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Research article

Anti-inflammatory and antioxidant properties of bark and fruit extracts of *Faidherbia albida* (Delile) A. Chev: A perspective from bio-prospecting assays to scientometric approach

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Abstract: *Faidherbia albida (Delile) A. Chev*, a type of tree in the Leguminosae family, has several traditional uses. This study investigates the antioxidant properties, phenolic and flavonoid contents, nitric acid modulatory effects, and cytotoxicity of methanolic and chloroform extracts of the bark and fruits of *Faidherbia albida*. Various assays were performed to evaluate the antioxidant properties of the extracts, including the Folin-Ciocalteu and $AlCl_3$ tests, the oxygen radical absorbance capacity (ORAC), the purple diphenyl picrylhydrazine (DPPH) scavenging ability, and the Ferric Reducing/Antioxidant Power (FRAP). The ability of the extracts to modulate the production of nitric

oxide (NO) was assessed, and the cytotoxicity of the extracts was evaluated in cultured cells. Additionally, a bibliometric analysis was performed on related research documents. The 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay was used to evaluate the cytotoxicity of the extracts in cultivated RAW 264.7 cells. A bibliometric analysis of 362 research documents related to *F. albida* published since 1913 was performed to understand the current state of knowledge to identify areas for further research using bibliometric computer packages. The results showed that the bark methanolic extract had the highest phenolic content, while the chloroform extract of the fruits had the highest flavonoid content. The chloroform extract of the fruits exhibited the highest inhibition of NO production. The extracts exhibited low cytotoxicity. The methanolic extract of the bark exhibited the strongest radical scavenging activities for FRAP and DPPH. The ORAC assay revealed that the antioxidant capacity of the methanolic extract of the fruits and the chloroform extract of the bark were approximately four times greater than that of quercetin, which is a known antioxidant compound. *F. albida* exhibits a significant antioxidant activity, which is influenced by both solvent polarity and specific botanical components.

Keywords: antioxidants; bibliometrics; *Faidherbia albida*; functional foods; nitric oxide

1. Introduction

Plants serve as the primary source of molecules that are used to create new drugs, and attracts the interest of multinational industries in exploring compounds derived from plants [1]. Many plant species remain understudied in terms of their biological and chemical properties, particularly their potential to alleviate inflammation and oxidative stress [2]. Anti-inflammatory medications can inhibit the inflammatory process, minimize tissue damage, and improve a patients' comfort levels [3]. Therefore, the effective development of new natural anti-inflammatory drugs is based on a multidisciplinary approach to discover new molecules from the wide range of plants available for investigation. Some plant compounds, such as antioxidants, exhibit various biopharmaceutical effects [4]. Phenolic compounds possess anti-inflammatory properties by modulating the arachidonic acid pathway and by inhibiting various enzymes, including hydrolases, ATPase, lipoxygenase, cyclooxygenase, prostaglandin, protein kinase, tyrosinases, NADH oxidase, metallopeptidases, peroxidases, and phospholipases. These compounds effectively suppress the production of inflammatory mediators, making them a subject of growing research for potential therapeutic applications to either inhibit or reducing inflammation [5,6].

F. albida, a type of tree in the Leguminosae family, has many traditional uses and is indigenous to Cameroon, Lesotho, Ethiopia, Kenya, Lebanon, Eritrea, Senegal, Somalia, Sudan, Swaziland, Tanzania, Uganda, and Zimbabwe. In West African agroforestry, it often planted with spacing between individual plants and intercropped with sorghum and millet. It has a robust root system, though its wood is not durable. The taxonomy of the species is still being clarified, and the name has been changed between *F. albida and Faidherbia albida* [7–9].

F. albida found to be rich in tannins, alongside alkaloids and phenols [10]. Phytochemical screening of the pod and bark extracts revealed the presence of various compounds including alkaloids, tannins, saponins, sterols, phenols, and triterpenes, with the pod extract additionally containing flavonoids and cardiac glycosides [11]. *F. albida* is commonly used in various applications, including either the topical application or oral consumption of its bark and roots to treat respiratory infections,

digestive problems, malaria, and fevers. The bark is said to contain fluorine, which suggests its potential for cleaning teeth. In addition, a bark extract is used to alleviate toothaches in humans and to treat eye infections in cattle [10,12]. Moreover, it is known to act as an emetic in fevers according to the Masai tradition and is traditionally used in Tanganyika for the treatment of diarrhea. In West African medicine, it used to treat colds, diarrhea, bleeding, and ophthalmia. Diarrhea treated with the bark of the Ana tree in several cultures, while leprosy is treated in Côte d'Ivoire. Nausea can be alleviated with a bark decoction. In cases of pneumonia, a steep bark cream can be used to wash and massage. Bark infusion helps in difficult deliveries and serves as a cough suppressant and febrifuge. The pods are worn as charms to protect African mothers and children from smallpox [11,13,14]. Therefore, this study aims to explore the antioxidant properties of *F. albida* using cellular and chemical models, and focuses on identifying the phytochemicals responsible for altering the properties of free oxygen and nitrogen radicals in these models. The study aims to review the current literature using advanced analytical tools.

2. Materials and methods

2.1. Preparation of plant specimen and extract

In April 2022, *F. albida* underwent a botanical collection at the Wadelmak Botanical Garden in Elnohoud, Sudan. The plant sample was identified by Dr. Wael Ali, and the voucher samples were preserved at the Jazan University Herbarium of the Medical Research Center (MRC-FA-1443-15). Each component was washed, dried in the shade for a week, and powdered. The powder then subjected to sequential extraction using methanol and chloroform solvents. The plant material was steeped in each solvent for three days. Subsequently, the solvents were removed using a rotary evaporator and the extracts were stored at 4 ℃ until needed. Four extracts were obtained: the chloroform extract of the fruits (FC), the methanolic extract of the fruits (FM), the chloroform extract of the bark (BC), and the methanolic extract of the bark (BM). Then, these extracts were tested against the following assays.

2.2. Total phenolic (TPC) and flavonoid (TFC) content

The total phenolic content (TPC) of *F. albida* was determined using the Folin-Ciocalteu technique [15]. Methanolic extracts of the plant were prepared at a concentration of 10 mg/mL. A small volume of the extract was mixed with the Folin-Ciocalteu reagent and a sodium bicarbonate solution. After a specified incubation period, the absorbance was measured at 765 nm. The TPC was calculated using a gallic acid standard curve and was expressed as the gallic acid equivalent (GAE) in milligrams per gram of extract.

The total flavonoid content (TFC) in the samples was determined using quercetin as a reference compound [16]. The test samples were dissolved in dimethylsulfoxide (DMSO), mixed with an $AlCl_3$ solution, and incubated. The absorbance of the resulting supernatant was measured at 435 nm. The TFC was reported as the quercetin equivalent (QE). A quercetin curve was generated by plotting the concentration against the absorbance. Both the TPC and TFC measurements were performed in triplicate to ensure the accuracy and reliability of the results.

2.3. Cellular model: Anti-inflammatory activity

In the cellular model of the study, RAW 264.7 cells were cultured in DMEM supplemented with FBS, glucose, antibiotics, L-glutamine, and sodium pyruvate. The cells were maintained at 37 ℃ with 5% CO_2. Before seeding them in a 96-well plate, cell attachment was induced by incubating the cells for two hours. The cell density was adjusted to ensure the viability of more than 90% based on trypan blue exclusion. For stimulation, the cells were treated with IFN-gamma and Lipopolysaccharide (LPS). IFN-gamma is a cytokine that plays a crucial role in immune responses, while LPS is a component of the outer membrane of Gram-negative bacteria and is known to activate immune cells. The cells were stimulated with 100 U/mL of IFN-gamma and 5 mg/mL of LPS in either the presence or the absence of the plant extract. The plant extract was added using dimethyl sulfoxide (DMSO) as the solvent, and a constant final concentration of 0.1% DMSO was maintained in all cultures. After stimulation, the cells were cultured for 17–20 h at 37 ℃ with 5% CO_2. The nitrite levels in the culture supernatant were measured using the Griess assay, which is a commonly used method to detect nitric oxide production [17]. The Griess reagent, which consisted of sulphanilamide and N-(l-naphthyl)-ethylene diamine dihydrochloride dissolved in H_3PO_4, was mixed with the culture supernatant. Color development was measured at 550 nm using a plate reader, and the amount of nitrite was determined using a standard curve prepared with sodium nitrite. Cell viability was assessed using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. After removing the supernatant, the MTT reagents were added to each well and incubated for 4 h at 37 ℃. The MTT reagents were converted by viable cells into formazan salts, which were dissolved using DMSO. The absorbance at 570 nm was measured using a plate reader, and cell viability was determined by comparing it to the cell viability of the IFN-gamma/LPS-induced group. These experimental procedures allowed us to evaluate the inhibitory effect of *F. albida* on nitric oxide production and to assess its cytotoxicity on cultured cells.

2.4. Antioxidant activity

The antioxidant activity of *F. albida* was evaluated using several methods.

2.4.1. DPPH free radical scavenging

The diphenyl picrylhydrazine (DPPH) scavenging method was used to assess the antioxidant activity [18]. The purple DPPH solution, which contains free radicals, was mixed with different concentrations of the plant extract samples. After 30 minutes of the reaction, the absorbance was measured at 518 nm. The percentage of antioxidant activity was calculated using the formula [(AB−AA)/AB] × 100, where AB represents the absorbance of the blank and AA represents the absorbance of the tested sample. Ascorbic acid was used as a positive control.

2.4.2. ORAC antioxidant activity assay

The oxygen radical absorbance capacity (ORAC) assay was performed using a modified Cao technique [19]. Samples were dissolved in PBS and incubated with a fluorescent sodium salt solution. After 45 minutes, an 2,2'-Azodiisobutyramidine dihydrochloride (AAPH) solution added, and the

fluorescence was measured over a two-hour period. The ORAC values were determined by calculating the differences the in areas under the curves between the blank and the sample. The results are reported as Trolox equivalents, which were determined by calculating the differences in the areas under the curves between the blank and the sample using fluorescence measurements. Quercetin served as the positive control.

2.4.3. Ferric reducing/antioxidant power (FRAP) assay

The total antioxidant activity was measured using the Ferric Reducing/Antioxidant Power (FRAP) test [20]. A working solution containing 2, 4, 6-tripyridyl-s-triazine (TPTZ), $FeCl_3 6H_2O$, and an acetate buffer was prepared and heated. The plant extract samples were mixed with the FRAP solution and the resulting ferrous tripyridyltriazine complex was measured at 593 nm. The results were compared to known antioxidants such as Butylated hydroxytoluene (BHT), quercetin, ascorbic acid, and catechin, and were expressed in dry M Fe (II)/g mass.

2.5. Statistical analysis

The reported values represent the mean ± S.E.M. of three independent experiments. The statistical analyses were performed using the GraphPad Prism software. A one-way analysis of variance (ANOVA) followed by the Dunnett test were used for multigroup comparisons. A significance level of $P < 0.05$ was used to determine statistically significant differences between the groups.

2.6. Bibliometric study

The methodology for the bibliometric study on research related to *F. albida* involved data collected from the Scopus database. The search terms used included the scientific name of the plant (*Faidherbia albida or Acacia albida*). The study followed the The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [21] to ensure the inclusion of relevant bibliographic data. The extracted data was compiled into a CSV file format. To analyze the data and visualize the bibliometric networks, the VOS viewer software was employed. VOS viewer enables the analysis of bibliometric networks, including coauthorship, citation, keyword cooccurrence, and journal co-citation. It helps identify key researchers, influential papers, research themes, and collaborative relationships within a field of study. The combination of the Scopus database, the PRISMA guidelines, and the VOS viewer software facilitated a comprehensive bibliometric analysis of the available research on *F. albida*.

3. Results and discussion

This study evaluated the antioxidant properties, total phenolic and flavonoid contents, nitric acid inhibition, and cytotoxic effects of *F. albida* bark and fruit extracts (FC, FM, BC, and BM). Medicinal plants are a key source of new compounds with potential therapeutic applications, and their antioxidant properties can help to prevent diseases. Natural antioxidants have gained the attention of the public and scientists for their health benefits, as oxidative stress has been linked to the pathophysiology of many diseases. Natural antioxidant agents are receiving attention for their ability to eliminate free

radicals, which can damage biological systems [22,23].

3.1. Yield and phenolic and flavonoid contents

Phenolic compounds are commonly present in both edible and non-edible plants and are known for their antioxidant activity [2]. The fruits and bark of *F. albida* extracted using methanol and chloroform solvents resulted in different yields for FC, FM, BC, and BM samples, as shown in Table 1. BM exhibited the highest total phenol content (366.77 ± 20.3 g of GAE/1 mg of extract), followed by FM (113.88 ± 10.3 µg GAE/1 mg of extract). The study showed that both bark and fruit extracts had a high phenolic content, where the bark contained more polyphenols compared to the fruits. Furthermore, the study evaluated the TFC concentration in the four extracts, and revealed that the TFC concentrations were not influenced by the polarity of the extract, although FC had a higher TFC concentration compared to BM. The polar extracts of plants have higher antioxidant activity compared to nonpolar extracts because they contain more soluble polar compounds, such as phenolic compounds and flavonoids. These compounds have strong antioxidant properties and can effectively neutralize free radicals. Nonpolar extracts, which contain nonpolar compounds such as lipids and essential oils, exhibit a lower antioxidant activity. Therefore, the presence of polar compounds in polar extracts contributes to their superior antioxidant activity [24].

Table 1. Yield and phenolic content.

F. albida	Samples	Starting plant material (g)	Weight of the extract (g)	Yield (%)	TPC (µg GAE/1mg extract)	TFC (mg QE 1g extract)
Fruits	FC	50	0.4712	0.94	32.32 ± 4.19^{a}	63.23 ± 1.25^{a}
	FM		5.88	11.76	113.88 ± 10.3^{b}	21.88 ± 1.25^{b}
Bark	BC	35	0.131	0.38	41.54 ± 1.15^{c}	36.26 ± 1.94^{c}
	BM		1.662	4.75	366.77 ± 20.3^{d}	58.30 ± 2.31^{a}

Note: FC: chloroform extract of fruits; FM: methanolic extract of fruits; BC: bark chloroform extract of bark; BM: methanolic extract of bark; TPC: total phenolic content; TFC: total flavonoid content; GAE: gallic acid equivalent; QE: quercetin equivalent. All values are mean ± S.E.M. of three different experiments.

3.2. Effects of extracts on murine cell viability and nitric oxide excretion

Nitric oxide (NO) inhibitors have shown promise in the treatment of inflammatory diseases [25]. It's an inflammatory mediator, and plays a role in various physiological and pathological processes, particularly in activated macrophage cells [26]. Inhibition of NO synthesis has been an important pharmacotherapy approach. This study investigated the effects of FC, FM, BC, and BM on NO production in macrophage cells. RAW 264.7 cells were induced with IFN-/LPS to simulate inflammation, which resulted in PGE_2 production as a reference value (100%). Among the extracts, FC showed the highest inhibition of NO in the culture medium (47.89% ± 2.47) at a concentration of 50 µg/mL that could be due the high TFC of this extract type. A significant difference was observed between the higher concentration of FC and the two lower concentrations. The control drug exhibited a 72% inhibition rate (Table 2). However, there was concern about the possibility that the selective

inhibition of FC, FM, BC, and BM in murine macrophage cells (RAW 264.7) was a false positive result due to the cytotoxic effects of these extracts. To address this, the cytotoxicity effects of FC, FM, and BM were evaluated using the MTT assay. Olonishuwa et al. reported NO inhibition of *F. albida* [27].

Table 2. Effect of *F. albida* extracts on nitric oxide activities on lipopolysaccharide/interferon-γ stimulated RAW cells *in vitro.*

Extracts		Concentration (µg/mL)		
		50	25	12.5
F. albida	Percentage of inhibition			
Fruits	FC	47.89 ± 2.47	21.93 ± 1.23	22.84 ± 1.25
	FM	27.41 ± 4.27	23.21 ± 2.41	20.11 ± 1.84
Bark	BC	20.11 ± 1.48	20.11 ± 1.82	20.11 ± 2.11
	BM	30.21 ± 2.48	26.28 ± 3.14	19.43 ± 1.78
Control drug		72.12 ± 4.15		

Note: FC: chloroform extract of fruits; FM: methanolic extract of fruits; BC: chloroform extract of bark; BM: methanolic extract of bark; TPC: phenolic content; GAE: gallic acid equivalent.

Figure 1 shows that there were no significant changes in the cell viability after treatments with either FC, FM, BC, or BM. This finding helps to dismiss the hypothesis that the inhibitory action is caused by the cytotoxicity of these extracts. A prior investigation demonstrated that the foliage, fruits, and stem bark of *F. albida* possessed a wide range of non-toxic chemical compounds, which provided a valid basis for their utilization in ethnomedicine [11].

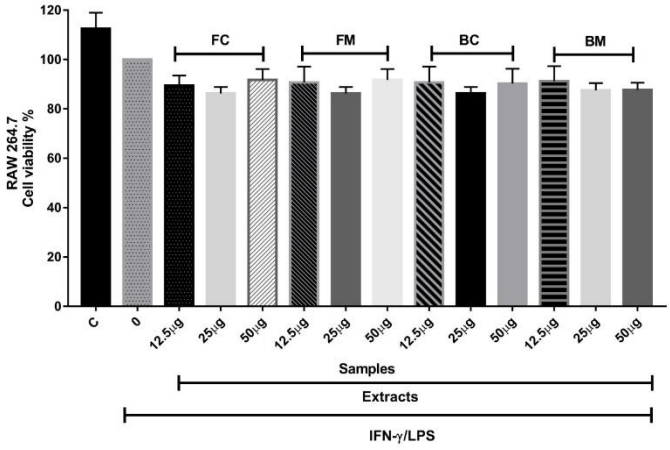

Figure 1. Effects of *F. albida* on RAW264.7 cell viability. Cells induced with a mixture of IFN-γ/LPS and treated with elevated doses of the extracts (12.5, 25, and 50 µg/mL). Cellular viability measured using the MTT test. C: control cells without IFN-γ/LPS induction; FC: chloroform extract of fruits; FM: methanolic extract of fruits; BC: chloroform extract of bark; BM: bark methanolic extract. All values are mean ± SEM of three different experiments.

3.3. Total antioxidant content

The FRAP test is commonly used in nutritional research to measure the total antioxidant content of meals and to study antioxidant absorption from diets [23]. The test is suitable evaluate low-molecular weight antioxidants with hydrophilic and/or hydrophobic properties [28]. It has been used to compare plant and animal antioxidant activities. In this study, the FRAP assay was performed on FC, FM, BC, BM, gallic acid, ascorbic acid, rutin, quercetin and Trolox, and the results are expressed as FRAP values. The polar bark extract (BM) exhibited a significantly different FRAP value compared to the other plant samples, measuring 4162.22 ± 14.52 (See Table 3). The polar fruit extract had the second highest score (1148.89 ± 20.72), though it did not statistically differ from the nonpolar bark extract. Surprisingly, the FRAP value of BM exceeded that of the positive control samples, which could be due to the total phenolic content of the BM extract. The polarity of antioxidants affects their micromechanics, and previous studies have shown that increasing the length of the alkyl chain reduces the polarity and influences the antioxidant efficacy[29,30]. The results indicate that the antioxidant property increases with the solvent polarity.

Table 3. FRAP assay: total antioxidant content.

Samples		FRAP
Fruits	FC	158.89 ± 10.502
	FM	1148.89 ± 20.72
Bark	BC	1190.00 ± 34.90
	BM	4162.22 ± 14.52
Positive controls	Galic acid	2885.56 ± 121.50
	Ascorbic acid	461.11 ± 11.25
	Retin	825.00 ± 68.95
	Quercetin	2561.11 ± 90.26
	Trolox	922.78 ± 81.575

Note: FRAP: iron-reducing antioxidant power; FC: chloroform extract of fruits; FM: methanolic extract of fruits; BC: chloroform extract of bark; BM: methanolic extract of bark. All values mean ± S.E.M. of three different experiments.

3.4. The oxygen radical absorbance capacity

The ORAC assay is a widely used method to detect antioxidants. It operates on the principle that the chemical 2,2-azobis(2-amidinopropan) dihydrochloride generates oxygen radicals (ROS) that are capable of oxidizing fluorescein [31]. The results of the ORAC assay (Figures 2 and 3) showed that the antioxidant activities of FM (ORAC values = 840.71±1.25 μmol TE/g) and BC (ORAC values = 818.29 ± 3.30 μg/mL (μM)) were approximately four times stronger than Quercetin (ORAC values = 219.49 ± 0.48 μg/mL (μM)). This suggests that *F. albida* has a significant antioxidant potential.

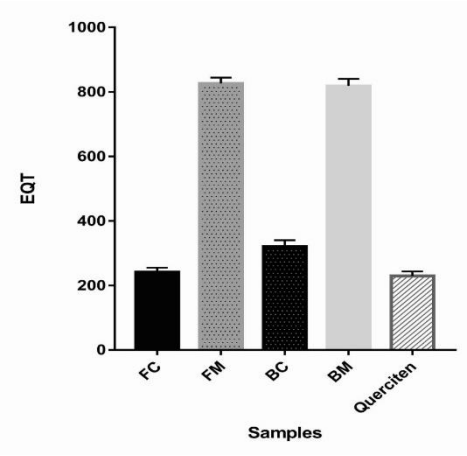

Figure 2. Antioxidant activity of *F. albida extracts* in the ORAC assay. FC: chloroform extract of fruits; FM: methanolic extract of fruits; BC: chloroform extract of bark; BM: methanolic extract of bark. All values are mean ± S.E.M. of three different experiments.

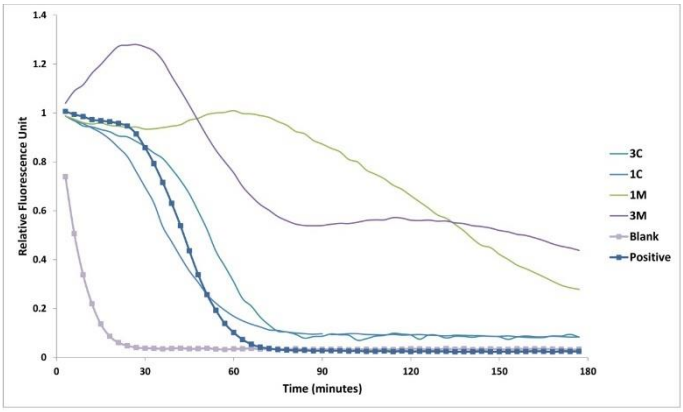

Figure 3. The fluorescence decay curves (AUC) of the samples compared to Quercetin (5µg/mL) and Blank (PBS). The plot shows that most samples have protective effects on fluorescein fluorescence over time, more in comparison to quercetin. This will eventually give them a higher Net AUC value compared to Quercetin when calculated. 1M: methanolic extract of the fruits; 1C: chloroform extract of the fruits; 3C: chloroform extract of the bark; 3M: methanolic extract of the bark. All values are mean ± S.E.M. of three different experiments.

3.5. DPPH radical cleaning activity

The DPPH scavenging assay is a simple and effective method to evaluate the antioxidant scavenging activity. In this assay, the DPPH radical, which is a stable free radical, was used to assess the antioxidant activity of natural substances. When neutralized, the purple color of DPPH changes to yellow, which indicates the degree of antioxidant activity [18,19]. In this study, all extracts demonstrated the ability to eliminate free radicals (Table 4). This indicates the concentration at which the DPPH absorbance is reduced by 50% compared to the blank. The ability of antioxidants to donate hydrogen is believed to contribute to their impact on DPPH elimination.

Table 4. DPPH radical scavenging activity in extracts of bark and fruits of *F. albida*.

		DPPH radical activity (IC_{50} μg/mL)
Fruits	FC	>50
	FM	2.43 ± 0.21^{a}
Bark	BC	>50
	BM	2.13 ± 0.17
Positive control	Galic acid	2.9 ± 0.62^{a}
	Ascorbic acid	7.2 ± 0.33^{b}
	Retin	12 ± 1.4^{c}
	Quercetin	3.12 ± 0.50^{a}

Note: All significant differences are at $P < 0.05$. Values having the same alphabets are significantly different from each other.

A previous study demonstrated that phenolic compounds from *F. albida* organs were very potent in the scavenging of in vitro free radicals DPPH and ABTS, and could have excellent iron-reducing power [32]. Mohammed and his research group isolated eight compounds from the ethanolic extract of the leaves of *F. albida*. They suggested that the antioxidant properties of this tropical tree might be due to the existence of these phenolic compounds when tested using the DPPH assay [33]. Additionally, the antioxidant properties and the identification of the phenolic content by HPLC-DAD were reported in different organs of *F. albida* [34].

3.6. Bibliometric study

A total of 362 publications were published in two hundred sources in 1913–2023. These documents were authored by 1,125 individuals affiliated with 896 institutions in seventy-four countries. The authors who have the most publications are Dreyfus, M., Roupsard, O. from France, and Birhane, E. The leading production organizations are the Interamerican Association for Environmental Defense (AIDA), the University of Montpellier (France) and United Mission for ReleifT (UMR) (Senegal). The authors utilized Agroforestry Systems, Forest Ecology and Management, and the Journal of Arid Environments as platforms to disseminate their publications on *F. albida*. Senegal, Ethiopia, and France have published the highest number of publications.

The prevalence of research on *F. albida* in African countries attributed to factors such as its indigenous knowledge and traditional medicinal use, the rich biodiversity and flora of Africa, efforts to manage sustainable resources, cultural importance, and collaboration with international institutions. These factors have stimulated interest in investigating the antioxidant and medicinal properties of *F. albida*, thus leading to a significant body of research in African countries. The studies aimed to validate traditional uses, explore new therapeutic applications, and contribute to the understanding of the potential benefits of this plant.

3.7. Mapping of knowledge structure

A total of 1,170 author keywords were analyzed to map the knowledge in the study. Among them, thirty-nine keywords occurred at least ten times. From these highly occurring keywords, nine clusters

were identified. Figure 4A shows the main keywords that occurred, including *Faidherbia albida*, *Acacia albida*, agroforestry, Ethiopia, nitrogen fixation, and Brady rhizobium. These keywords reflect the focus of the research on the habitat of trees and various branches of forest research. *F. albida* is a nitrogen-fixing tree species native to Africa. It has the potential to play an important role in sustainable agriculture and land management by improving the soil fertility, increasing the crop yields, and providing other benefits to the farmers and livestock [35]. The green cluster specifically emphasizes the genetic studies of this tree. In Figure 4B, the trending topics are highlighted, including remote sensing, climate change, soil depth, *Acacia tortilis*, and Burkina Faso. A previous study found that *F. albida* trees increased the soil moisture content at depths of 20–30 cm in a semi-arid region of Kenya. This increased soil moisture content was associated with increased maize yields [36]. A previous study concluded that climate change is a serious threat to the distribution and survival of *F. albida* in Ethiopia. The study recommended that conservation efforts should focus on protecting existing *F. albida* populations and planting new trees in areas that are projected to remain suitable for the species under climate change [37]. Figure 5 illustrates the co-authorship networks among countries. Countries represented as nodes, and collaborations as links. Based on TLS values, the United States emerged as the leading collaborative country.

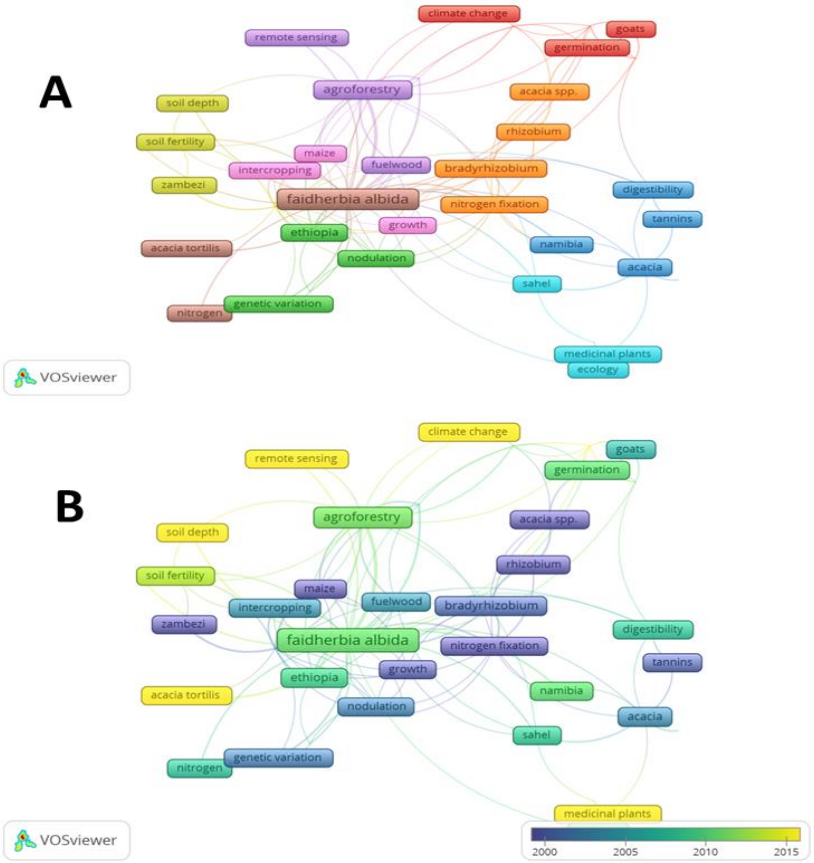

Figure 4. Mapping of the knowledge structure. A: 1170 keywords used to map the knowledge. Thirty-nine of these keywords met the minimum of four occurrences. Nine clusters extracted from these highly occurring keywords. To analyze the data and visualize the bibliometric networks, VOS viewer software was employed. This software allows for the examination of keyword associations within the collected literature. B: Temporal analysis. Trending topics shown in yellow.

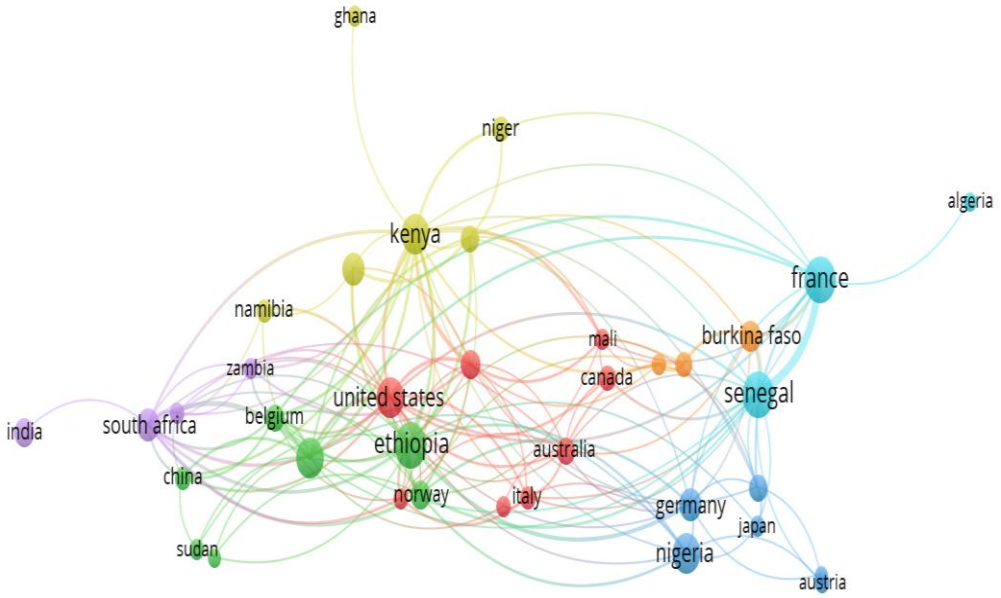

Figure 5. The co-authorship networks among countries analyzed using VOS viewer, where countries represented as nodes, and collaborations as links. Based on TLS values, the United States emerged as the leading collaborative country.

4. Conclusions

In conclusion, the findings of this investigation showed that the aqueous and nonpolar extracts of both the bark and the fruits of *F. albida* have the potential to function as antioxidants, where the bark exhibited more effective actions compared to the fruits. According to the findings of these experiments, the therapeutic benefits of this plant may be attributable to its antioxidant potential. However, more research is required to investigate its potential utility in preventing and treating various disorders. The bibliometric study of the plant suggested research gaps. Additionally, the study recommendations were aimed to guide further research, improve scientific collaboration, ensure consistency in the methodologies, protect the plant populations, and promote the practical application of research findings. Bibliometric studies face limitations in capturing nuanced research impacts, but offer promising future perspectives through evolving methods and interdisciplinary applications to understand scholarly trends and dynamics.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Conflict of interest

All authors declare no conflicts of interest in this paper.

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