

SCIENCE

Effects of Bark Harvesting Intensity on the Phytochemical Composition of *Vitellaria paradoxa* and *Prosopis africana* in Selected Local Government Areas of Jigawa State, Nigeria

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Published October 2026

Abstract

Bark of *Vitellaria paradoxa* and *Prosopis africana* is widely harvested for traditional medicine in northern Nigeria, yet the effect of harvesting intensity on its phytochemical composition is poorly documented. This study compared the phytochemical composition of bark from overharvested (OH; $\geq 50\%$ bark removed in the preceding two to three years) and minimally harvested (MH) trees in Kazaure, Gwiwa, Roni and Yankwashi Local Government Areas (LGAs) of Jigawa State, Nigeria. Seventeen bark samples (13 *V. paradoxa*, 4 *P. africana*) were screened qualitatively for eight phytochemical classes, and saponins, flavonoids, tannins, alkaloids and cardiac glycosides were quantified. All eight classes were present in every sample. In *V. paradoxa*, overharvested trees had significantly higher saponin ($10.67 \pm 1.59\%$ vs $8.24 \pm 1.85\%$; $p = 0.028$) and cardiac glycoside ($0.86 \pm 0.10\%$ vs $0.73 \pm 0.08\%$; $p = 0.032$) contents than minimally harvested trees, whereas flavonoid, tannin and alkaloid contents did not differ significantly. No significant differences were detected in *P. africana*, which was sampled in Kazaure only ($n = 2$ per group). Among LGAs, flavonoid content in *V. paradoxa* differed significantly ($p = 0.017$), being higher in Kazaure ($17.50 \pm 2.65\%$) than in Gwiwa ($10.00 \pm 1.73\%$; Tukey $p = 0.035$); the other compounds did not differ among LGAs. Saponin and cardiac glycoside contents were higher in overharvested than in minimally harvested trees in all four LGAs. Bark removal did not eliminate any screened phytochemical class and was associated with higher saponin and cardiac glycoside concentrations in *V. paradoxa*. Replicated sampling at larger scale is required to confirm these patterns and to relate them to tree health and sustainable harvesting.

Keywords: bark harvesting; phytochemicals; *Vitellaria paradoxa*; *Prosopis africana*; Jigawa State; medicinal trees

1 Introduction

Traditional medicine remains widely used for the management of ailments in West Africa (D'Almeida et al., 2024), and the bark of savanna trees is an important source of remedies.

In northern Nigeria, the bark of indigenous savanna trees such as *Vitellaria paradoxa* C.F.Gaertn. (Hausa: 'Kadanya') and *Prosopis africana* (Guill. & Perr.) Taub. (Hausa: 'Kiriya') is used in the management of diarrhoea and bacterial infections. *Vitellaria paradoxa* has more than 150 identified phytoconstituents, including oleanane-type triterpene glycosides and flavonoids, and its extracts

show anti-diarrhoeal, antibacterial and antioxidant activities (Ojo et al., 2021). Extracts and isolated compounds of *P. africana* show antibacterial and antioxidant activities that support its traditional use against bacterial infections (Yanda et al., 2022).

Both species are under pressure from human use. *Prosopis africana* is a multipurpose species considered to be under threat in West Africa because of overexploitation and land-use change (Gbadamassi et al., 2025). Bark harvesting, particularly by ring-barking, can reduce the survival and reproductive capacity of harvested trees, and the consequences differ among species. In South Africa, heavy harvesting of *Curtisia dentata* bark (68% of trees) reduced the number of large reproductive individuals, whereas *Ocotea bullata*, although also heavily harvested, appeared relatively unaffected (Leaver and Cherry, 2025). In Ghana, the bark recovery rates of four medicinal tree species differed markedly after harvesting (Mohammed et al., 2022).

Secondary metabolites function as a primary chemical defence against biotic and abiotic stress (Khan et al., 2025), and flavonoid content in particular changes under different stress conditions (Shomali et al., 2022). Chronic bark removal may therefore alter the concentrations of bioactive compounds in the remaining bark, although the composition of bark extracts also depends on tree age, species, bark maturity, harvest season and soil conditions (Szmechtyk and Małecka, 2024). Quantitative comparisons of bark from heavily and lightly harvested trees of *V. paradoxa* and *P. africana* in the Sudan savanna are lacking.

This study therefore compared the phytochemical composition of bark from overharvested (OH) and minimally harvested (MH) *V. paradoxa* and *P. africana* trees, and compared the composition among four LGAs of Jigawa State (Kazaure, Gwiwa, Roni and Yankwashi).

2 Materials and methods

2.1 Study area

The study was conducted in four Local Government Areas (LGAs) of Jigawa State, northern Nigeria: Kazaure (12°39'N, 8°25'E), Gwiwa (12°45'N, 8°17'E), Roni (12°35'N, 8°20'E) and Yankwashi (12°45'N, 8°31'E). Together they span approximately latitudes 12°35'–12°45'N and longitudes 8°17'–8°31'E. The area lies within the Sudan savanna ecological zone, which is characterised by a marked wet season followed by a prolonged dry season, relatively low and erratic rainfall, and an open vegetation structure of sparse, scattered trees over a continuous herbaceous layer. The woody vegetation is dominated by drought-tolerant, fire-resistant species, and tree density and species richness are generally low compared with the more humid Guinea savanna to the south (Abdulrashid et al., 2022).

2.2 Tree selection and sampling

Trees of *V. paradoxa* and *P. africana* were identified and tagged in each LGA and classified as overharvested (OH; ≥50% of bark removed within the preceding two to three years) or minimally harvested (MH; little or no bark removed). Bark samples were collected following ethical and botanical guidelines to minimise further damage to the trees. A total of 17 samples were analysed. Sample codes follow the format species–LGA–harvesting class–tree number (for example, VP-KAZ-OH-T01 denotes *V. paradoxa*, Kazaure, overharvested, tree 1). *Prosopis africana* was sampled in Kazaure only.

The distribution of the bark samples is given in Table 1.

Table 1. Distribution of bark samples by LGA, species and harvesting class.

LGA	Species	Overharvested (OH)	Minimally harvested (MH)	Total
Kazaure	<i>P. africana</i>	2	2	4
	<i>V. paradoxa</i>	2	2	4
Gwiwa	<i>V. paradoxa</i>	1	2	3
Yankwashi	<i>V. paradoxa</i>	1	2	3
Roni	<i>V. paradoxa</i>	2	1	3
Total		8	9	17

OH, overharvested; MH, minimally harvested.

2.3 Phytochemical analysis

Phytochemical analyses were carried out at the Department of Pharmacognosy and Herbal Medicine, Faculty of Pharmaceutical Sciences, Bayero University, Kano. Qualitative screening for saponins (frothing test), tannins (ferric chloride test), flavonoids (alkaline reagent test), alkaloids (Dragendorff's test), cardiac glycosides (Keller–Killiani test), terpenoids (Salkowski test), steroids (Liebermann–Burchard test) and phenols was performed using standard procedures (Harborne, 1998; Sofowora, 2008).

Saponins were quantified gravimetrically as the *n*-butanol fraction of an 80% methanolic extract, and flavonoids as the dry weight of the 80% methanolic extract, each expressed as a percentage of the initial sample weight (Harborne, 1998; Sofowora, 2008). Tannins and cardiac glycosides were determined spectrophotometrically against standards (cardiac glycosides by the Baljet reaction, absorbance at 495 nm) and expressed as percentages of the initial sample weight. Alkaloids were quantified as a percentage of the initial sample weight using the gravimetric method of Harborne (1998).

2.4 Statistical analysis

Concentrations are presented as mean $\pm$ standard deviation. Overharvested and minimally harvested trees were compared within each species using Welch's *t*-test. Among LGAs, *V. paradoxa* concentrations were compared by one-way analysis of variance followed by Tukey's HSD test; the Kruskal–Wallis test was used as a non-parametric check. Differences were considered significant at $p < 0.05$. Comparison among LGAs was not possible for *P. africana*, and within-LGA comparisons of harvesting classes are presented descriptively because of the small number of trees per cell. Analyses were performed in Python using the SciPy library.

3 Results

3.1 Qualitative phytochemical composition

Saponins, flavonoids, tannins, alkaloids, cardiac glycosides, terpenoids, phenols and steroids were detected in all 17 bark samples of both species, irrespective of harvesting class and LGA.

3.2 Overharvested versus minimally harvested trees

In *V. paradoxa*, overharvested trees ($n = 6$) had significantly higher saponin content than minimally harvested trees ($n = 7$) ($10.67 \pm 1.59\%$ vs $8.24 \pm 1.85\%$; $p = 0.028$) and significantly higher cardiac glycoside content ($0.86 \pm 0.10\%$ vs $0.73 \pm 0.08\%$; $p = 0.032$) (Table 2). Flavonoid content was higher in overharvested trees ($16.33 \pm 4.68\%$ vs $12.34 \pm 3.27\%$) and tannin content was marginally higher ($2.64 \pm 0.25\%$ vs $2.49 \pm 0.36\%$), but neither difference was significant ($p = 0.114$ and $p = 0.374$). Alkaloid content did not differ significantly ($1.50 \pm 0.55\%$ vs $1.86 \pm 0.90\%$; $p = 0.401$). In *P. africana* ($n = 2$ per group), no compound differed significantly between harvesting classes ($p = 0.333$ – 0.757).

Table 2. Phytochemical concentrations (% , mean $\pm$ SD) in bark of overharvested (OH) and minimally harvested (MH) trees.

Species	Compound	Overharvested (OH)	Minimally harvested (MH)	p-value
<i>V. paradoxa</i>	Saponins	10.67 ± 1.59	8.24 ± 1.85	0.028*
	Flavonoids	16.33 ± 4.68	12.34 ± 3.27	0.114
	Tannins	2.64 ± 0.25	2.49 ± 0.36	0.374
	Alkaloids	1.50 ± 0.55	1.86 ± 0.90	0.401
	Cardiac glycosides	0.86 ± 0.10	0.73 ± 0.08	0.032*
<i>P. africana</i>	Saponins	6.00 ± 2.26	8.70 ± 0.42	0.333
	Flavonoids	12.00 ± 2.83	13.00 ± 2.83	0.757
	Tannins	2.35 ± 0.50	2.08 ± 0.05	0.574
	Alkaloids	1.50 ± 0.71	1.00 ± 0.00	0.500
	Cardiac glycosides	0.83 ± 0.11	0.77 ± 0.02	0.564

*Significant at $p < 0.05$ (Welch's *t*-test). *V. paradoxa*: OH, $n = 6$; MH, $n = 7$. *P. africana*: OH, $n = 2$; MH, $n = 2$.

3.3 Comparison among local government areas

Among the four LGAs, flavonoid content in *V. paradoxa* differed significantly ($F = 5.80$, $p = 0.017$; Kruskal–Wallis $p = 0.048$) (Table 3). Kazaure ($17.50 \pm 2.65\%$) and Roni ($17.00 \pm 3.61\%$) had the highest values and Gwiwa ($10.00 \pm 1.73\%$) and Yankwashi ($11.13 \pm 3.44\%$) the lowest; the only significant pairwise difference was between Kazaure and Gwiwa (Tukey $p = 0.035$). Saponin ($p = 0.772$), tannin ($p = 0.375$) and alkaloid ($p = 0.340$) contents did not differ among LGAs. Cardiac glycoside content was highest in Roni ($0.92 \pm 0.05\%$) but the difference was not significant ($p = 0.135$).

Table 3. Phytochemical concentrations (% , mean $\pm$ SD) in bark of *Vitellaria paradoxa* among LGAs.

LGA	n	Saponins	Flavonoids	Tannins	Alkaloids	Cardiac glycosides
Kazaure	4	10.10 ± 2.50	17.50 ± 2.65 a	2.75 ± 0.36	1.75 ± 0.96	0.74 ± 0.11
Gwiwa	3	9.50 ± 1.13	10.00 ± 1.73 b	2.33 ± 0.33	1.00 ± 0.00	0.75 ± 0.12
Yankwashi	3	8.27 ± 3.33	11.13 ± 3.44 ab	2.56 ± 0.28	2.00 ± 1.00	0.78 ± 0.09
Roni	3	9.33 ± 1.22	17.00 ± 3.61 ab	2.52 ± 0.16	2.00 ± 0.00	0.92 ± 0.05
p-value (ANOVA)		0.772	0.017*	0.375	0.340	0.135

*Significant at $p < 0.05$ (one-way ANOVA). Means sharing a letter within a column do not differ significantly (Tukey's HSD, $p < 0.05$).

Within each LGA, saponin and cardiac glycoside contents of *V. paradoxa* were higher in overharvested than in minimally harvested trees in all four LGAs (Table 4). Flavonoid content was higher in overharvested trees in Kazaure, Yankwashi and Roni but lower in Gwiwa. Tannin content was higher in overharvested trees in Kazaure and Gwiwa and lower in Yankwashi and Roni, and alkaloid content was lower or equal in overharvested trees in all LGAs. In Kazaure, where both species were sampled, *P. africana* showed no consistent difference between harvesting classes (Table 2).

Table 4. Mean phytochemical concentrations (%) in bark of *Vitellaria paradoxa* by harvesting class within each LGA.

LGA	Class	n	Saponins	Flavonoids	Tannins	Alkaloids	Cardiac glycosides
Kazaure	OH	2	10.60	18.50	2.93	1.50	0.78
	MH	2	9.60	16.50	2.59	2.00	0.70
Gwiwa	OH	1	10.80	8.00	2.71	1.00	0.87
	MH	2	8.85	11.00	2.14	1.00	0.70
Yankwashi	OH	1	12.00	15.00	2.43	1.00	0.88
	MH	2	6.40	9.20	2.63	2.50	0.73
Roni	OH	2	10.00	19.00	2.43	2.00	0.94
	MH	1	8.00	13.00	2.70	2.00	0.89

OH, overharvested; MH, minimally harvested. Values are descriptive; n per cell ranges from 1 to 2.

4 Discussion

The detection of all screened phytochemical classes in every sample shows that bark removal did not eliminate any class of compounds from either species. This agrees with the diversity of phytoconstituents, including triterpene glycosides and flavonoids, reported for *V. paradoxa* (Ojo et al., 2021) and with the bioactive properties reported for *P. africana* (Yanda et al., 2022). The tests are qualitative, however, and the quantitative data are more informative about the effect of harvesting.

In *V. paradoxa*, saponins and cardiac glycosides were present at higher concentrations in OH trees, and the same direction was observed in each of the four LGAs. This pattern is consistent with the role of secondary metabolites as defence compounds that accumulate under stress (Khan et al., 2025) and with reported changes in flavonoid content under stress conditions (Shomali et al., 2022), although the mechanisms by which stress modulates the accumulation of individual compound classes are not fully understood (Khan et al., 2025). Flavonoids and tannins also tended to be higher in OH trees, but not significantly, and alkaloids showed no consistent trend. The higher concentrations in OH trees should be interpreted with caution: a stress response is one explanation, while differences in tree age, size, bark maturity, microsite or sampling season, which were not controlled, may also contribute, since each of these factors influences the composition of bark extracts (Szmechtyk and Małecka, 2024). Higher concentrations of individual compounds do not by themselves establish improved therapeutic quality, and they do not offset the damage that repeated debarking can cause to tree survival and regeneration (Leaver and Cherry, 2025).

Quantitative data on the bark of both species are scarce, and published values vary with extraction solvent, quantification method and the age and maturity of the bark (Szmechtyk and Małecka, 2024). Comparisons with other studies should therefore take the methods into account, and the present concentrations are best compared within the study.

The contrast between the response of *V. paradoxa* and the absence of a detectable response in *P. africana* may reflect species-specific responses to harvesting. Bark recovery after harvesting differed among four medicinal tree species in Ghana (Mohammed et al., 2022), and two heavily harvested South African medicinal trees were affected differently, with severe effects on the population structure of one species but not the other (Leaver and Cherry, 2025). Nevertheless, with only two trees per harvesting class, the *P. africana* result cannot be interpreted conclusively.

The significant difference in flavonoid content among LGAs, with higher values in Kazaure and Roni than in Gwiwa, indicates that site-related factors influence bark chemistry independently of harvesting class, in line with the dependence of bark composition on season and soil conditions (Szmechtyk and Małecka, 2024). Such factors were not measured in this study, and the small number of trees per LGA limits the inference that can be drawn. Notably, the direction of the harvesting effect on flavonoids differed between Gwiwa and the other LGAs, which suggests that site conditions may modify the response of bark chemistry to harvesting; this requires confirmation with larger samples.

From a conservation perspective, the persistence of bark chemistry after heavy harvesting does not make heavy harvesting sustainable. In Ghana, minimal harvesting was recommended for a species with slow bark recovery and rotation periods for repeated harvest of species that recover more readily (Mohammed et al., 2022), and a moratorium on harvesting and regeneration assessments were recommended for a heavily harvested South African species (Leaver and Cherry, 2025). Similar species-specific guidance is needed for *V. paradoxa* and *P. africana*.

For *P. africana* only two trees per harvesting class were available, all from Kazaure, so the absence of significant differences cannot be interpreted as absence of an effect.

5 Conclusion

Bark of *V. paradoxa* and *P. africana* from overharvested and minimally harvested trees in Kazaure, Gwiwa, Roni and Yankwashi LGAs contained all eight screened phytochemical classes. In *V. paradoxa*, overharvested trees had significantly higher saponin and cardiac glycoside concentrations than minimally harvested trees, with the same direction in all four LGAs, while flavonoid concentration varied significantly among LGAs, being higher in Kazaure than in Gwiwa. No significant harvesting effect was detected in *P. africana*, for which the sample was small. These findings are exploratory and indicate that bark chemistry in these species responds to harvesting history and varies with locality.

6 Recommendations

1. Herbalists, harvesters and community leaders should be trained in sustainable harvesting, supported by community-based monitoring of harvested trees.
2. Further studies should increase the number of replicate trees per harvesting class and LGA, particularly for *P. africana*, control for tree size, age, site and season, and include analytical replicates and validated quantification methods.
3. Future work should combine bark chemistry with measurements of tree health, mortality and regeneration, and with survey data on harvesting practices, to assess the conservation consequences of bark extraction.

Acknowledgements

The authors sincerely acknowledge the Tertiary Education Trust Fund (TETFund) for providing financial support for this research through its Institution-Based Research (IBR) intervention. The authors also express profound appreciation to Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa State, for its institutional support and for providing the enabling environment for the successful conduct of the research. The financial assistance and institutional support received are gratefully acknowledged and were instrumental in facilitating the research activities and the development of its findings.

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