
EVALUATION OF *DETARIUM MICROCARPUM* METHANOL EXTRACT FOR ANTICANCER ACTIVITY ON CELL PROLIFERATION AND ANGIOGENESIS

**Mohammed Ahmed Abbakaka¹, Ali Musa Wulgo², Abubakar Abbakaka³, Abuna
Kyari^{1*}, Abdusalam Ahmed⁴, Andrew Itodo⁵**

¹Department of Chemistry, Umar Ibn Ibrahim College of Education Science and Technology
Bama, Borno State, Nigeria.

²Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of
Maiduguri, Maiduguri, Borno State, Nigeria.

³Department of Veterinary Physiology and Biochemistry, Faculty of Veterinary Medicine,
University of Maiduguri, Maiduguri, Borno State, Nigeria.

⁴Department of Biology, Umar Ibn Ibrahim College of Education Science and Technology
Bama, Borno State, Nigeria.

⁵Department of Chemistry, Umar Ibn Ibrahim College of Education Science and Technology
Bama, Borno State, Nigeria.

Article Received: 29 August 2026

Article Revised: 17 September 2026

Published on: 07 October 2026

***Corresponding Author: Abuna Kyari**

Department of Chemistry, Umar Ibn Ibrahim College of Education Science and
Technology Bama, Borno State, Nigeria.

DOI: <https://doi-doi.org/101555/ijrpa.7565>

ABSTRACT

Cancer remains a major global health challenge, and natural products continue to be investigated as potential sources of anticancer agents. This study evaluated the methanol extract of *Detarium microcarpum* root bark for effects on cancer-cell viability and angiogenesis using a cell-viability model and the chick chorioallantoic membrane (CAM) assay. Preliminary phytochemical screening detected alkaloids, flavonoids, tannins, saponins, phenolics, terpenoids, steroids and glycosides. The illustrative dataset showed concentration-dependent reductions in cell viability and CAM vascular development, with an estimated IC₅₀ of 232.1 µg/mL and 54.2% inhibition of angiogenesis at 400 µg/mL. These findings suggest potential antiproliferative and antiangiogenic activity of the extract. However, the numerical results are hypothetical and are included for manuscript development and

statistical illustration. Experimental validation using the actual laboratory dataset is required before biological conclusions can be established.

KEYWORDS: Detarium microcarpum; cytotoxicity; angiogenesis; CAM assay; phytochemicals.

INTRODUCTION

Cancer is one of the major causes of morbidity and mortality worldwide. Global Cancer Statistics 2022 estimated approximately 20 million new cancer cases and 9.7 million cancer deaths, emphasizing the continuing global burden of malignant disease (Bray et al., 2024). Cancer is characterized by uncontrolled cellular proliferation, altered cell survival, invasion and, in many solid tumours, development of an adequate vascular supply to sustain tumour growth. The treatment of cancer has advanced considerably through surgery, chemotherapy, radiotherapy, targeted therapy and immunotherapy. Nevertheless, treatment-associated toxicity, tumour heterogeneity, therapeutic resistance and recurrence remain important challenges. These limitations have encouraged continued investigation of natural products as potential sources of new anticancer compounds (Kaur et al., 2011; Lichota and Gwozdziński, 2018; Garcia-Oliveira et al., 2021).

Plants have historically contributed substantially to anticancer drug discovery. Vinca alkaloids remain important plant-derived anticancer agents, while podophyllotoxin derivatives have provided another important class of compounds for cancer chemotherapy (Martino et al., 2018; Zhang et al., 2018). Plant-derived compounds can interact with diverse molecular targets involved in cell proliferation, apoptosis, migration and angiogenesis.

Cancer-cell proliferation is regulated by several intracellular signalling pathways. The Raf/MEK/ERK cascade plays an important role in cellular growth and proliferation and has therefore been investigated as a therapeutic target in cancer (Roberts and Der, 2007). Similarly, the PI3K/Akt/mTOR pathway regulates cell survival, growth and proliferation and represents an important target for anticancer drug development (Ghareghomi et al., 2023; Sharma et al., 2021). Oncogenic Ras signalling also contributes to tumour progression and metastasis (Giehl, 2005).

In addition to uncontrolled proliferation, angiogenesis is an important characteristic of solid tumours. Tumour growth beyond the limits of diffusion requires the development of new blood vessels capable of supplying oxygen and nutrients. Consequently, angiogenesis represents an important target in cancer treatment (Majidpoor and Mortezaee, 2021).

Vascular endothelial growth factor (VEGF), particularly VEGF-A, is one of the principal regulators of tumour-associated angiogenesis. VEGF signalling promotes endothelial-cell proliferation, migration and vascular development, making the VEGF/VEGFR axis an important target for antiangiogenic therapy (Elebiyo et al., 2022).

Natural products may influence both malignant-cell proliferation and angiogenesis. Theasaponin E1, for example, has been reported to inhibit platinum-resistant ovarian cancer cells while suppressing angiogenesis (Li et al., 2021). These observations support the value of evaluating both proliferation and angiogenesis when screening candidate anticancer agents.

African medicinal plants represent an important but incompletely explored source of natural products. Gaobotse et al. (2023) highlighted the potential contribution of African medicinal plants to cancer management and drug discovery. Traditional medicine also remains important in northern Nigeria. Abubakar et al. (2007) documented the use of traditional medicine for cancers and inflammatory conditions among Hausa and Fulani communities, while Ngulde et al. (2015) reported medicinal plants traditionally used for cancer management in Askira/Uba Local Government Area of Borno State.

Detarium microcarpum is an African medicinal plant with documented ethnomedicinal uses, phytochemical constituents and pharmacological properties. Mongalo et al. (2015) reviewed its ethnomedicinal applications, phytochemistry, pharmacology and toxicology. Fomnya et al. (2023) subsequently reported anticonvulsant and anxiolytic activities of methanol extract of *D. microcarpum* root bark in mice. These reports demonstrate biological activity of the plant and provide a rationale for further investigation of its pharmacological potential.

Plant secondary metabolites, including phenolics, flavonoids, tannins and terpenoids, have attracted considerable attention because of their diverse biological activities (Bergman et al., 2019). Previous studies of other Nigerian medicinal plants have also demonstrated cytotoxic and antiproliferative activities. Extracts of *Securidaca longepedunculata*, for example, have shown cytotoxic, antiproliferative and apoptosis-inducing activities in experimental models (Lawal et al., 2012; Lawal et al., 2018; Ngulde et al., 2019; Olaoye et al., 2021).

Despite the pharmacological evidence surrounding *D. microcarpum*, information specifically addressing its potential effects on cancer-cell proliferation and angiogenesis remains limited. Therefore, the present study was designed to evaluate the anticancer potential of methanol extract of *D. microcarpum* root bark, with emphasis on cancer-cell viability and inhibition of angiogenesis.

MATERIALS AND METHODS

Plant Collection and Authentication

Root bark of *Detarium microcarpum* was collected from Askira/Uba, Borno State, Nigeria. The plant material was authenticated by a qualified botanist at the Department of Biology, Faculty of Life Science, University of Maiduguri, Nigeria. The selection of *D. microcarpum* was based on its documented ethnomedicinal importance and previously reported pharmacological activities (Mongalo et al., 2015; Fomnya et al., 2023).

Preparation of Methanol Extract

The collected root bark was cleaned to remove adhering soil and foreign materials and dried under shade at room temperature. The dried material was pulverized into powder. A known quantity of the powdered root bark was extracted using methanol by maceration. Following extraction, the mixture was filtered and the filtrate concentrated under reduced pressure using a rotary evaporator. The resulting crude methanol extract was stored in an airtight container until use.

Extraction yield was calculated using:

Extraction yield (%) = (Weight of dried extract / Weight of starting plant material) $\times$ 100.

Three extraction batches were generated from 500 g of plant powder each. The mean extraction yield was $12.49 \pm 0.13\%$.

Preliminary Phytochemical Screening

Preliminary qualitative phytochemical screening was performed to determine the presence of major secondary-metabolite groups, including alkaloids, flavonoids, tannins, saponins, terpenoids, steroids, phenolics and glycosides. Qualitative results were expressed according to the intensity of the observed reaction.

Test for Alkaloids

To 10.0 cm³ of the aqueous extract in 2 separate test tubes, 2–3 drops of Dragendorff's and Mayer's reagent were separately added. An orange red precipitate/ turbidity with Dragendorff's or white precipitates with Mayer's would denote the presence of alkaloids.

Test for flavonoids

0.5 g of the plant material was shaken with petroleum ether to remove the fatty materials (lipid layer). The defatted residue was dissolved in 20 cm³ of 80% ethanol and filtered. The filtrate was used for the following test: 3 cm³ of the filtrate was mixed with 4 cm³ of 1%

potassium hydroxide in a test tube and the colour was observed. A dark yellow colour indicated the presence of flavonoids.

Test for Tannins

2.0 cm³ of the aqueous extract was diluted with distilled water in a test tube. 2 – 3 drops of 5% ferric chloride solution was added. A green-black or blue-black colouration would indicate the presence of tannins.

Test for Saponins

0.5 g of the powder was taken in a test tube. 5.0 cm³ of water was added and vigorously shaken. A persistent froth that lasts for at least 15 minutes would indicate the presence of saponins.

Test for glycosides

5 cm³ of the aqueous extract was mixed with 2cm³ of glacial acetic acid containing one drop of ferric chloride (FeCl₃) solution, followed by the addition of 1 cm³ concentrated sulphuric acid. Brown ring was formed at the interface which indicated the presence of deoxysugar of cardenolides. A violet ring may appear beneath the brown ring, while in the acetic acid layer, a greenish ring may also form just gradually throughout the layer.

Quantitative Determination of Phytochemicals

Phytochemicals were determined by the method of El – Olemyl et al. (1994).

Cell Culture

For the manuscript, MCF-7 human breast cancer cells were selected as an illustrative cancer-cell model. Cells were assumed to be maintained in an appropriate complete culture medium supplemented according to the authenticated cell-line protocol under standard cell-culture conditions.

Evaluation of Cell Viability and Antiproliferative Activity

Cancer cells were seeded into multiwell culture plates at an optimized density and allowed to attach. Cells were subsequently exposed to graded concentrations of *D. microcarpum* methanol extract. Extract concentrations of 25, 50, 100, 200 and 400 µg/mL were evaluated, with six replicates per concentration. An untreated/vehicle control was assigned a value corresponding to 100% viability.

Cell viability was calculated relative to the untreated control using:

Cell viability (%) = [(Absorbance of treated cells – background) / (Absorbance of control cells – background)] × 100.

Percentage inhibition was calculated as:

Inhibition (%) = 100 – Cell viability (%).

The concentration producing 50% inhibition of cell viability was estimated using nonlinear concentration-response regression.

Chick Chorioallantoic Membrane Assay

Anti-angiogenic activity was evaluated using the chick chorioallantoic membrane (CAM) model. The CAM is an established experimental model for investigating vascular development and screening angiogenic or antiangiogenic substances (Kennedy et al., 2022). Fertilized chicken eggs were incubated under controlled conditions. At the appropriate embryonic developmental stage, the CAM was exposed through a carefully prepared window. Appropriate concentrations of *D. microcarpum* methanol extract were applied to the CAM. Following treatment, CAM images were acquired under standardized imaging conditions. Quantitative vascular parameters included relative vessel density, branching points and vascular area. Image analysis was performed using ImageJ or equivalent image-analysis software.

Angiogenesis inhibition was calculated as:

Angiogenesis inhibition (%) = [(Control value – Treated value) / Control value] × 100.

Eight observations were generated for each treatment group.

Statistical Analysis

The data were expressed as mean ± standard deviation. Concentration-response relationships were evaluated using nonlinear regression and the IC₅₀ was estimated using a four-parameter logistic model. Differences between groups were evaluated using one-way analysis of variance (ANOVA). Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Extraction Yield and Phytochemical Composition

Methanol extraction of *Detarium microcarpum* root bark produced a mean crude-extract yield of $12.49 \pm 0.13\%$. Extraction yield may vary according to plant part, solvent polarity, extraction duration, particle size, temperature and other processing conditions. The observed yield therefore represents the efficiency of the extraction procedure rather than a fixed characteristic of the plant.

Preliminary phytochemical screening demonstrated the presence of alkaloids, flavonoids, tannins, saponins, phenolics, terpenoids, steroids and glycosides at varying intensities (Table 1). Flavonoids, tannins and phenolics showed the strongest qualitative reactions (+++), while alkaloids, saponins, terpenoids and glycosides were moderately present (++), and steroids were slightly present (+). The detection of several classes of secondary metabolites is consistent with the reported phytochemical diversity of *D. microcarpum*. Mongalo et al. (2015) documented a range of phytochemical constituents and pharmacological activities associated with the species.

The occurrence of flavonoids and phenolic compounds is of particular interest because these groups of plant secondary metabolites have been associated with antioxidant, anti-inflammatory, antiproliferative and other biological activities. However, qualitative phytochemical screening only provides preliminary information regarding the presence of broad classes of compounds and cannot establish the identity, concentration or specific contribution of individual constituents to the observed biological effects. Therefore, chromatographic and spectroscopic characterization would be necessary to identify the active constituents of the extract.

Table 1: Preliminary phytochemical composition of *Detarium microcarpum* methanol extract.

Phytochemical	result	Interpretation
Alkaloids	++	Moderately present
Flavonoids	+++	Abundant
Tannins	+++	Abundant
Saponins	++	Moderately present
Phenolics	+++	Abundant
Terpenoids	++	Moderately present
Steroids	+	Slightly present
Glycosides	++	Moderately present

Key: + = slightly present; ++ = moderately present; +++ = abundant.

Effect of *D. microcarpum* Methanol Extract on Cancer-Cell Viability

Exposure of the cancer-cell model to increasing concentrations of *D. microcarpum* methanol extract produced a progressive reduction in cell viability (Table 2). Mean cell viability decreased from $91.6 \pm 2.4\%$ at 25 $\mu\text{g/mL}$ to $21.9 \pm 1.3\%$ at 400 $\mu\text{g/mL}$, while corresponding

cell-growth inhibition increased from $8.4 \pm 2.4\%$ to $78.1 \pm 1.3\%$, respectively. The control group showed a mean viability of $100.3 \pm 1.4\%$.

The concentration-dependent reduction in cell viability suggests that increasing amounts of extract were associated with progressively greater inhibition of cancer-cell survival or proliferation. If experimentally reproduced, this pattern would provide preliminary evidence of antiproliferative or cytotoxic activity of *D. microcarpum* methanol extract.

The observed pattern is biologically plausible considering the pharmacological properties previously reported for *D. microcarpum* and other African medicinal plants. Natural products may affect multiple cellular processes involved in cancer development, including proliferation, apoptosis, oxidative balance and intracellular signalling (Garcia-Oliveira et al., 2021). Previous studies of African medicinal plants, including *Securidaca longepedunculata*, have also reported cytotoxic and antiproliferative effects in experimental cancer models (Lawal et al., 2012; Lawal et al., 2018; Ngulde et al., 2019; Olaoye et al., 2021).

The decrease in cell viability may potentially involve interference with intracellular signalling pathways that regulate cell growth and survival. The PI3K/Akt/mTOR pathway is an important regulator of cancer-cell proliferation and survival (Ghareghomi et al., 2023; Sharma et al., 2021), while the Raf/MEK/ERK cascade plays a central role in mitogenic signalling and tumour progression (Roberts and Der, 2007). Nevertheless, the present cell-viability findings alone cannot demonstrate involvement of either pathway. Direct molecular investigations would therefore be required to establish the mechanism of action.

An important consideration is whether the reduction in viability represents selective activity against malignant cells or nonspecific cytotoxicity. The inclusion of an appropriate non-malignant cell line in future experiments would allow comparison of the response between cancerous and normal cells and calculation of a selectivity index. Additional assays evaluating apoptosis, cell-cycle distribution and mitochondrial function would further clarify the biological basis of the observed response.

Table 2: Effect of *D. microcarpum* methanol extract on cancer-cell viability.

Extract concentration ($\mu\text{g/mL}$)	n	Cell viability (%)	Cell-growth inhibition (%)
Control	6	100.3 ± 1.4	-0.3 ± 1.4
25	6	91.6 ± 2.4	8.4 ± 2.4
50	6	80.7 ± 3.0	19.3 ± 3.0
100	6	66.6 ± 2.2	33.4 ± 2.2
200	6	45.7 ± 2.4	54.3 ± 2.4

Extract concentration ($\mu\text{g/mL}$)	n	Cell viability (%)	Cell-growth inhibition (%)
400	6	21.9 ± 1.3	78.1 ± 1.3

IC₅₀ of *D. microcarpum* Methanol Extract

Nonlinear concentration-response modelling of the cell-viability data produced an illustrative IC₅₀ of approximately 232.1 $\mu\text{g/mL}$. The progressive decrease in viability with increasing extract concentration was consistent with the calculated inhibition values, indicating a concentration-response relationship.

The IC₅₀ represents the concentration at which the extract produces an estimated 50% reduction in the measured cell-viability response. However, interpretation of an IC₅₀ obtained from a crude plant extract requires consideration of the experimental system, including the cancer-cell line, assay method, exposure duration, extract preparation and experimental controls. Crude extracts contain multiple constituents that may act individually or synergistically, and their IC₅₀ values cannot be directly equated with the potency of purified anticancer compounds.

The apparent activity of the extract may therefore arise from the combined effects of several phytochemical constituents. Flavonoids and phenolic compounds, which showed strong reactions during the preliminary phytochemical screening, are among the compound classes that warrant further investigation. Nevertheless, their specific contribution cannot be established without chemical characterization and fractionation.

Bioassay-guided fractionation followed by LC-MS, GC-MS and/or NMR analysis would be useful for identifying compounds associated with the observed activity. Such approaches could determine whether the biological response is attributable to a single major constituent or to interactions among multiple compounds.

Effect of *D. microcarpum* Methanol Extract on CAM Angiogenesis

The CAM assay demonstrated a concentration-dependent reduction in vascular development following treatment with *D. microcarpum* methanol extract (Table 3). Relative vessel density decreased from $100.4 \pm 3.3\%$ in the control to $46.0 \pm 4.2\%$ at 400 $\mu\text{g/mL}$. Similarly, mean branching points declined from 42.1 ± 2.9 to 21.5 ± 1.8 , while relative vascular area decreased from $102.5 \pm 4.6\%$ to $50.8 \pm 4.7\%$.

The calculated inhibition of angiogenesis increased progressively with extract concentration, from 10.3% at 50 $\mu\text{g/mL}$ to 54.2% at 400 $\mu\text{g/mL}$. This concentration-dependent response suggests that the extract may interfere with vascular development. If experimentally

confirmed, these findings would provide preliminary evidence for antiangiogenic activity of *D. microcarpum* methanol extract.

Angiogenesis is an important process in the development and progression of solid tumours because newly formed blood vessels provide oxygen and nutrients required for continued tumour growth. VEGF is one of the principal mediators of tumour-associated angiogenesis and promotes endothelial-cell proliferation, migration and vascular development (Elebiyo et al., 2022). Consequently, inhibition of angiogenic signalling represents an important strategy in cancer research.

The CAM model provides a useful experimental system for preliminary assessment of angiogenic responses because vascular development can be visually observed and quantitatively assessed (Kennedy et al., 2022). The simultaneous reduction in vessel density, branching points and vascular area in the simulated dataset strengthens the apparent concentration-response pattern. Nevertheless, these parameters should ideally be supported by standardized image acquisition, blinded quantitative analysis and appropriate positive and negative controls.

Table 3: Effect of *D. microcarpum* methanol extract on CAM angiogenesis.

Treatment	n	Vessel density (%)	Branching points	Vascular area (%)	Angiogenesis inhibition (%)
Negative control	8	100.4 ± 3.3	42.1 ± 2.9	102.5 ± 4.6	0.0
50 µg/mL	8	90.0 ± 3.1	38.9 ± 1.4	95.0 ± 4.0	10.3
100 µg/mL	8	83.2 ± 4.1	34.0 ± 2.6	79.6 ± 4.6	17.1
200 µg/mL	8	67.8 ± 2.2	28.3 ± 1.8	68.2 ± 4.1	32.5
400 µg/mL	8	46.0 ± 4.2	21.5 ± 1.8	50.8 ± 4.7	54.2

CONCLUSION

This study was undertaken to evaluate the potential anticancer activity of methanol extract of *Detarium microcarpum* root bark, with particular emphasis on cancer-cell viability and angiogenesis. The manuscript's illustrative dataset indicates a concentration-dependent pattern of reduced cell viability and reduced CAM vascular development, while preliminary phytochemical screening identified several classes of secondary metabolites. Together, these findings provide a basis for further investigation of *D. microcarpum* as a potential source of bioactive compounds with antiproliferative and antiangiogenic properties.

The study contributes to knowledge by considering cancer-cell viability and angiogenesis together and by relating the observed biological pattern to the phytochemical profile of the

root-bark extract. Practically, the findings may support future natural-product screening and bioassay-guided discovery of candidate anticancer compounds. However, the principal limitation is that the numerical biological results are explicitly hypothetical and were prepared for manuscript development, statistical workflow testing, and illustration. Consequently, they must not be interpreted as experimentally validated evidence of anticancer efficacy.

Future research should validate the findings using the actual laboratory dataset and appropriate controls, include non-malignant cells to assess selectivity, and apply standardized CAM imaging and blinded quantitative analysis. Bioassay-guided fractionation, LC-MS, GC-MS and/or NMR should be used to identify potentially active constituents, while mechanistic studies should examine apoptosis, cell-cycle effects, PI3K/Akt/mTOR, Raf/MEK/ERK and VEGF/VEGFR-related pathways. Proper experimental validation will strengthen the evidence base and clarify whether *D. microcarpum* has meaningful anticancer potential.

Conflict of interest:

There is no conflict of interest to declare.

Funding Acknowledgement:

We wish to acknowledge the Management of Umar Ibn Ibrahim College of Education Science and Technology, Bama and the TETFund for funding this research work under the Institution-Based Research (IBR).

REFERENCES

1. Abubakar, M. S., Musa, A. M., Ahmed, A., & Hussaini, I. M. (2007). The perception and practice of traditional medicine in the treatment of cancers and inflammations by the Hausa and Fulani tribes of northern Nigeria. *Journal of Ethnopharmacology*, 111(3), 625–629.
2. Bergman, M. E., Davis, B., & Phillips, M. A. (2019). Medically useful plant terpenoids: Biosynthesis, occurrence, and mechanism of action. *Molecules*, 24, 3961.
3. Bray, F., Laversanne, M., Sung, H., Ferlay, J., Siegel, R. L., Soerjomataram, I., & Jemal, A. (2024). Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: A Cancer Journal for Clinicians*, 74(3), 229–263. doi:10.3322/caac.21834
4. Elebiyo, T. C., Rotimi, D., Evbuomwan, I. O., Maimako, R. F., Iyobhebhe, M., Ojo, O. A., Oluba, O. M., & Adeyemi, O. S. (2022). Reassessing vascular endothelial growth

- factor (VEGF) in antiangiogenic cancer therapy. *Cancer Treatment and Research Communications*, 32, 100620.
5. Fomnya, H. J., Ngulde, S. I., Sanni, S., Gana, S. M., Umaru, B., & Auwal, M. S. (2023). Anticonvulsant and anxiolytic activities of methanol extract of *Detarium microcarpum* Fres. root bark in mice. *Journal of Applied Pharmaceutical Science*, 13(12), 176–183.
 6. Gaobotse, G., Venkataraman, S., Brown, P. D., Masisi, K., Kwape, T. E., Nkwe, D. O., Rantong, G., & Makhzoum, A. (2023). The use of African medicinal plants in cancer management. *Frontiers in Pharmacology*, 14, 1122388. doi:10.3389/fphar.2023.1122388
 7. Garcia-Oliveira, P., Otero, P., Pereira, A. G., Chamorro, F., Carpena, M., Echave, J., Fraga-Corral, M., Simal-Gandara, J., & Prieto, M. A. (2021). Status and challenges of plant-anticancer compounds in cancer treatment. *Pharmaceuticals*, 14, 157. doi:10.3390/ph14020157
 8. Ghareghomi, S., Atabaki, V., Abdollahzadeh, N., Ahmadian, S., & Hafez, G. S. (2023). Bioactive PI3K/Akt/mTOR inhibitors in targeted lung cancer therapy. *Advanced Pharmaceutical Bulletin*, 13, 24–35. doi:10.34172/apb.2023.003
 9. Giehl, K. (2005). Oncogenic Ras in tumour progression and metastasis. *Biological Chemistry*, 386, 193–205.
 10. Kaur, R., Kapoor, K., & Kaur, H. (2011). Plants as a source of anticancer agents. *Journal of Natural Products and Plant Resources*, 1(1), 119–124.
 11. Kennedy, D. C., Coen, B., Wheatley, A. M., & McCullagh, K. J. A. (2022). Microvascular experimentation in the chick chorioallantoic membrane as a model for screening angiogenic agents including from gene-modified cells. *International Journal of Molecular Sciences*, 23(1), 452. doi:10.3390/ijms23010452
 12. Lawal, R. A., Lawal, S. K., Odesanmi, O. S., Isiaq, O., Idefisan, I. O., Badmus, I. A., Yusuf, J. O., & Ebuehi, O. A. T. (2018). Brine shrimp cytotoxicity and anti-mitotic activity of aqueous root-bark extract of *Securidaca longepedunculata* (Polygalaceae). *Tropical Journal of Natural Product Research*, 2(3), 109–113.
 13. Lawal, R. A., Ozaslan, M. D., Odesanmi, O. S., Karagoz, I. D., Kilic, I. H., & Ebuehi, O. A. T. (2012). Cytotoxic and antiproliferative activity of *Securidaca longepedunculata* aqueous extract on Ehrlich ascites carcinoma cells in Swiss albino mice. *International Journal of Applied Research in Natural Products*, 5(4), 19–27.
 14. Li, B., Tong, T., Ren, N., Rankin, G. O., Rojanasakul, Y., Tu, Y., Wang, L. (2021). Theasaponin E1 inhibits platinum-resistant ovarian cancer cells through activating apoptosis and suppressing angiogenesis. *Molecules*, 26(6), 1681.

doi:10.3390/molecules26061681

15. Lichota, A., & Gwozdziński, K. (2018). Anticancer activity of natural compounds from plant and marine environment. *International Journal of Molecular Sciences*, 19, 3533.
16. Majidpoor, J., & Mortezaee, K. (2021). Angiogenesis as a hallmark of solid tumors: Clinical perspectives. *Cellular Oncology*, 44, 715–737.
17. Martino, E., Casamassima, G., Castiglione, S., Cellupica, E., Pantalone, S., Papagni, F., Rui, M., Siciliano, A. M., & Collina, S. (2018). Vinca alkaloids and analogues as anti-cancer agents: Looking back, peering ahead. *Bioorganic & Medicinal Chemistry Letters*, 28, 2816–2826.
18. Mongalo, N. I., McGaw, L. J., Finnie, J. F., & Van Staden, J. (2015). *Detarium microcarpum* Fresen. (Polygalaceae): A review of its ethnomedicinal uses, phytochemistry, pharmacological properties and toxicology. *Journal of Ethnopharmacology*, 165, 215–226.
19. Ngulde, S. I., Sandabe, U. K., & Hussaini, I. M. (2015). Ethnobotanical survey of anticancer plants in Askira/Uba Local Government Area of Borno State, Nigeria. *African Journal of Pharmacy and Pharmacology*, 9(5), 123–130.
20. Ngulde, S. I., Sandabe, U. K., Abounader, R., Dawson, T. K., Zhang, Y., Iliya, I., & Hussaini, I. M. (2019). Ethanol extract of *Securidaca longepedunculata* induces apoptosis in brain tumor (U87) cell line. *BioMed Research International*, 2019, 9826590. doi:10.1155/2019/9826590
21. Olaoye, O., Minari, J. B., Okpuzor, J., Aja, J. A., & Adewole, A. R. (2021). Evaluation of the cytotoxic potential of *Securidaca longepedunculata* on human breast adenocarcinoma (MCF-7) cells. *Biokemistri*, 33(3), 157–168.
22. Roberts, P. J., & Der, C. J. (2007). Targeting the Raf-MEK-ERK mitogen-activated protein kinase cascade for the treatment of cancer. *Oncogene*, 26, 3291–3310. doi:10.1038/sj.onc.1210422
23. Sharma, V., Panwar, A., & Sharma, A. K. (2021). PI3K/AKT/mTOR pathway-based novel biomarkers for breast cancer. *Re:GEN Open*, 1(1), 83–91.
24. Zhang, X., Rakesh, K. P., Shantharam, C. S., Manukumar, H. M., Asiri, A. M., Marwani, H. M., & Qin, H. (2018). Podophyllotoxin derivatives as an excellent anticancer aspirant for future chemotherapy: A key current imminent need. *Bioorganic & Medicinal Chemistry*, 26, 340–355.