

NUTRITIONAL AND PHYTOCHEMICAL PROFILING OF *Vernonia amygdalina* AND *Dacryodes edulis* LEAVES: IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT GOALS

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ABSTRACT

*This study provides an in-depth analysis of the nutritional composition and phytochemical profile of aqueous extracts from *Vernonia amygdalina* (*V. amygdalina*) and *Dacryodes edulis* (*D. edulis*) leaves. Proximate and mineral analyses, along with phytochemical screening and HPLC quantification, were conducted to evaluate their nutritional and phytochemical constituents. Significant differences ($p < 0.05$) were observed between the two plants in crude protein, ash content, moisture content, nitrogen-free extracts, crude fiber, and crude lipids. Macro and micronutrient compositions also varied, with *V. amygdalina* having higher concentrations of zinc, iron, potassium, sodium, and magnesium, while *D. edulis* had higher levels of copper and chromium. Phytochemical analysis indicated the presence of saponins, flavonoids, tannins, alkaloids, steroids, and phenolic compounds in both plants. HPLC identified various polyphenols, revealing that *V. amygdalina* had significantly higher ($p < 0.05$) concentrations of luteolin, syringic acid, chlorogenic acid, and naringenin, whereas *D. edulis* showed higher levels of quinic acid and arbutin. These findings highlight the nutritional significance and potential health benefits of *V. amygdalina* and *D. edulis* leaves. Additionally, the alignment of these results with the United Nations Sustainable Development Goals (SDGs) emphasizes their role in combating malnutrition and promoting health and well-being. Overall, this research demonstrates the potential of these plants to contribute to global efforts towards sustainable development and improved human health.*

KEYWORDS: *Vernonia amygdalina*, *Dacryodes edulis*, Phytochemicals, HPLC, SDGs

INTRODUCTION

In sustainable development contexts, medicinal plants are highly regarded for their potential to enhance health and support the achievement of SDGs (Singh,

2016). Their diverse contributions across health, economic, and environmental domains make them essential elements of sustainable development plans.

Medicinal plants provide alternate treatment options by utilizing natural resources and traditional knowledge, especially in underserved and rural communities where access to conventional healthcare services may be limited (Pramesti *et al.*, 2024). *V. amygdalina* and *D. edulis* leaves are two examples of medicinal plants that can be harvested and grown sustainably to promote biodiversity and ecosystem services, which are essential for SDG 15. The conservation and sustainable use of these plants preserve traditional knowledge and ensure future natural resource availability (United Nations, 2021).

For generations, African communities have relied on the medicinal properties of *V. amygdalina*, commonly known as bitter leaf in English and referred to as “oriwo” in Edo, “ewuro” in Yoruba, “shikawa” in Hausa, and “olubu” in Igbo (Oboh and Masodje, 2009). Similarly, *Dacryodes edulis*, often called “Ube” in Igbo, “Mzembe” in Tiv, “Eben” in Akwa Ibom and Cross River, African pear, Bush butter tree, Bush fruit tree, and Safoutier in French, holds a significant place in traditional medicine systems and has garnered increasing scientific interest due to its pharmacological potential and relevance to modern health challenges. The utilization of these plants not only enhances healthcare but also aligns with the Sustainable Development Goals (SDGs) of the UN, particularly SDG 3 (Good Health and Well-Being) and SDG 15 (Life on Land).

In Nigeria, malaria remains a critical public health issue caused by *Plasmodium* parasites (Irabor *et al.*, 2023; Pucca *et al.*, 2024). Due to challenges associated with conventional malaria treatments, such as drug resistance and cost, there is growing

interest in herbal remedies (Kumar *et al.*, 2023). In traditional medicine, both the roots and leaves of *V. amygdalina* are employed to address various health conditions like fever, hiccups, kidney ailments, and stomach discomfort (Mishra *et al.*, 2023; Ogwu and Ikhajiagbe, 2024). Furthermore, in several West African countries such as Cameroon, Ghana, and Nigeria, the stem and root of *V. amygdalina* serve as chewing sticks, showcasing its diverse utility in local customs and traditions (Yeap *et al.*, 2010). Extensive research has been conducted on the medicinal properties of *V. amygdalina*, particularly focusing on its potential in malaria and diabetes treatment (Ojmelukwe and Amaechi, 2019; Yeap *et al.*, 2010; Asante and Wiafe, 2023; Akah, 2024). (Mishra *et al.*, 2023; Ogwu and Ikhajiagbe, 2024).

V. amygdalina contains sesquiterpene lactones, which have demonstrated antimalarial properties by inhibiting the growth of *Plasmodium falciparum* (Abay *et al.*, 2015). Additionally, it has been found that the plant's extracts exhibit antidiabetic properties, as evidenced by their ability to lower blood glucose levels and improve antioxidant status in diabetic models (Atangwho *et al.*, 2009).

Known colloquially as African or bush pear, *D. edulis* is an evergreen tree native to western and eastern Africa, where it is primarily consumed as food either on its own or in conjunction with other foods (Erukainure *et al.*, 2017). In traditional medicine, its various parts of *D. edulis* are utilized for treating ailments such as diabetes, malaria, hypertension, labor pain, stunted growth, skin disorders, leprosy, oral and aural conditions, and epilepsy (Ajibesin, 2011; Conrad and Uche, 2013). Studies have demonstrated

the anti-diabetic properties of *D. edulis* fruit (Erukainure *et al.*, 2017, Sanni *et al.*, 2020), as well as the antioxidant benefits of both its leaves and fruits (Conrad and Uche, 2013; Erukainure *et al.*, 2017). Additionally, its antimalarial and antimicrobial properties have been documented (Zofou *et al.*, 2011; Zofou *et al.*, 2013). The fruit is rich in phytochemicals, including terpenoids and flavonoids, known for their anti-inflammatory and antioxidant properties. Research conducted on diabetic animal models has indicated that extracts of *D. edulis* can reduce hyperglycemia and enhance glucose tolerance (Okugbo and Killian, 2022, Erukainure *et al.*, 2020, Ononamadu *et al.*, 2019). This tree species thus, holds significant medicinal value in Nigeria.

In this study, we investigate the nutritional and phytochemical properties of aqueous leaf extracts from *V. amygdalina* and *D. edulis*. Despite their extensive use in traditional medicine and cooking, there is a lack of systematic comparisons regarding their nutritional and bioactive compounds. Such comparisons could shed light on their potential roles in dietary health interventions and sustainable farming practices. Considering also, the global impact of diseases such as diabetes and malaria, there is increasing interest in investigating natural remedies and traditional medicines for their management and treatment. Indigenous plants like *V. amygdalina* and *D. edulis*, known for their diverse pharmacological properties and rich chemical composition, present promising opportunities for drug discovery and development.

This study aims to shed light on the nutritional and phytochemical profiles of

these plants, offering valuable insights into their potential therapeutic applications and supporting ongoing efforts to tackle public health issues. Additionally, we aim to explore how the use of these medicinal plants aligns with and contributes to the broader objectives outlined in the United Nations Sustainable Development Goals (SDGs).

MATERIALS AND METHODS

Plant Collection and Authentication

The fresh leaves of *V. amygdalina* and *D. edulis* were collected in Benin City, Edo State, Nigeria. The identification and authentication were carried out in the Department of Plant Biology and Biotechnology, University of Benin, Benin City, Edo State.

Preparation of Vernonia amygdalina and Dacryodes edulis Leaf Extracts

Fresh leaves of *D. edulis* and *V. amygdalina* were hand-crushed after being air-dried to a constant weight. The leaves were macerated in distilled water for 24 hours with constant stirring. The filtrates obtained after filtering the crude extracts with doubled muslin cloth were concentrated using a rotary evaporator (Patil, 2020). The resulting plant extracts were stored at 4°C in a refrigerator for later use.

Analytical Methods

Moisture: A portion of 10g each of shredded fresh leaves of *D. edulis* and *V. amygdalina* underwent drying separately in a ventilated oven set at 105°C until reaching a stable weight. The reduction in weight served as the moisture measurement, following the AOAC protocol from 1984.

Preparation of Samples for Protein, Ash, and Mineral Analysis: Leaves were sliced into small fragments and dried in a

ventilated oven at 60°C for 5 days until consistent weight was achieved. Subsequently, the dried vegetables were ground into powder form and stored in sealed containers for analysis.

Crude Protein Determination: The Kjeldahl method was employed to assess crude protein. A quantity of 0.2g of dried and pulverized leaf material was digested in 2 ml of concentrated H₂SO₄ with a selenium catalyst until a clear solution was obtained, following the AOAC guidelines of 1984. The nitrogen content of the diluted digest was measured colorimetrically at 630nm, as per Charlot's method from 1964. Protein content was calculated as the nitrogen content multiplied by 6.25.

Ash Analysis: The ash content was determined by ashing the dried and pulverized vegetable material at 550°C in a muffle furnace.

Determination of Percentage Crude Fibre

The crude fibre was estimated as per standard procedure stated in methods of analysis AOAC (1990) and the value was expressed in percentage.

Determination of Nitrogen Free Extract (NFE)

The sum of the percentages of the entire proximate components was subtracted from 100.

Mineral Analysis

Minerals were obtained by ashing 2.0g of dried and ground samples in a muffle furnace at 550°C. The resulting ash was dissolved in 10ml of 20% nitric acid and

filtered through acid-washed Whatman No. 541 filter paper into a 100ml volumetric flask. The filtrate was diluted with deionized water and utilized for the analysis of phosphorus, zinc and iron. Phosphorus content was determined colorimetrically using the vanadomolybdate method. Zinc and iron were analyzed via atomic absorption spectrophotometry at 630nm. All analyses were conducted in triplicate.

HPLC Analysis of Phenolic Compounds

High-performance liquid chromatography was used to identify and quantify the polyphenols in the extracts according to the method described by Kellev *et al.* (1994).

Data Analysis

Results were expressed as mean ± SEM. One-way analysis of variance (ANOVA) was used to perform the statistical analysis using Minitab and Microsoft Excel statistical packages. Fisher pairwise comparison test at 95% significance level was used to determine significant differences between the mean values ($\alpha = 0.05$).

RESULTS

Table 1 below shows the proximate analysis of the dried leaves of *V. amygdalina* and *D. edulis*. Crude protein, and ash content, are present in higher concentrations in *V. amygdalina* compared to *D. edulis*. While moisture content, nitrogen-free extracts of crude fibre and crude lipids are present in higher amounts in *D. edulis* compared to *V. amygdalina*.

Table 1: Proximate Compositions of *Vernonia amygdalina* and *Dacryodes edulis*

| Samples | % MC | NFE | % CP | % ASH | % CF | % CL |
|----------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| <i>Dacryodes edulis</i> | 9.42±0.006 ^a | 47.02±0.06 ^a | 11.37±0.01 ^b | 12.30±0.2 ^b | 15.63±0.01 ^a | 4.42±0.08 ^a |
| <i>Vernonia amygdalina</i> | 6.88±0.006 ^b | 45.97±0.05 ^a | 24.52±0.03 ^a | 13.08±0.07 ^a | 6.23±0.01 ^b | 3.51±0.015 ^b |

Key: CF = Crude Fibre, NFE= Nitrogen Free Extract, CP= Crude Protein, MC = Moisture Content, CL= Crude Lipids. Values are expressed in percentages. Results are expressed as Mean ± SD. Mean values that do not share the same alphabet as superscript were considered significantly different ($p < 0.05$)

Macro and Micro nutrient Compositions of the leaves of *Vernonia amygdalina* and *Dacryodes edulis*

As shown in Table 2, Zinc, iron, potassium, sodium and magnesium, are present in high concentrations in *V.*

amygdalina when compared to *D. edulis* ($p < 0.05$). On the other hand, copper, and chromium are present in high concentration in *D. edulis* when compared to *V. amygdalina* ($p < 0.05$).

Table 2: Elemental Composition of *Vernonia amygdalina* and *Dacryodes edulis* Leaves

| Mineral | <i>Vernonia amygdalina</i> (ppm) | <i>Dacryodes edulis</i> (ppm) |
|---------|----------------------------------|-------------------------------|
| Mn | 0.08±0.05 ^a | 0.05±0.01 ^b |
| Se | 0.02 ±0.001 ^a | 0.02±0.004 ^a |
| Zn | 1.52±0.01 ^a | 1.02±0.006 ^b |
| Fe | 3.60±0.02 ^a | 2.32±0.02 ^b |
| Cu | 0.11±0.01 ^b | 1.13±0.12 ^a |
| Mg | 0.65±0.01 ^a | 0.28±0.04 ^b |
| Cr | 0.05±0.06 ^a | 0.06±0.06 ^a |
| K | 292.80±1.24 ^a | 179.82±1.72 ^b |
| Na | 8.49±0.53 ^a | 5.22±0.38 ^b |

Results are presented as Mean ± SEM. Mean values across the row that do not share the same alphabet as superscript are significantly different ($p < 0.05$)

Table 3: Phytochemical Composition of *V. amygdalina* and *D. edulis*

| Phytochemical group | <i>Vernonia amygdalina</i> | <i>Dacryodes edulis</i> |
|---------------------|----------------------------|-------------------------|
| Saponins | + | + |
| Flavonoids | ++ | + |
| Tannins | + | + |
| Alkaloids | ++ | + |
| Steroids | + | + |
| Phenolic compound | + | + |

Key: + = moderate concentration ++ = high concentration

Quantification of Polyphenols using High Performance Liquid Chromatography (HPLC)

As shown in Tables 4 and 5, luteolin, luteolin 7-O- beta glucoside, syringic acid,

vanillic acid, piperic acid, 1,5-dicaffeoylquinic acid, 1,3,5-dicaffeoylquinic acid, chlorogenic acid, 4,5- dicarffeoylquinic acid and naringenin are contained in higher concentrations in

the aqueous extract of *V. amygdalina*. Catechin, quinic acid, arbutin and chlorogenic acid were present in significant amounts in the aqueous extract of *D. edulis* compared to *V. amygdalina*.

Both extracts were in moderate amounts of gallic acid, ferulic acid, caffeic acid, galocatechin, ellagic acid, epigallocatechin, quercetin, o-Coumaric acid, and kaemferol.

Table 4: Characterization of Polyphenols present in the Aqueous Leaf Extracts of *V. amygdalina* using High-Performance Liquid Chromatography (HPLC)

| Phenolic compound | Amount (mg/100 g) | Percentage composition |
|-------------------------------------|-------------------|------------------------|
| Catechin | 1.174 | 0.085 |
| Quinic Acid | Trace | Trace |
| Arbutin | Trace | Trace |
| Vanillic Acid | 32.228 | 2.325 |
| O- Coumaric Acid | Trace | Trace |
| Epicatechin | 0.036 | 0.003 |
| P-hydroxybenzoic Acid | Trace | Trace |
| Gallic Acid | 5.892 | 0.425 |
| Caffeic Acid | 2.780 | 0.201 |
| Ferulic Acid | 6.047 | 0.440 |
| Syringic Acid | 194.810 | 14.050 |
| 1,5-Dicaffeoylquinic Acid | 392.267 | 28.296 |
| Sinapinic Acid | Trace | Trace |
| 3,5-Dicaffeoylquinic Acid | 140.462 | 10.132 |
| Apigenin | Trace | Trace |
| Naringenin Chalcone | Trace | Trace |
| Naringenin | 44.797 | 3.230 |
| 4,5-Dicaffeoylquinic Acid | 179.783 | 12.968 |
| Luteolin-7-O-beta-glucoside | 169.254 | 12.210 |
| Kaemferol | 4.085 | 0.295 |
| Capsaicin | Trace | Trace |
| Luteolin | 86.413 | 6.233 |
| Epigallocatechin | 0.019 | 0.001 |
| Gingerol | T | T |
| Ellagic Acid | 2.083 | 0.150 |
| Quercetin | Trace | Trace |
| Isorhamnetin | Trace | Trace |
| Myricetin | Trace | Trace |
| Chlorogenic Acid | 123.399 | 8.900 |
| 3-O-Caffeoylquinic | 0.534 | 0.039 |
| Rosmarinio Acid | Trace | Trace |
| Curcumin | Trace | Trace |
| Rutin | 0.255 | 0.018 |
| 4-O-methyl-epi-gallocatechin | Trace | Trace |
| Phenyl-6-O-malonyl-beta-D-glucoside | Trace | Trace |
| Epi-gallocatechin-3-O-gallate | Trace | Trace |
| Total | 1386.324 | 100.000 |

Table 5: Characterization of Polyphenols present in the Aqueous Leaf Extracts of *D. edulis* using High-Performance Liquid Chromatography (HPLC)

| Polyphenol | Amount (mg/100 g) | Percentage composition |
|-------------------------------------|-------------------|------------------------|
| Catechin | 4.344 | 0.338 |
| Quinic Acid | 705.062 | 54.925 |
| Arbutin | 272.778 | 21.250 |
| Vanillic Acid | Trace | Trace |
| O-coumaric Acid | Trace | Trace |
| Epicatechin | 4.820 | 0.375 |
| P-hydroxybenzoic Acid | Trace | Trace |
| Gallic Acid | Trace | Trace |
| Caffeic Acid | Trace | Trace |
| Ferulic Acid | 0.033 | 0.003 |
| Syringic Acid | Trace | Trace |
| Piperic Acid | Trace | Trace |
| Sinapinic Acid | Trace | Trace |
| Apigenin | Trace | Trace |
| Genistein | Trace | Trace |
| Naringenin Chalcone | Trace | Trace |
| Naringenin | Trace | Trace |
| Shogaol | Trace | Trace |
| Glycitein | Trace | Trace |
| Kaemferol | Trace | Trace |
| Luteolin | 0.022 | 0.002 |
| Capsaicin | Trace | Trace |
| Epigallocatechin | Trace | Trace |
| Gingerol | Trace | Trace |
| Ellagic Acid | Trace | Trace |
| Quercetin | 0.003 | 0.001 |
| Isorhamnetin | Trace | Trace |
| Myricetin | Trace | Trace |
| Chlorogenic Acid | 294.761 | 22.962 |
| 3-O-Caffeoylquinic | Trace | Trace |
| Rosmarinio Acid | Trace | Trace |
| Curcumin | Trace | Trace |
| Rutin | 1.857 | 0.145 |
| 4-O-methyl-epi-gallocatechin | Trace | Trace |
| Phenyl-6-O-malonyl-beta-D-glucoside | Trace | Trace |
| Epi-gallocatechin-3-O-gallate | Trace | Trace |
| Total | 1283.685 | 100.000 |

DISCUSSION

The exploration of *V. amygdalina* and *D. edulis* leaves, focusing on their nutritional and phytochemical attributes, particularly concerning malaria and

diabetes management, bears profound significance for Nigeria's pursuit of Sustainable Development Goals (SDGs). Plant-based diets like the vegetarian diet have been associated with several health

benefits because of their nutritional makeup (Tuso *et al.*, 2013). Vegetarians have been shown to have lower blood pressure, cholesterol, and body weight (Bruns *et al.*, 2024). Additionally, compared to non-vegetarians, they exhibit a lower incidence of stroke, cancer, and heart-related mortality. (Herpich *et al.*, 2022).

The study found that *V. amygdalina* has higher ash content and crude protein content than *D. edulis*, while *D. edulis* has higher crude fibre, crude lipids, moisture content, and nitrogen-free extracts. These findings indicate that both species are essential sources of nutrition, with *V. amygdalina* being a high-protein dietary supplement for muscle growth and repair, and *D. edulis* potentially being a source of good fats for energy production and nutrient absorption. This observation is consistent with previous studies. Igile *et al.* (1994) reported similar trends in proximate composition, highlighting the nutritional richness of *V. amygdalina* leaves. Additionally, Alabi and Amusa (2005) found comparable results regarding the moisture content and lipid composition of *D. edulis* leaves.

Hence, the plants leaves are considered highly nutritious. The findings of this study validate the works of Farombi and Owoeye, (2011) and Adedapo *et al.* (2014) who in their separate studies identified moisture content, crude fibre, protein, lipids and nitrogen-free extract in the dry leaves of *V. amygdalina* and *D. edulis* respectively.

Saponins, tannins, and other phytochemicals found in these plant extracts possess pharmacological qualities, suggesting their potential to contribute to SDG 3 by providing alternative and accessible treatments for

various health conditions. Additionally, the nutritional composition of *D. edulis* and *V. amygdalina* extracts supports SDG 2 by promoting diverse and nutritious diets, which are essential for achieving food security and improved nutritional outcomes (Craig, 2010).

Flavonoids, phenolic compounds, alkaloids, and tannins are among the most frequently isolated secondary metabolites (Evans, 2009). The presence of these metabolites varies among plants due to varying climatic conditions. Both *D. edulis* and *V. amygdalina* extracts were found to contain alkaloids, flavonoids, tannins, phenolics, and steroids, as outlined in Table 3.

The antioxidant activity of medicinal plants is closely associated with their phytochemical compositions (Liu *et al.*, 2008). The presence of phytoconstituents such as phenols, flavonoids, tannins, and saponins in the aqueous extracts of *D. edulis* and *V. amygdalina* leaves likely plays a crucial role in its traditional application for managing various diseases, including malaria and diabetes. Total phenols and flavonoids have been shown to modulate lipid peroxidation, a process implicated in atherogenesis and carcinogenesis (Mbabie *et al.*, 2011). This modulation is particularly relevant for diabetes management, as oxidative stress plays a significant role in the pathogenesis of diabetes complications. Tannins, as polyphenolic compounds, exhibit antidiuretic and anti-diarrheal properties (Okwu, 2004), which can be beneficial in managing symptoms related to malaria. Additionally, saponins have demonstrated potential therapeutic activities, including antifungal, antibacterial, and antioxidant effects (Aluko *et al.*, 2012), which are valuable in combating malaria by reducing

oxidative stress and supporting immune function. Tannins, often called terpenoids, have been linked to anti-inflammatory, anti-diabetic, and antimalarial properties (Singh and Singh, 2017). The polyphenols in the leaf extract may synergistically contribute to its enhanced antioxidant capabilities, offering potential complementary benefits in the management of both malaria and diabetes.

In this study also, leaf extracts from both *D. edulis* and *V. amygdalina* were discovered to contain phenolic compounds, tannins, saponins, and flavonoids. This finding is consistent with the research conducted by Aponjolosun and Fasola (2022).

Studies have shown that phenolic acids and flavonoids are strong anticancer agents that also scavenge free radicals to shield cells from oxidative damage (Galati and O'brien, 2004; Kopustinskiene *et al.*, 2020). When dissolved in aqueous solutions, flavonoids have been demonstrated to have diuretic, laxative, antibacterial, and antioxidant effects (Młynarczyk *et al.*, 2018).

Variations in polyphenolic content have been linked to plants with varying levels of antioxidant activity. Plant antioxidant potentials are primarily predicted by these polyphenols (Aberoumand and Deokule, 2008). Using HPLC, the polyphenolic content of *D. edulis* and *V. amygdalina* leaves were examined. When comparing *V. amygdalina* to *D. edulis*, the results indicate that the former has significantly higher concentrations of luteolin, luteolin 7-O- beta glucoside, syringic acid, vanillic acid, piperic acid, 1,5-dicaffeoylquinic acid, 1,3,5-dicaffeoylquinic acid, chlorogenic acid, 4,5- dicarffeoylquinic acid, and naringenin. This supports the

research by Izevbogie *et al.* (2004), which showed that *V. amygdalina* had these polyphenols in dominant concentrations. Conversely, both extracts contained modest levels of o-Coumaric acid, kaemferol, gallic acid, ferulic acid, caffeic acid, gallocatechin, ellagic acid, epigallocatechin, and quercetin.

In addition to being a great antidiabetic, luteolin is regarded as a safe antioxidant. By stopping the production of ROS, scavenging ROS, and safeguarding the constituents of other antioxidant systems, luteolin reduces the pathophysiology of diabetes mellitus (Lin *et al.*, 2008). The hypoglycemic potential and antioxidant activity of luteolin safeguard the pancreas and encourage the secretion of insulin. Using experimental diabetic animal models, it has been demonstrated that lipid peroxidation is suppressed and free radical generation is inhibited. (Zhang *et al.*, 2017). The progression of diabetes results in the generation of ROS wherein glycation of proteins culminates in oxidative stress. The increase in ROS generation during disease progression is curbed by luteolin in experimental mice (Zang *et al.*, 2016). The free radical scavenging activity of luteolin is reportedly through Nrf2 pathway (Li *et al.*, 2015).

Studies by Josic *et al.* (2010) and Cremonini *et al.* (2016), have revealed the effects of epicatechin on insulin sensitivity. According to the studies, the consumption of epicatechin rich green tea led to the reduction of glucose and oral testing insulin values. On the other hand, epicatechin reduces systolic blood pressure (Dower *et al.*, 2015) but has no significant effect on the diastolic blood pressure values (Ellinger *et al.*, 2012).

Investigating phytochemicals and their radical scavenging activities in plants like *D. edulis* and *V. amygdalina* has profound implications for advancing several United Nations Sustainable Development Goals (SDGs). The identification of these compounds underscores their potential contribution to SDG 3 (Good Health and Well-being) by providing natural antioxidants that enhance overall health and wellness. Additionally, the discovery of phytochemicals in the leaf extracts of *D. edulis* and *V. amygdalina* supports SDG 2 (Zero Hunger) and SDG 3, as these plants could be sustainable sources of nutrients and therapeutic agents. The presence of flavonoids and phenolic acids, recognized for their anticancer and antioxidant properties, further underscores their role in supporting SDG 3 by combating chronic diseases and reducing mortality rates (Ullah *et al.*, 2020).

The application of advanced analytical techniques such as high-performance liquid chromatography (HPLC) in assessing phytochemical content contributes to SDG 9 (Industry, Innovation, and Infrastructure). These advancements in analytical technologies and research methodologies enable the precise identification and quantification of bioactive compounds, thereby facilitating the development of evidence-based health interventions and disease prevention strategies.

Furthermore, specific polyphenolic compounds identified in *V. amygdalina*, such as luteolin and epicatechin, exhibit potential antidiabetic effects. This aligns with SDG 3 and SDG 1 (No Poverty) by addressing health disparities and promoting access to affordable healthcare solutions (Ong *et al.*, 2011). Through these multifaceted contributions, the exploration

of phytochemicals in these plants significantly supports the achievement of multiple SDGs, particularly those related to health, nutrition, innovation, and poverty reduction.

CONCLUSION

The nutritional value and phytochemical profiles of the aqueous extracts of leaves of *D. edulis* and *V. amygdalina* from this study demonstrated that these leaves not only have good nutritional value but also possess significant antimalarial, antidiabetic, anti-inflammatory, and antioxidant properties, which align with SDGs 2 and 3.

The presence of micronutrients and minerals in these plant leaves underscores their nutritional value. Thus, their addition to human diets and use in traditional medicine can benefit nutrition, health promotion, and disease prevention.

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REFERENCES

- Abay, S. M., Lucantoni, L., Dahiya, N., Dori, G., Dembo, E. G., Esposito, F., Lupidi, G., Ogboi, S., Ouédraogo, R. K., Sinisi, A. and Taglialatela-Scafati, O. (2015). Plasmodium transmission-blocking activities of *Vernonia amygdalina* extracts and isolated compounds. *Malaria Journal*, 14: 1–19.
- Aberoumand, A. and Deokule, S. S. (2008). Comparison of Phenolic Compounds of Some Edible Plants

- of Iran and India. *Pakistan Journal of Nutrition*, 7: 582:587.
- Adedapo, A. A., Aremu, O. J. and Oyagbemi, A. A. (2014). Anti-oxidant, anti-inflammatory and antinociceptive properties of the acetone leaf extract of *Vernonia amygdalina* in some laboratory animals. *Advanced Pharmaceutical Bulletin*, 4 (2): 591 -598.
- Adodo, A., and Iwu, M.M. (2020). *Healing Plants of Nigeria: Ethnomedicine and Therapeutic Applications* (15). CRC Press.
- Ajibesin, K. K. (2011). *Dacryodes edulis* (G. Don) HJ Lam: a review of its medicinal, phytochemical, and economical properties. *Research Journal of Medicinal Plants*, 5(1): 32–41.
- Akah, P. A. (2024). *Vernonia amygdalina* Del (bitter leaf), a traditional anti-diabetic gold mine (Mini Review). *Journal of Ayurveda and Integrated Medical Sciences*, 9(1):170–175.
- Alabi, D. A., and Amusa, N. A. (2005). Chemicals and Nutritional Composition of Four Botanicals with Fungitoxic Properties. *World Journal of Agricultural Sciences*, 1(1): 84–88.
- Aluko, B. T., Oloyede, O. I., and Afolayan, A. J. (2013). Polyphenolic contents and free radical scavenging potential of extracts from leaves of *Ocimum americanum* L. *Pakistan Journal of Biological Sciences*, 16(1): 22-30.
- AOAC (1990). *Official Methods of Analysis*, 15th ed., Association of Official Analytical Chemists, Washington D. C.
- AOAC, Association of Official Analytical Chemists (1984). *Official Methods of Analysis* (14th ed). Association of Official Analytical Chemists, Washington D. C.
- Aponjolosun, B. S. and Fasola, T. R. (2022). Phytochemical, Antimicrobial and Toxicity Assessment of *Dacryodes edulis* (G. Don.) HJ Lam Leaf Extracts. *African Journal of Biomedical Research*, 25(1): 101-106.
- Asante, D. B. and Wiafe, G. A. (2023). Therapeutic Benefit of *Vernonia amygdalina* in the Treatment of Diabetes and Its Associated Complications in Preclinical Studies. *Journal of Diabetes Research*, 2023, Article 3159352, 10.1155/2023/3159352
- Association of Analytical Chemists (1984). *Standard Official Methods of Analysis of the Association of Analytical Chemists*. 14th edition, S. W. Williams (Ed), Washington, D. C. 121.
- Atangwho, I. J., Ebong, P. E., Eyong, E. U., Williams, I. O., Eten, M. U. and Egbung, G. E. (2009). Comparative chemical composition of the leaves of some antidiabetic medicinal plants: *Azadirachta indica*, *Vernonia amygdalina*, and *Gongronema latifolium*. *African Journal of Biotechnology*, 8(18).
- Bruns, A., Greupner, T., Nebl, J. and Hahn, A. (2024). Plant-based diets and cardiovascular risk factors: a comparison of flexitarians, vegans, and omnivores in a cross-sectional study. *BMC Nutrition*, 10(1): 29.
- Charlot, G. (1964). *Colorimetric Determination of Elements. Principles and Methods*, Elsevier Publishing Company, 320–322.

- Conrad, O. A. and Uche, A.I. (2013). Assessment of the *in vivo* antioxidant properties of *Dacryodes edulis* and *Ficus exasperata* as anti-malaria plants. *Asian Pacific Journal of Tropical Disease*, 3(4): 294–300.
- Craig, W. J. (2010). Nutrition concerns and health effects of vegetarian diets. *Nutrition in Clinical Practice*. 25(6): 613-620.
- Cremonini, E., Bettaieb, A., Haj, F. G., Fraga, C. G., and Oteiza, P. I. (2016). (-)-Epicatechin Improves Insulin Sensitivity in High Fat Diet-Fed Mice. *Archives of Biochemistry and Biophysics*. 599: 13-21.
- Dower, J. I., Geleijnse, J. M., Gijsbers, L., Zock, P. L., Kromhout, D. and Hollman, P. C. (2015). Effects of the Pure Flavonoids Epicatechin and Quercetin on Vascular Function and Cardio Metabolic Health: A Randomized, Double-Blind, Placebo-Controlled and Crossover Trial. *American Journal of Clinical Nutrition*, 101(5): 914–921.
- Ellinger, S., Reusch, A., Stehle, P. and Helfrich, H. P. (2012). Epicatechin Ingested via Cocoa Products Reduces Blood Pressure in Humans: A Nonlinear Regression Model with a Bayesian approach. *American Journal of Clinical Nutrition*, 95(6): 1365–1377.
- Erukainure, O. L., Ijomone, O. M., Chukwuma, C. I., Xiao, X., Salau, V. F., and Islam, M. S. (2020). *Dacryodes edulis* (G. Don) HJ Lam modulates glucose metabolism, cholinergic activities, and Nrf2 expression while suppressing oxidative stress and dyslipidemia in diabetic rats. *Journal of Ethnopharmacology*. 255: 2744.
- Erukainure, O. L., Mopuri, R., Oyeboode, O. A., Koorbanally, N.A. and Islam, M. S. (2017). *Dacryodes edulis* enhances antioxidant activities, suppresses DNA fragmentation in oxidative pancreatic and hepatic injuries, and inhibits carbohydrate digestive enzymes linked to type 2 diabetes. *Biomedicine & Pharmacotherapy*. 96: 37–47.
- Evans, W. C. (2009). Trease and Evans' pharmacognosy. Elsevier Health Sciences.
- Farombi, E. O. and Owoeye, O. (2011). Antioxidative and chemopreventive properties of *Vernonia amygdalina* and *Garcinia biflavonoid*. *International Journal of Environmental Research and Public Health*, 8(6): 2533-2555.
- Galati, G. and O'brien, P. J. (2004). Potential toxicity of flavonoids and other dietary phenolics: significance for their chemopreventive and anticancer properties. *Free radical biology and medicine*. 37(3): 287-303.
- Herpich, C., Müller-Werdan, U. and Norman, K. (2022). Role of plant-based diets in promoting health and longevity. *Maturitas*, 165: 47–51.
- Igile, G. O., Iwara, I. A., Igile, V. O. and Ojiako, O. A. (1994). Proximate Composition and Phytochemical Constituents of *Vernonia amygdalina* and *Telfairia occidentalis* Leaves. *Plant Foods for Human Nutrition*, 45(4): 345–350.
- Irabor, F., Ebohon, O., Alegun, O., Okugbo, T. O., and Omoregie, S. E. (2023). The Biochemical Effects of Ascorbic Acid Co-Administration

- with Antimalarial Drug in Plasmodiasis. *Animal Research International*, 20(3): 5017 – 5029.
- Izevbigie, E. B., Bryant, J. L. and Walker, A. (2004). A novel natural inhibitor of extracellular signal-regulated kinases and human breast cancer cell growth. *Experimental Biology and Medicine*, 229(2): 163-169.
- Josic, J., Olsson, A. T., Wickeberg, J., Lindstedt, S. and Hlebowicz, J. (2010). Does Green Tea Affect Postprandial Glucose, Insulin and Satiety in Healthy Subjects: A randomized Controlled Trial. *Journal of Nutrition*, 9(1): 63-70.
- Kellev, B., Tapan, B., Tapas, P. and Ramen, K. (1994). Estimation of Flavonoid, Polyhenolic Content and In-Vitro Anti-Oxidant Capacity of Leaf of *Tephrosia purpurea* linn. (Leguminosae). *International Journal of Pharmacological Science and Research*. 1(1): 66-77.
- Kopustinskiene, D. M., Jakstas V., Savickas, A., Bernatoniene, J. (2020). Flavonoids as anticancer agents. *Nutrients*, 12: 457.
- Kumar, Y., Jain, A. and Kumar, R. (2023). Limitations of Current Drugs and Prospects of Plant-Based Compounds and Their Constructed Analogs as Therapeutics for the Treatment of Malaria. In *Natural Product-Based Drug Discovery against Human Parasites: Opportunities and Challenges* (pp. 451-469), Singapore: Springer Nature Singapore.
- Li, M., Li, Q., Zhao, Q., Zhang, J. and Lin, J. (2015). Luteolin Improves the Impaired Nerve Functions in Diabetic Neuropathy: Behavioural and Biochemical Evidence. *International Journal of Clinical and Experimental Pathology*, 8(9): 10112-10120.
- Lin, Y., Shi, R., Wang, X. and Shen, H. M. (2008). Luteolin, a flavonoid with potentials for cancer Prevention and therapy. *Current Cancer Drug Targets*, 8(7): 634–646.
- Mbaebie, B. O., Edeoga, H. O. and Afolayan, A. J. (2012). Phytochemical analysis and antioxidants activities of aqueous stem bark extract of *Schotia latifolia* Jacq. *Asian Pacific Journal of Tropical Biomedicine*, 2012: 118-124.
- Mishra, N., Gupta, E., Singh, P., Soni, S. and Noor, U. (2023). Insight on *Vernonia* Plant for its Pharmacological Properties: A Review. *Recent Advances in Food Nutrition and Agriculture*, 14(2): 84–93.
- Młynarczyk, K., Walkowiak-Tomczak, D. and Łysiak, G. P. (2018). Bioactive properties of *Sambucus nigra* L. as a functional ingredient for food and pharmaceutical industry. *Journal of Functional Foods*, 40: 377-390.
- Oboh, F. O. and Masodje, H. I. (2009). Nutritional and antimicrobial properties of *Vernonia amygdalina* leaves. *International Journal of Biomedical and Health Sciences*, 5(2): 51 – 56.
- Ogwu, M. C. and Ikhajiagbe, B. (2023). *Vernonia amygdalina* Delile (Asteraceae): An Overview of the Phytochemical Constituents, Nutritional Characteristics, and Ethnomedicinal Values for Sustainability. *Herbal Medicine Phytochemistry: Applications and Trends*. 1–29.

- Okugbo, O. T. and Killian, A. E. (2022). Antidiabetic Effect of Aqueous Extracts of *Vernonia amygdalina* and *Dacryodes edulis* Leaves and Their Combination in Alloxan-Induced Diabetic Rats. *BIU Journal of Basic and Applied Sciences*, 7(1): 105–118.
- Okwu, D. E. (2004). Phytochemicals and vitamin content of indigenous spices of Southeastern Nigeria. *J. Sustain. Agric. Environ.*, 6 (1): 30-37.
- Ong, K. W., Hsu, A., Song, L., Huang, D. and Tan, B. K. (2011). Polyphenols-rich *Vernonia amygdalina* shows anti-diabetic effects in streptozotocin-induced diabetic rats. *Journal of Ethnopharmacology*, 133(2): 598-607.
- Ononamadu, C. J., Alhassan, A. J., Ibrahim, A., Imam, A. A., Ihegboro, G. O., Owolarafe, T. A. and Sule, M.S. (2019). Methanol extracts and fractions of *Dacryodes edulis* leaves ameliorate hyperglycemia and associated oxidative stress in streptozotocin-induced diabetic Wistar rats. *Journal of Evidence-Based Integrative Medicine*, 24:
- Patil, A. S. (2020). Plant Secondary Metabolites: Isolation, Characterization, and Biological Properties. Studera Press.
- Pramesti, A. A. I., Parsa, I. W. and Bagiastra, I. N. (2024). Ethnomedical entities in health law and sustainable development: a literature review. *Bali Medical Journal*, 13(1): 400–404.
- Pucca, M. B., Nobrega de Sousa, T., Melo, G. C., and Viana, G. M. R. (2024). Challenges for the Diagnosis, Treatment, and Elimination of Malaria. *Frontiers in Tropical Diseases*, 5: 1394693
- Sanni, O., Erukainure, O. L., and Islam, M. S. (2020). *Dacryodes edulis*: protective antioxidant effects on diabetes pathology. In Pathology. 205–212. Academic Press.
- Singh, Z. (2016). Sustainable development goals: challenges and opportunities. *Indian Journal of Public Health*, 60(4): 247–250.
- Tuso, P. J., Ismail, M. H., Ha, B. P. and Bartolotto, C. (2013). Nutritional update for physicians: plant-based diets. *The Permanente Journal*, 17(2): 61.
- Ullah, A, Munir, S, Badshah, S. L., Khan, N., Ghani, L., Poulson, B. G., Emwas, A. H. and Jaremko, M. (2020). Important Flavonoids and Their Role as a Therapeutic Agent. *Molecules*, 25(22): 5243.
- United Nations Department of Economics. (2021). World Social Report 2021: Reconsidering Rural Development United Nations.
- Yeap, S. K., Ho, W. Y., Beh, B. K., Liang, W. S., Ky, H., Yousr, A. H. N. and Alitheen, N. B. (2010). *Vernonia amygdalina*, an ethnoveterinary and ethnomedical green vegetable with multiple bioactivities. *Journal of Medicinal Plant Research*, 4(25): 2787–2812.
- Zang, Y., Igarashi, K. and Li, Y. (2016). Anti-diabetic effects of luteolin and luteolin-7-O-glucoside on KK-A y mice. *Bioscience, Biotechnology, and Biochemistry*, 80(8): 1580-1586.
- Zhang, Y. J., Gan, R. Y., Li, S., Zhou, Y., Li, A. N., Xu, D. P. and Li, H. B. (2015). Antioxidant phytochemicals for the prevention and treatment of

- chronic diseases. *Molecules*, 20(12): 21138-21156.
- Zhang, Y. (2015). Antioxidant Phytochemicals for the Prevention and Treatment of Chronic Diseases. *Molecules*. 20(12): 211-218.
- Zofou, D., Tematio, E. L., Ntie-Kang, F., Tene, M., Ngemenya, M. N., Tane, P., and Titanji, V. P. (2013). New antimalarial hits from *Dacryodes edulis* (Burseraceae)-Part I: Isolation, *in vitro* activity, in silico “drug-likeness” and pharmacokinetic profiles. *PloS One*, 8(11): e79544.
- Zofou, D., Tene, M., Ngemenya, M. N., Tane, P., and Titanji, V. P. (2011). *In vitro* antiplasmodial activity and cytotoxicity of extracts of selected medicinal plants used by traditional healers of Western Cameroon. *Malaria Research and Treatment*. <https://doi.org/10.4061/2011/561342>