015
25	15.3	trigalloyl glucose (kurigalin) isomer 1	635			557, 443	Comandini et al. 2014; Fernandes et al. 2011; Sanz et al. 2010
26	18.7	trigalloyl glucose (kurigalin) isomer 2	635			557, 443	Comandini et al. 2014; Fernandes et al. 2011; Sanz et al. 2010
27	19.6	Ellagic acid-hexoside	463			331, 301	
28	22.4	Punicalagin §	1083		541	917, 611, 313	** Orlando et al., 2019
29	23.1	Eucaglobulin	497			313	Boulekbache-Makhlouf et al. 2010
30	25.3	Tellimagrandin I	785		392	633, 301	** Orlando et al., 2019
31	25.4	Ellagic acid pentoside	433			301	Fernandes et al., 2011; ** Orlando et al., 2019
32	26.6	Ellagic acid §	301				
33	28.3	3,3′-*O*-dimethyl ellagic acid 4-*O*-β-glucopyranoside	491			447, 301, 249	** Orlando et al., 2019
34	29.0	Ellagic acid-dihexoside	625			491, 301	Lantzouraki et al. 2015
35	29.7	Di-methyl-ellagic acid pentoside isomer 1	461			301	** Orlando et al., 2019; Enass Y.A. Salih et al. 2017
36	30.2	Di-methyl-ellagic acid pentoside isomer 2	461			301	** Orlando et al., 2019; Enass Y.A. Salih et al. 2017
37	31.7	Di-methyl-ellagic acid pentoside isomer 3	461	923		301	** Orlando et al., 2019; Enass Y.A. Salih et al. 2017
38	32.8	Di-methyl-ellagic acid pentoside isomer 4	461			301	
39	36.1	Dehydrated tergallic acid C-glucoside isomer 1	613	1227		329	Enass Y.A. Salih et al. 2017
40	37.1	Dehydrated tergallic acid C-glucoside isomer 2	613	1227		329	Enass Y.A. Salih et al. 2017
41	39.5	3,3′,4-Tri-*O*-methylflavellagic acid	359			329, 314, 301	** Orlando et al., 2019

b) Triterpenoids and saponins

n°	Rt (min)	Compound	$[M-H]^-$	$[2M-H]^-$	$[M-2H]^{2-}$	Fragment ions	References
1T	19.3	Olean-type derivative 1	469	939		425 (-CO_2)	Enass Y.A. Salih et al. 2017
2T	28.7	Olean-type derivative 2	491			477 (-CO_2)	Enass Y.A. Salih et al. 2017
3T	31.3	Olean-type derivative 3	491			477(-CO_2)	Enass Y.A. Salih et al. 2017
4T	31.9	Hydroxylated-trachelosperogenin hexoside	681+HCOOH[a]			519 (-hexoside)	
5T	34.2	Trachelosperogenin hexoside	697			679 (-H_2O), 519 (-O-hexoside)	
6T	34.5		665+ HCOOH[a]			503 (-hexoside)	
		Arjungenin or sericic acid glycoside der1					Gouveia-Figueira and Castilho 2015; Rosaceae et al. 2021
7T	34.8	Olean-type derivative 4	469	939		425 (-CO_2)	Enass Y.A. Salih et al. 2017
8T	35.1	Sericoside	665			503 (-glu)	Chaabi et al. 2008; Hamzaoui et al. 2013
9T	35.2	Arjungenin or sericic acid glycoside der 2	1169			711, 665, 503	
10T	35.3	Trachelosperoside E1	681			503 (-O-hexoside)	Chaabi et al. 2008
11T	38.5	Trachelosperogenin glycoside der 1	681			519 (-hexoside)	
12T	38.7	Trachelosperogenin	519	1039		503 (-H_2O)	Chaabi et al. 2008; Hamzaoui et al. 2013
13T	38.8	Olean-type derivative 5	469	939		425 (-CO_2)	Enass Y.A. Salih et al. 2017
14T	39.2	Arjungenin or sericic acid	503	1007		473 (-CH_2OH)	Chaabi et al. 2008; Hamzaoui et al. 2013
15T	39.6	Arjungenin or sericic acid der 1	503			485 (-H_2O), 359	Chaabi et al. 2008; Hamzaoui et al. 2013
16T	39.8	Arjungenin or sericic acid der 2	503	1007		485 (-H_2O), 359	Chaabi et al. 2008; Hamzaoui et al. 2013



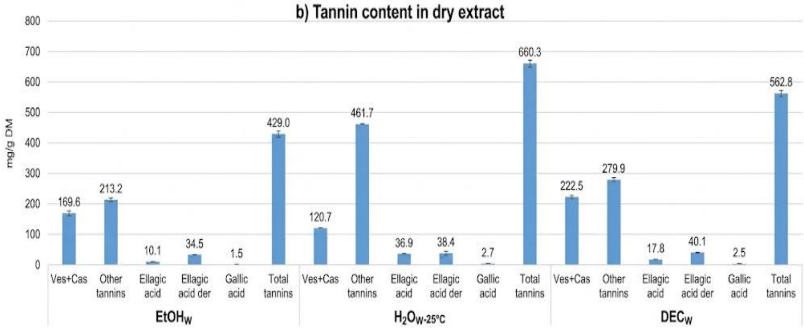


Figure 31. Tannin content in ethanol and water extracts of AL stem bark; the data (a mean of triplicate) are expressed as mg/g on: a) dry stem bark (DM) and b) dry extracts (DE).

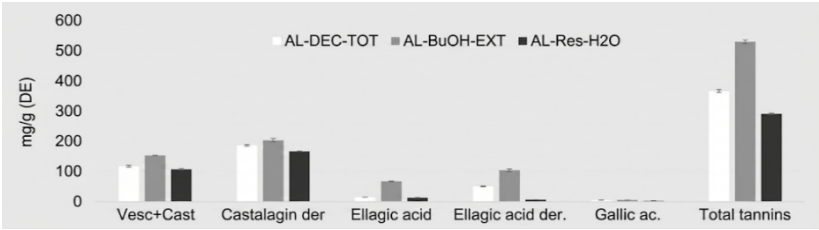


Figure 34: Distribution of the different classes of phenolic compounds in the extracts from A. leiocarpus stem bark and its fractionated products; the data (mean of triplicates) are expressed as mg/g on dry stem bark dry extracts (DE). AL-DEC-Tot, decoction of Anogeissus leiocarpus; Al-BuOH-EXT, fraction extracted from decoction through fractionation process and its correlated aqueous residue, Al-RES H_20

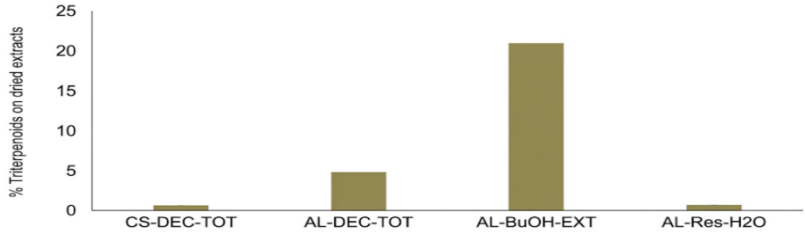


Figure 32: Triterpenoid amounts in the four extracts evaluated by 1 H-NMR; data are expressed as % on the dry extract (DE); the values are a mean of triplicates.

IDENTIFICATION OF TROPICAL FOODS AS FUNCTIONAL FOODS AND NUTRACEUTICALS

Liver health and oxidative stress management are critical areas where plant-derived foods and beverages show promise. Madam Vice Chancellor, we use animal models and biochemical assays (ALT, AST, total protein, MDA**)** alongside HPLC-DAD/MS profiling, studies to evaluate hepatoprotective and antioxidant potentials of tropical vegetables, teas, and functional beverages. Ethanolic extracts of selected vegetables significantly reduced CCl_4-induced liver damage in rats, lowering ALT, AST, protein, and lipid peroxidation levels. Functional beverages from acha–tigernut blends exhibited notable radical scavenging activity (DPPH, ABTS, FRAP), measurable phenolic and flavonoid content, and favorable sensory qualities, supporting their role in food security. Collectively, these findings confirm that tropical vegetables, and grain–nut beverages are rich in bioactive compounds with hepatoprotective and antioxidant benefits, reinforcing their potential as functional foods for health promotion (**Salawu** & Akindahunsi, 2007; **Salawu** *et al*., 2019; Badejo, 2017).

Table 28 : Effect of Some Selected Vegetable Extracts At 250 mg/kg of Body Weight On Serum ALT and AST Activities and Total Protein Content in CCl_4-Intoxicated Rats

Group	Treatment	ALT (IU/L)	AST (IU/L)	Total protein (g/L)
1	Control + corn oil	13.12 ± 1.20	27.21 ± 2.10	70.00 ± 1.90
2	Corn oil + CCl4	40.60 ± 3.50	80.60 ± 5.10	73.20 ± 1.87
3	CCl4 + corn oil + *T. occidentalis*	14.00 ± 1.33	29.00 ± 2.70	62.10 ± 2.40
4	CCl4 + corn oil + *M. utilissima*	12.00 ± 0.90	36.10 ± 3.00	66.00 ± 2.00
5	CCl4 + corn oil + *S. sparejanophora*	13.12 ± 1.02	48.00 ± 2.10	65.00 ± 1.30
6	CCl4 + corn oil + *O. graticimum*	14.00 ± 1.70	36.10 ± 1.50	63.00 ± 2.00

Group	Treatment	ALT (IU/L)	AST (IU/L)	Total protein (g/L)
7	CCl4 + corn oil + *S. macrocarpon*	11.21 ± 1.90	36.00 ± 2.50	65.00 ± 1.50
8	CCl4 + corn oil + *C. olitorius*	16.22 ± 1.00	34.11 ± 3.00	64.00 ± 2.00
9	CCl4 + corn oil + *A. caudatus*	14.00 ± 1.40	33.00 ± 3.30	70.13 ± 3.00

Data are mean SD values (n 5).

Table 29: Effect of Some Selected Vegetable Extracts At 500 mg /kg of Body Weight on Serum ALT and AST Activities and Total Protein Content in CCl4 -Intoxicated Rats

Group	Treatment	ALT (IU/L)	AST (IU/L)	Total protein (g/L)
1	Control + corn oil	13.12 ± 1.20	27.21 ± 2.10	70.00 ± 1.90
2	Corn oil + CCl4	40.60 ± 3.50	80.60 ± 5.10	73.20 ± 1.87
10	CCl4 + corn oil + *T. occidentalis*	18.00 ± 1.06	52.00 ± 3.5	71.00 ± 3.10
11	CCl4 + corn oil + *M. utilissima*	14.00 ± 1.00	41.00 ± 1.50	70.00 ± 2.80
12	CCl4 + corn oil + *S. sparejanophora*	16.00 ± 1.50	59.00 ± 2.20	69.00 ± 2.30
13	CCl4 + corn oil + *O. graticimum*	17.00 ± 1.30	44.00 ± 2.30	68.00 ± 2.40
14	CCl4 + corn oil + *S. macrocarpon*	13.00 ± 1.20	52.00 ± 2.60	72.00 ± 2.10
15	CCl4 + corn oil + *C. olitorius*	21.00 ± 1.30	47.00 ± 1.50	73.00 ± 1.90
16	CCl4 + corn oil + *A. caudatus*	19.00 ± 1.00	40.00 ± 2.5	74.00 ± 3.10

Data are mean SD values (*n* 5).

Table 30:. Effect of Some Selected Vegetable Extracts At 250 mg /kg of Body Weight on Liver Homogenate ALT and AST Activities and Total Protein Content in CCl_4 -Intoxicated Rats

Group	Treatment	ALT (IU/L)	AST (IU/L)	Total protein (g/L)
1	Control + corn oil	900.00 ± 3.16	1,270.00 ± 10.05	150.00 ± 2.70
2	Corn oil + CCl4	1,300.00 ± 7.38	1,660.00 ± 13.69	250.00 ± 7.51
3	CCl4 + corn oil + *T. occidentalis*	940.00 ± 3.26	1,150.00 ± 5.57	175.00 ± 4.30

Group	Treatment	ALT (IU/L)	AST (IU/L)	Total protein (g/L)
4	CCl4 + corn oil + *M. utilissima*	960.00 ± 5.03	1,270.00 ± 9.38	180.00 ± 2.00
5	CCl4 + corn oil + *S. sparejanophora*	1,020.00 ± 4.25	1,440.00 ± 5.51	150.00 ± 3.12
6	CCl4 + corn oil + *O. graticimum*	980.00 ± 4.40	1,270.00 ± 4.95	185.00 ± 3.00
7	CCl4 + corn oil + *S. macrocarpon*	960.00 ± 2.29	1,530.00 ± 4.99	185.00 ± 4.15
8	CCl4 + corn oil + *C. olitorius*	900.00 ± 3.05	1,400.00 ± 6.95	170.00 ± 3.85
9	CCl4 + corn oil + *A. caudatus*	954.00 ± 3.72	1,150.00 ± 9.50	165.00 ± 3.39

Data are mean SD values (*n* 5).

Table 31. Effect of Some Selected Vegetable Extracts At 500mg /kg of Body Weight on Liver Homogenate ALT and AST Activities and Total Protein Content in CCl_4 -Intoxicated Rats

Group	Treatment	ALT (IU/L)	AST (IU/L)	Total protein (g/L)
1	Control + corn oil	900.00 ± 3.16	1,270.00 ± 10.05	150.00 ± 2.70
2	Corn oil + CCl4	1,300.00 ± 7.38	1,660.00 ± 13.39	250.00 ± 7.51
10	CCl4 + corn oil + *T. occidentalis*	1,020.00 ± 7.50	1,530.00 ± 8.50	190.00 ± 6.70
11	CCl4 + corn oil + *M. utilissima*	1,025.00 ± 7.40	1,500.00 ± 12.03	195.00 ± 3.58
12	CCl4 + corn oil + *S. sparejanophora*	1,100.00 ± 6.39	1,660.00 ± 8.69	165.00 ± 5.50
13	CCl4 + corn oil + *O. graticimum*	1,100.00 ± 6.81	1,670.00 ± 7.99	210.00 ± 4.41
14	CCl4 + corn oil + *S. macrocarpon*	1,040.00 ± 3.20	1,660.00 ± 5.76	190.00 ± 6.82
15	CCl4 + corn oil + *C. olitorius*	900.00 ± 3.05	1,400.00 ± 6.95	170.00 ± 3.85
16	CCl4 + corn oil + *A. caudatus*	1,030.00 ± 8.80	1,440.00 ± 11.38	200.00 ± 4.59

Data are mean SD values (*n* 5).

Table 32: Effect of Some Selected Vegetable Extracts on Lipid Peroxide Content

Group	Treatment	MDA 250 mg/kg body weight	MDA 500 mg/kg body weight
1	Control + corn oil	45.00 ± 0.07	45.00 ± 0.07
2	Corn oil + CCl4	82.00 ± 0.02	82.00 ± 0.07
3 and 10	CCl4 + corn oil + *T. occidentalis*	46.00 ± 0.08	52.00 ± 0.06
4 and 11	CCl4 + corn oil + *M. utilissima*	44.00 ± 0.03	47.00 ± 0.07
5 and 12	CCl4 + corn oil + *S. sparejanophora*	50.00 ± 0.01	53.00 ± 0.09
6 and 13	CCl4 + corn oil + *O. graticimum*	45.00 ± 0.07	60.00 ± 0.10
7 and 14	CCl4 + corn oil + *S. macrocarpon*	52.00 ± 0.06	52.00 ± 0.06
8 and 15	CCl4 + corn oil + *C. olitorius*	49.00 ± 0.08	56.00 ± 0.06
9 and 16	CCl4 + corn oil + *A. caudatus*	47.00 ± 0.03	51.00 ± 0.08

Data are mean SD values (n=5)

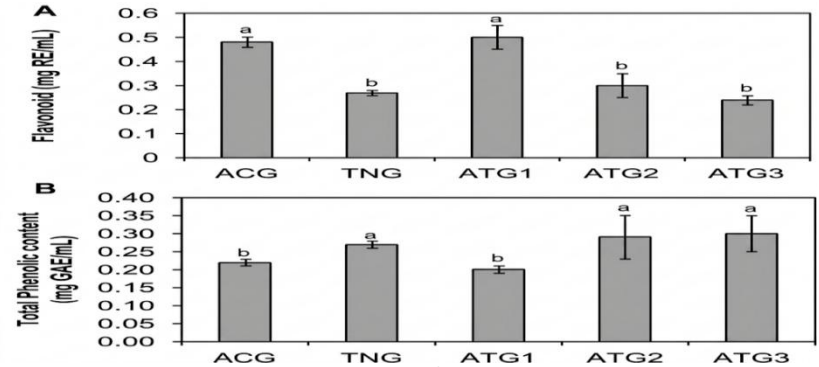


Figure 33): Flavonoids and phenolic contents of acha–tigernut–ginger beverages. Values are mean±SEM (n=3). *Bars with the same alphabets* are not significantly different (P<0.05). ACH, 100% malted acha+ginger extracts; TNG, 100% tigernut+ginger extracts; ATG1, 75% malted acha+25% tigernut+ginger extracts; ATG2, 50% malted acha+50% tigernut+ginger extracts; ATG3, 25% malted acha+75% tigernut+ginger extracts

Table 33): Antioxidant activities of acha–tigernut–ginger beverages

Samples	DPPH (%)	ABTS (µmol TE/mL)	FRAP (µg VitC E/mL)
ACG	20.72 ± 0.13^{d}	10.27 ± 0.13^{b}	0.91 ± 0.04^{b}
TNG	32.53 ± 1.27^{a}	14.06 ± 0.09^{a}	1.66 ± 0.09^{a}
ATG1	23.30 ± 0.95^{c}	10.35 ± 0.05^{b}	0.91 ± 0.07^{b}
ATG2	30.33 ± 2.16^{b}	5.49 ± 0.09^{c}	0.43 ± 0.05^{c}
ATG3	34.91 ± 3.15^{a}	5.13 ± 0.06^{d}	0.21 ± 0.08^{d}

Values are mean±SEM (n=3). Values with the same superscript within a column are not significantly different (P<0.05). ACH, 100% malted acha+ginger extracts; TNG, 100% tigernut+ginger extracts; ATG1, 75% malted acha+25% tigernut+ginger extracts; ATG2, 50% malted acha+50% tigernut+ginger extracts; ATG3, 25% malted acha+75% tigernut+ginger extracts. TE, Trolox equivalent; VitC E, vitamin C equivalent

Table 34: Sensory Evaluation of Acha–Tigernut–Ginger Beverages

Sample	Flavour	Taste	Appearance	Mouthfeel	Overall acceptability
ACG	4.07 ± 0.57^{d}	3.67 ± 0.45^{d}	3.87 ± 0.49^{e}	4.20 ± 0.50^{f}	3.73 ± 0.55^{d}
TNG	4.67 ± 0.45^{cd}	7.47 ± 0.49^{a}	5.33 ± 0.41^{d}	5.07 ± 0.21^{d}	5.40 ± 0.38^{c}
ATG1	5.00 ± 0.49^{c}	5.60 ± 0.55^{c}	6.20 ± 0.40^{c}	5.87 ± 0.38^{c}	6.07 ± 0.24^{b}
ATG2	6.27 ± 0.55^{b}	6.67 ± 0.37^{b}	7.13 ± 0.36^{b}	6.80 ± 0.28^{b}	7.00 ± 0.53^{a}
ATG3	7.33 ± 0.40^{a}	6.70 ± 0.11^{b}	7.80 ± 0.30^{a}	7.33 ± 0.21^{a}	7.47 ± 0.43^{a}

Values are Mean±SEM (n=3). Values with the same superscript within a column are not significantly different (P<0.05). ACH, 100% malted acha+ginger extracts; TNG, 100% tigernut+ginger extracts; ATG1, 75% malted acha+25% tigernut+ginger extracts; ATG2, 50% malted acha+50% tigernut+ginger extracts; ATG3, 25% malted acha+75% tigernut+ginger extracts

EVALUATION OF TROPICAL PLANTS IN THE MANAGEMENT OF DEPRESSION & ANXIETY

Mental health disorders, particularly anxiety and depression, are escalating globally due to diverse stressors that activate the autonomic nervous system, HPA axis, and neuroendocrine pathways, leading to biomarkers such as cortisol, catecholamines, and cytokines. Research highlights the role of stress-related psycho-physiological changes and the need to link them with diagnostic biomarkers for improved management.

Studies in Nigeria reveal high prevalence of psycho-social stress among workers and teachers, while global data show hundreds of millions affected by depression and anxiety, with suicide and substance use adding to the burden. Investigations into biological stress pathways, molecular cues, and epigenetic dynamics emphasize the importance of interdisciplinary approaches for early intervention, personalized therapies, and reducing the global impact of mental illness. Collectively, these findings as reported together with my research collaborators, underscore the urgent need to integrate biomarker research with sociocultural insights to advance mental health care (Akinduko, *et al*., 2025; WHO, 2011; Chen *et al*., 2011; Onigbogi & Banerjee, 2019; Asa & Lasebikan, 2016; WHO, 2017; WHO, 2020; WHO, 2022).

Natural products are increasingly explored for managing neuro-psychiatric disorders linked to oxidative stress, neurotransmitter imbalance, and chronic stress. Using ethanolic extracts, *in vitro* assays (cholinesterase inhibition, lipid peroxidation), *in vivo* rat models (anxiety, depression, stress), and computational approaches (network pharmacology, docking, molecular dynamics). Madam Vice Chancellor, we evaluated *Ficus capensis* and *Parquetina nigrescens*. *Ficus capensis* exhibited a rich neuroactive phytochemical profile, with luteolin emerging as a potent multi-target lead, showing strong cholinesterase and HDAC1 inhibition supported by docking and MD simulations. *Parquetina nigrescens* demonstrated antidepressant, and anxiolytic effects in PTZ-induced rats, correcting oxidative and neurochemical dysfunctions. Both *Parquetina nigrescens* and *Ficus capensi* extracts reversed behavioral, oxidative, and neurochemical abnormalities in chronic forced swim stress models, restoring antioxidant status and neurotransmitter balance. Collectively, these findings as reported together with my research collaborators, highlight tropical plants as promising sources of bioactive compounds with neuroprotective,

antidepressant, anxiolytic, and anti-stress potential, supporting their development as adjunct therapies for mental health management (Akinduko, *et al*., 2024; Akinduko, *et al*., 2025; Akinduko, *et al*., 2026; Akingbesote & **Salawu**, 2023; Akingbesote, *et al***.,** 2024).

Table 35: Phenolic compositions of *Parquetina nigrescens* and *Ficus capensis*

S/N	Compound	P. nigrescens (mg/g)	F. capensis (mg/g)
1	Coumarin	0.001 ± 0.000[a]	0.008 ± 0.000[a]
2	Catechin	0.386 ± 0.015[a]	7012.239 ± 22.206[b]
3	Gentisic Acid	0.001 ± 0.000[a]	0.019 ± 0.001[b]
4	Protocatechuic Acid	0.002 ± 0.000[a]	3734.863 ± 6.607[b]
5	p-coumaric Acid	0.070 ± 0.001[a]	8624.083 ± 8.002[b]
6	Epicatechin	0.315 ± 0.009[a]	2244.535 ± 0.958[b]
7	Vanillic Acid	0.061 ± 0.001[b]	0.027 ± 0.002[a]
8	O-coumaric Acid	0.086 ± 0.037[a]	0.092 ± 0.006[a]
9	Eugenol	0.013 ± 0.001[b]	0.004 ± 0.000[a]
10	Isoeugenol	0.005 ± 0.001[a]	0.003 ± 0.000[a]
11	Gallic Acid	770.246 ± 0.753[a]	3115.749 ± 2.131[b]
12	Caffeic Acid	0.685 ± 0.012[a]	9707.739 ± 4.046[b]
13	p-hydroxybenzoic Acid	1282.483 ± 1.357[b]	178.037 ± 2.167[a]
14	Ferulic Acid	0.032 ± 0.002[b]	0.011 ± 0.002[a]
15	Syringic Acid	0.002 ± 0.000[a]	0.029 ± 0.001[b]
16	Piperic Acid	0.001 ± 0.000[a]	0.003 ± 0.000[b]
17	Sinapinic Acid	0.001 ± 0.000[a]	0.002 ± 0.000[a]
18	Daidzein	7.04E-05 ± 0.000[a]	0.001 ± 0.000[b]
19	Coumestrol	0.000 ± 0.000[a]	0.004 ± 0.000[b]
20	Apigenin	0.171 ± 0.002[a]	0.495 ± 0.013[b]
21	Naringenin	0.068 ± 0.001[b]	0.018 ± 0.002[a]
22	Glycitein	0.007 ± 0.001[b]	0.001 ± 0.000[a]
23	Naringenin Chalcone	0.035 ± 0.002[b]	0.018 ± 0.001[a]
24	Genistein	0.002 ± 0.000[a]	0.004 ± 0.000[a]

S/N	Compound	P. nigrescens (mg/g)	F. capensis (mg/g)
25	Shogaol	0.006 ± 0.000[a]	0.007 ± 0.000[a]
26	Kaempferol	31.049 ± 0.635[b]	12.625 ± 0.807[a]
27	Capsaicin	0.004 ± 0.000[a]	0.002 ± 0.000[a]
28	Luteolin	76.927 ± 0.471[b]	16.750 ± 0.395[a]
29	Epigallocatechin	2.299 ± 0.025[a]	1.895 ± 0.158[a]
30	Isoquercitrin	8254.043 ± 2.132[b]	0.002 ± 0.000[a]
31	Ellagic Acid	0.306 ± 0.018[a]	1.758 ± 0.115[b]
32	Quercetin	1474.493 ± 2.029[a]	8777.065 ± 0.588[b]
33	Isorhamnetin	5.668 ± 0.561[b]	0.008 ± 0.001[a]
34	Myricetin	3.492 ± 0.247[b]	0.007 ± 0.000[a]
35	Chlorogenic Acid	208.56 ± 5.283[a]	248.162 ± 1.934[b]
36	3-O-caffeoylquinic	1.89E-05 ± 0.000[a]	8.79E-07 ± 0.000[a]
37	Rosmarinic Acid	0.001 ± 0.000[a]	0.001 ± 0.000[a]
38	Curcumin	9.36E-05 ± 0.000[a]	0.000422 ± 0.000[b]
39	Rutin	9410.992 ± 9.889[a]	16,162.01 ± 0.000[b]
40	4-O-methl-epi-gallo-catechin	0.000345 ± 0.000[a]	0.006 ± 0.000[b]
41	Phenyl-6'-O-malonyl-beta-D-glucoside	0.002 ± 0.000[a]	0.011 ± 0.002[b]
42	Epi-gallocatechin-3-O-gallate	0.109 ± 0.025[a]	0.601 ± 0.012[b]

Values are mean ± standard deviation (triplicates). Values with different letter (in superscript), across the row, are significantly different at P<0.05

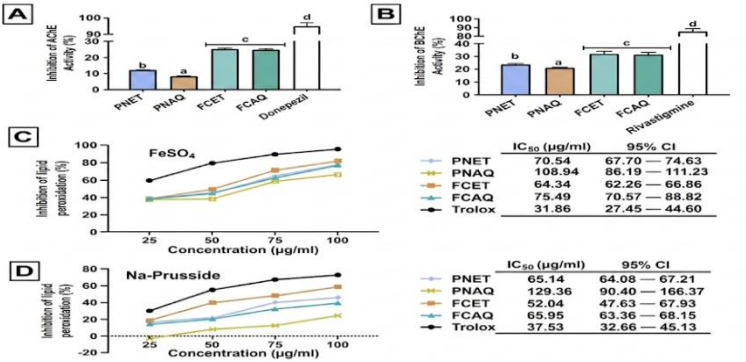


Figure 34: *In vitro* biological activity of *Parquetina nigrescens* and *Ficus Capensis* leaf extracts. Inhibitory effect of extracts against (A) Acetylcholinesterase (AChE) and B). Butyrylcholinesterase (BChE), as well as cerebral lipid peroxidation induced by C). Iron (II) Sulphate (FeSO4) and D). Sodium (Na) nitroprusside. Data are expressed as mean ± standard deviation (triplicate). IC50 values were computed from nonlinear

Table 36: Impact of Extracts On Behavioral Metrics Of Rats In The Open Field Test

Treatment Group	Ambulation	Rearing	Center crossing
CONTROL	58.40 ± 3.06	15.20 ± 3.11	7.00 ± 1.73
STRESSED	43.00 ± 7.07^{c}	12.00 ± 2.65	3.67 ± 1.53^{b}
ETEPN+ STRESSED	62.80 ± 2.89^{z}	16.00 ± 0.71	7.33 ± 1.58^{y}
ETEFC+ STRESSED	71.60 ± 5.12^{z}	16.75 ± 2.22^{w}	8.25 ± 0.96^{z}
IMIPRAMINE+ STRESSED	67.33 ± 5.00^{z}	17.00 ± 2.53^{w}	6.00 ± 0.89

Results are presented as the means ± SDs (n=6). cp<0.001, bp<0.01 vs. CONTROL. zp<0.0001, yp<0.001, wp<0.05 vs. STRESSED. Abbreviations: CONTROL: naive rats; STRESSED: 7 days of forced swim stress for 1 h (FSS); ETEPN+STRESSED: FSS with 250 mg/kg *Parquetina nigrescens* leaf extract 1 h before stress; ETEFC+STRESSED: FSS with 250 mg/kg *Ficus capensis* leaf extract 1 h before stress; IMIPRAMINE+STRESSED: FSS with 30mg/kg imipramine 1 h before stress.

Table 37: Impact of Extracts On Behavioral Metrics Of Rats In The Elevated Plus Maze Test

Treatment Group	TE	OAE (%)	CAE (%)	OAT (%)	CAT (%)
CONTROL	8.75 ± 1.71	35.73 ± 2.15	64.27 ± 2.15	27.30 ± 4.15	72.70 ± 4.15
STRESSED	5.67 ± 1.53	23.19 ± 2.96^{d}	76.81 ± 2.96^{d}	4.79 ± 4.14^{d}	95.22 ± 4.14^{d}
ETEPN + STRESSED	9.00 ± 2.24^{w}	34.33 ± 3.20^{z}	64.28 ± 5.55^{z}	13.79 ± 0.70^{w}	86.31 ± 0.70^{x}
ETEFC + STRESSED	12.20 ± 2.39^{z}	35.35 ± 2.65^{z}	64.65 ± 2.65^{z}	14.96 ± 1.32^{y}	85.05 ± 1.32^{y}
IMIPRAMINE + STRESSED	9.00 ± 1.22^{w}	42.96 ± 2.57^{z}	57.04 ± 2.57^{z}	28.05 ± 5.18^{z}	71.95 ± 5.18^{z}

Results are presented as the means ± SDs (n=6). dp<0.0001 vs. CONTROL. p<0.0001, yp<0.001, xp<0.01, wp<0.05 vs. STRESSED. Abbreviations: CONTROL: naive rats; STRESSED: 7 days of forced swim stress for 1 h (FSS); ETEPN+STRESSED: FSS with 250 mg/kg *Parquetina nigrescens* leaf extract 1 h before stress; ETEFC+STRESSED: FSS with 250 mg/kg *Ficus capensis* leaf extract 1h before stress; IMIPRAMINE+STRESSED: FSS with 30 mg/kg imipramine 1 h before stress; TE: total number of entries into open and closed arms; %OAE: percentage of open arm entries; %CAE: percentage of closed arm

entries; %OAT: percentage of time spent in open arms; %CAT: percentage of time spent in closed arms.

Table 38: Impact Of Extracts On Behavioral Metrics of Rats In The Forced Swim Test

Treatment Group	Time immobile (%)	Latency to immobility (s)
CONTROL	69.72 ± 1.95	43.40 ± 5.77
STRESSED	81.56 ± 3.24^{d}	29.00 ± 4.36^{a}
ETEPN + STRESSED	56.17 ± 1.19^{z}	58.75 ± 7.62^{z}
ETEFC + STRESSED	51.61 ± 5.19^{z}	97.50 ± 10.61^{z}
IMIPRAMINE STRESSED	38.58 ± 4.24^{z}	119.00 ± 7.07^{z}

Results are presented as the means ± SDs (n=6). dp<0.0001, ap<0.05 vs. CONTROL. zp<0.0001 vs. STRESSED. Abbreviations: CONTROL: naive rats; STRESSED: 7 days of forced swim stress for 1 h (FSS); ETEPN+STRESSED: FSS with 250 mg/kg *Parquetina nigrescens* leaf extract 1 h before stress; ETEFC+STRESSED: FSS with 250 mg/kg *Ficus capensis* leaf extract 1 h before stress; IMIPRAMINE+STRESSED: FSS with 30 mg/kg imipramine 1 h before stress.

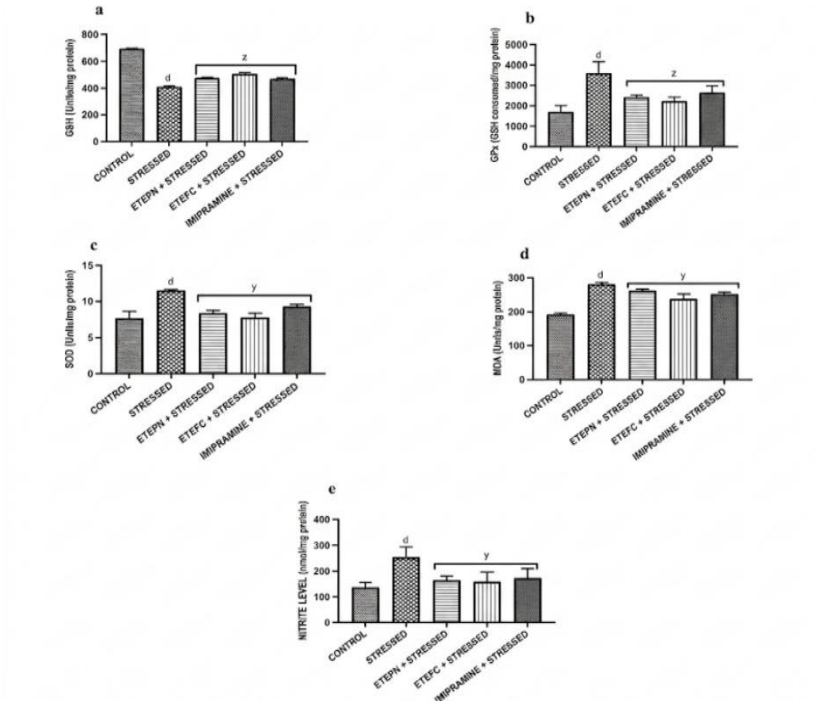


Figure 41: Effects of Parquetina nigrescens and Ficus capensis on the following antioxidant parameters in the cerebral homogenates of rats: (a) GSH level, (b) GPx activity, (c) SOD activity, (d) MDA level, and (e) nitrite level. The results are presented as the means ± SDs (n=6). dp<0.0001 vs. CONTROL. p<0.0001, yp<0.001, xp<0.01, wp<0.05 vs. STRESSED. Abbreviations: CONTROL: naive rats; STRESSED: 7 days of forced swim stress for 1 h (FSS); ETEPN+STRESSED: FSS with 250 mg/kg Parquetina nigrescens leaf extract 1 h before stress; ETEFC+STRESSED: FSS with 250 mg/kg Ficus capensis leaf extract 1 h before stress; IMIPRAMINE+STRESSED: FSS with 30 mg/kg imipramine 1 h before stress.

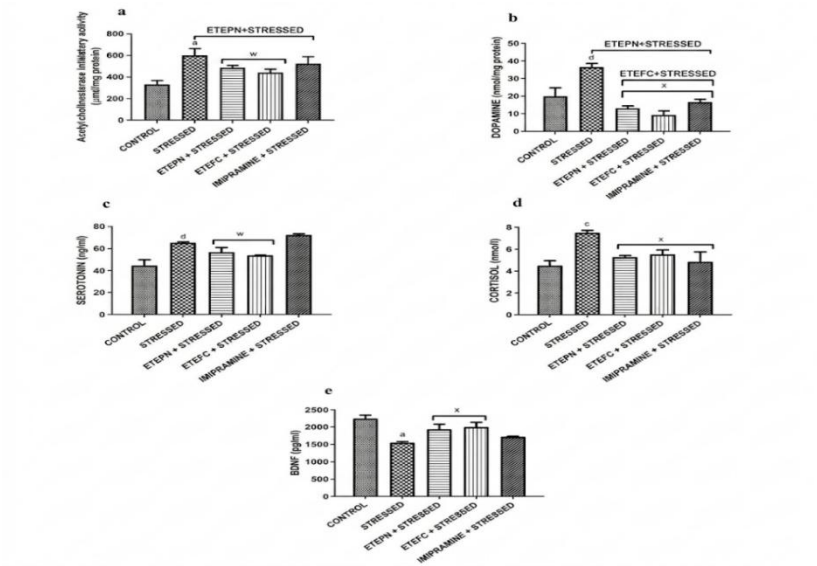


Figure 35: Effects of Parquetina nigrescens and Ficus capensis on the following neurological parameters of rats: (a) acetylcholinesterase activity, (b) dopamine level, (c) serotonin level, (d) cortisol level, and (e) brain-derived neurotrophic factor (BDNF) level. The results are presented as the means ± SDs (n=6). dp<0.0001, cp<0.001 vs. CONTROL. zp<0.0001, x p<0.01, wp<0.05 vs. STRESSED. Abbreviations: CONTROL: naive rats; STRESSED: 7 days of forced swim stress for 1 h (FSS); ETEPN+STRESSED: FSS with 250 mg/kg Parquetina nigrescens leaf extract 1 h before stress; ETEFC+STRESSED: FSS with 250 mg/kg Ficus capensis leaf extract 1 h before stress; IMIPRAMINE+STRESSED: FSS with 30 mg/kg imipramine 1 h before stress.

CONCLUSION

Nigerian vegetables, cereals, legumes, spices, and medicinal plants have been systematically shown to possess rich

antioxidant, anti-inflammatory, and neuroprotective properties. This elevates traditional dietary practices into scientifically recognized strategies for disease prevention and management. By emphasizing simulated gastrointestinal digestion over solvent extraction, the lecture highlights a paradigm shift in evaluating nutraceuticals. This ensures that functional food research reflects real human absorption and utilization, not just laboratory potential. The characterization of phenolic compounds across tropical crops demonstrates their stability, abundance, and therapeutic relevance. This expands the global database of bio-active molecules and positions African foods as reservoirs of functional nutrition. Beyond physical disease prevention, the lecture underscores how nutraceuticals influence emotional resilience and mental health. Findings on medicinal plants reveal their antidepressant, anxiolytic, and hepatoprotective potentials, offering holistic solutions to modern health challenges. The development of affordable, culturally relevant foods-such as pearl millet–tiger nut biscuits, and acha–tigernut beverages-demonstrates practical pathways for food security, public health improvement, and economic empowerment.

This body of work contributes to knowledge by positioning nutraceuticals and functional foods not merely as dietary supplements, but as nature's holistic arsenal against the trilogy of human health challenges-physical, emotional, and mental. It validates indigenous resources, advances scientific methodology, and opens new frontiers for sustainable health interventions.

RECOMMENDATIONS

National development is fundamentally driven by sustained investment in education, particularly tertiary education. Unfortunately, Nigeria's funding for education remains

significantly below international standards. With education spending at approximately **2.14% of GDP in 2026**, Nigeria falls well below the UNESCO benchmark and behind countries such as South Africa (6.7%), Brazil (5.6%), Kenya (4.8%), India (4.1%), and Ghana (3.4%).

This trend poses a serious threat to the nation's future and must be reversed through increased and diversified funding. The government should prioritize education as a strategic investment, drawing lessons from countries such as Brazil and Germany, where access to higher education is heavily subsidized or free. Rather than comparing Nigeria's education system with that of the United States, policymakers should adopt models that better align with Nigeria's developmental needs.
Researchers, lecturers, and students constitute the intellectual backbone of every nation.

However, Nigerian universities and other tertiary institutions have experienced a significant loss of skilled academics due to inadequate funding, poor remuneration, and unfavorable working conditions. This brain drain undermines innovation, research excellence, and global competitiveness. To reverse this trend, the government must increase education funding, improve infrastructure, and implement competitive remuneration and welfare packages that promote productivity, innovation, and academic excellence.

Nigeria's rich biodiversity also presents immense opportunities for improving public health and driving economic growth. Plant foods and medicinal plants are valuable natural resources that should be systematically explored for drug discovery and nutraceutical development. A comprehensive regulatory framework should be established to support the commercial production of safe and effective plant-based medicines.

To maximize these opportunities, I recommend the establishment of a Central Botanical and Drug Research Institutes to coordinate research, innovation, and the development of novel phytomedicines. In addition, a National Nutraceutical Research Centre should be created to strengthen basic and translational research in nutraceuticals, accelerate healthcare innovation, and promote the sustainable utilization of Nigeria's botanical resources.

By making strategic investments in education, research, and scientific innovation, Nigeria can build a knowledge-driven economy, rather than import-dependent and monolithic economy in Nigeria, because this transition will improve healthcare outcomes, geared towards maintaining sound physical, emotional and mental well-being, and to secure sustainable national development.

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Mo mọ̀rẹ́ Oluwa, emi mọ̀rẹ́.
Ọwọ́ mi lókè mo gbé ọ ga, mo mọ̀rẹ́.
Ìjọ lèsè mi, mo gbé ọ ga, mo mọ̀rẹ́."

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