Magna Scientia Advanced Biology and Pharmacy

eISSN: 2582-8363

Cross Ref DOI: 10.30574/msabp

Journal homepage: https://magnascientiapub.com/journals/msabp/

(RESEARCH ARTICLE)

Check for updates

Antibacterial, Antioxidant potential, nutritional value and phytochemical content of the fruits of *Dacryodes edulis* (Burseraceae) and *Litchi chinensis* (Sapindaceae) from the Democratic Republic of Congo

Bashige Chiribagula Valentin [1,*], Ngoie Kyampoyo Laurette [1], Manya Mboni Henri [1], Bakari Amuri Salvius [2] and Okusa Ndjolo Philippe [1]

[1] *Department of Pharmacology, Laboratory of Therapeutic Chemistry and Analysis of Natural Substances, Faculty of Pharmaceutical Sciences, University of Lubumbashi (UNILU), 27, av. Kato, Commune Kampemba, Lubumbashi, DR Congo.*
[2] *Department of Pharmacology, Laboratory of Pharmacognosy, Faculty of Pharmaceutical Sciences, University of Lubumbashi (UNILU), 27, av Kato, Commune Kampemba, Lubumbashi - DR Congo.*

Magna Scientia Advanced Biology and Pharmacy, 2025, 15(02), 075-088

Publication history: Received on 10 July 2025; revised on 17 August 2025; accepted on 19 August 2025

Article DOI: https://doi.org/10.30574/msabp.2025.15.2.0058

Abstract

Dacryodes edulis (DAED) and *Litchi chinensis* (LICH) fruits are staples in Haut-Katanga (DRC) and traditionally used in Lubumbashi to treat gastrointestinal, urinary and respiratory infections despite a lack of efficacy data. This study assessed the antibacterial activity of DAED and LICH fruit extracts against six pathogens—*Escherichia coli*, *Salmonella typhi*, *Shigella sonnei*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Streptococcus pneumoniae*—and simultaneously characterized their nutritional profiles, radical-scavenging capacity and phytochemical content (polyphenols, flavonoids, tannins). Antibacterial efficacy was determined by broth microdilution (MIC) and agar diffusion (inhibition zone diameters), antioxidant potential by DPPH assay, and nutritional–phyto-chemical composition by spectrophotometric quantification of dietary fiber, reducing sugars, vitamin E, minerals and bioactive groups. Both extracts exhibited strong antibacterial activity, notably against *E. coli* and *K. pneumoniae* (MIC 3.1–6.3 µg/mL; inhibition zones 20–21 mm), and potent radical-scavenging effects (IC_{50}: 3.1 µg/mL for DAED; 5 µg/mL for LICH). Nutritional analysis revealed elevated dietary fiber (20–27 g/100 g), vitamin E (10–14 mg/100 g) and zinc (11–18 mg/100 g), exceeding recommended daily intakes. Phytochemical screening detected flavonoids, tannins, steroids and terpenoids. DAED was distinguished by high lipid (53.4 g/100 g), potassium (444 mg/100 g), magnesium (149 mg/100 g) and total polyphenols (978 mg GAE/100 g) contents, whereas LICH was richer in total flavonoids (230 mg QE/100 g), tannins (40 mg GAE/100 g), carbohydrates (71 g/100 g) and calcium (300 mg/100 g). These findings provide the first scientific validation of DAED and LICH's traditional antimicrobial applications in Lubumbashi and pave the way for standardizing fruit-based phytotherapeutics and isolating their bioactive principles.

Keywords: Edible fruits; *E. coli*; *K. pneumoniae*; Gastrointestinal; Urinary and respiratory infections.

1. Introduction

Regular consumption of fruits and vegetables contributes to the prevention of numerous chronic and infectious diseases [1]. In developing countries such as the Democratic Republic of Congo, nutritional requirements depend primarily on local products—especially seasonal fruits and vegetables—which underpin both food security and household economies in rural and urban areas [2]. Under pathological conditions, the efficacy of pharmacological treatments is significantly enhanced when combined with appropriate nutritional supplementation: this synergy markedly improves clinical outcomes in gastrointestinal, urinary, and respiratory infections [3]. These infections, which are highly prevalent in sub-Saharan Africa and DRC, lead to substantial losses of potassium, calcium, and magnesium, thereby worsening

* Corresponding author: Bashige Chiribagula Valentin

patients' clinical status and delaying recovery [4,5]. In a context of limited resources, most populations struggle to reconcile antimicrobial needs with nutritional requirements. Local ethnobotanical expertise therefore emerges as a promising approach to address both health and food-security imperatives simultaneously.

Ethnobotanical surveys carried out in Central Africa and Southeast Asia have shown that *Dacryodes edulis* and *Litchi chinensis* occupy a central place in traditional medicine. In the DRC and Cameroon, safou (*D. edulis*) is eaten fresh, boiled, or smoked to alleviate dermatoses, hypertension, and anemia, while also serving as a major nutritional and economic resource [6,7]. In southern China, decoctions of litchi pericarp or seeds are used to treat cough, fever, digestive disorders and to promote circulation [8,9].

Previous phytochemical investigations reveal that *D. edulis* is rich in polyunsaturated fatty acids, tocopherols (0.6–1.0 g/kg), carotenoids, flavonoids, and phenolic acids, conferring potent antioxidant capacity and *in vitro* antibacterial activity (MIC = 6.25 µg/mL against *Salmonella typhi* and *Staphylococcus aureus*) [10,11]. Concerning *L. chinensis*, its content of flavan-3-ols, anthocyanins, and vitamin C inhibits lipid peroxidation and exerts bacteriostatic activity against Salmonella spp. and other gastrointestinal pathogens [12,13].

In Lubumbashi, these two species are integrated into traditional practices for the management of gastroenteritis, urinary infections, respiratory disorders, wounds, dysentery, diabetes, and viral ailments. This study aims to provide a scientific validation of these local uses against urinary, gastrointestinal, and respiratory infections, to evaluate the antioxidant activity of the fruits, and to assess their nutritional potential and content of bioactive secondary metabolites.

2. Material and Methods

2.1. Plant material

Fruits of *Dacryodes edulis* and *Litchi chinensis* were collected in May 2021 from the Mzee Lubumbashi market, Haut-Katanga, Democratic Republic of Congo. Botanical authentication was performed by Professor Edouard Ilunga of the Faculty of Agronomy, University of Lubumbashi.

Following air-drying at ambient temperature (25 °C), the samples were ground using an electric stainless-steel mill (Plymix PX-MFC 90 D, Belgium). A 350 g portion of the resulting powder was macerated in 1 L of methanol (Sigma-Aldrich, CAS 67-56-1) at 25 °C for 72 hours with continuous agitation. The extract was then filtered through Whatman No. 1 filter paper (Whatman, USA) and concentrated under reduced pressure (180 mbar) at 50 °C using a rotary evaporator (Büchi R-210, Switzerland).

2.2. Determination of Proximate Composition

The air-dried samples were analyzed for proximate composition, dry matter (MS), ash (CT), crude fat (MG), crude fiber (FB), and crude protein contents (PT), total carbohydrate (ST), using the methods of Association of Official Analytical Chemists [14]. The dry matter content was determined by drying a known weight of the homogenized sample at 105 °C in an oven, until a constant weight was reached. For the total ash determination, the samples were weighed and converted to dry ash in a muffle furnace at 550 °C. The fat content was obtained by extraction with petroleum either using a Soxhlet apparatus. Kjeldahl method was used for crude protein determination while the total carbohydrate was estimated by phenol-sulfuric acid method [15]. The gross energy content (kcal/100 g) was calculated multiplying the percentages of the crude protein, crude fat, and carbohydrate contents by 4.0, 9.0 and 4.0, respectively [16].

2.3. Minerals determination

Mineral analyses were carried out according to a previously described procedure [17]. Briefly, 500 mg were incinerated for 24h at 550 °C (Muffle Furnace mLs1200, Thermo Scientific, Madrid, Spain), weighed and desilicated with 3 mL of 40% HCl (Sigma– Aldrich, Saint-Quentin Fallavier, France) and 1 mL 70% HNO_3 (Sigma– Aldrich, Saint Louis, USA). The obtained solution was then evaporated at 90 °C to dryness. The residue was mixed with 50 mL distilled water followed by filtration. Detection of sodium, potassium, calcium, magnesium, phosphorus, copper, zinc, iron, Manganese, and chrome, were realized using inductive coupled plasma atomic emission spectrometry (ICP-AES, Varian Vista) with coupled charge device detector (Agilent France, Massy). All the standards were obtained from Fisons Scientific Equipment (Loughborough, England). Quantification of element concentrations was done using specific calibration of 5 points for each element in the range 0–1000 mg/L. The limits of quantification (LOQ) related to samples were 0.0500 mg/ 100 g for Ca, K, Na, Mg, P and 0.0010 mg/100 g for Fe, Zn, Mn, Cu, Cr.

2.4. Determination of Vitamins Contents

Vitamin cotenant were determined by spectrophotometric method: Vitamin A was performed by β-carotene assay [18] using a factor 1µg of β-carotene = 0.167 µg of ERE (retinol equivalent), Ascorbic Acid (C), by 2,6-dichlorophenolindophenol (DCPIP) assay [19], Tocopherol (E), by 2, 2′-dipyridyl reagent assay [20].

2.5. Preliminary phytochemical screening

The whole plant powders were analyzed for the presence of alkaloids, coumarins, flavonoids, saponins, steroids, tannins, terpenoids, and phenols. This was conducted using standard tube reactions, as previously reported [21–23].

2.6. Determination of total phenol, flavonoid and tannin content

The total phenolic content of each sample was quantified using a Folin-Ciocalteu method [24]. The procedure involved the preparation of a solution of extract (100 µg . mL^{-1}) or gallic acid (100-600 µg . mL^{-1}) in 1 mL of 10% (w/v) Folin-Ciocalteu reagent, which was then mixed with 2.5 mL of the solution. Subsequently, 2.0 mL of Na_2CO_3 (75%) was added to the mixture, which was then incubated at 50 °C for 10 minutes with intermittent stirring. Subsequently, the sample was cooled, and the absorbance was measured using a UV spectrophotometer (Shimazu, UV-1800) at 765 nm against a blank. The results were expressed in milligrams of gallic acid equivalents per gram of dry extract (mg GAE.g^{-1}) using a calibration curve (y = 0.0696x + 0.0113, R^2 = 0.998; linearity range, 1–1200 mg. mL^{-1}).

As previously described, the total flavonoid content was quantified using an aluminum trichloride assay [25]. Briefly, An aliquot of 1 mL extract solution (100 µg . mL^{-1}) or quercetin (25-250 µg. mL^{-1}) was combined with 0.2 mL of a 10% (w/v) $AlCl_3$ solution in methanol, 0.2 mL of a 1 M potassium acetate solution, and 5.6 mL of distilled water. The mixture was incubated for 30 minutes at room temperature, after which the absorbance was measured at 415 nm against the blank. The results were expressed in milligrams of quercetin equivalents per gram of dry extract (mg QE.g^{-1}) using a quercetin calibration curve (y = 0.006 x + 0.004, R^2 = 0.996; linearity range, 0.1 to 150 mg. mL^{-1}).

The total condensed tannin content was determined using a vanillin method, as previously described [26]. Briefly, 1 mL of a solution of the extract (100 µg/mL) or gallic acid (100-600 µg/mL) was mixed with 5 mL of a vanillin solution (0.5 g reagent and 200 mL 4% HCl in methanol). The absorbance at 500 nm, following a 20-minute reaction time, was quantified using a spectrophotometer (SP 2000 UV, Bel Photonics®, Piracicaba, SP, Brazil) in comparison to a blank. The results were expressed in milligrams of gallic acid equivalents per gram of plant dry extract (mg GAE.g-1ED) using a calibration curve based on gallic acid (y = 0.005 x + 0.0012, R^2 = 0.997; linearity range, 1 - 100 mg. L^{-1}).

2.7. DPPH assay

The antioxidant activity of the samples was evaluated using the DPPH assay, as previously described [27]. Briefly, 50 µL of extracts (or positive control) were prepared at different dilutions of order 2 in methanol from 100 g. mL^{-1} solution, was interacted with 1950 µL of 0.002% DPPH in a 96-well plate (Nunc WVR, Germany). Following a 30-minute incubation period in the dark, the solution was read at 492 nm (Thermo Fisher Scientific Inc., Waltham, USA). The assays were conducted in triplicate, with the 0.002% DPPH solution as the negative control. The percentage of antioxidant activity was calculated using the following formula :

$$\text{AAO (\%)} = \frac{(\mathbf{Ab}-\mathbf{Ae})}{\boldsymbol{Ab}} \boldsymbol{x}\ \mathbf{100}\ \% \ldots\ldots\ldots (1)$$

Where, (Ab) is the absorbance measured in the presence of the negative control, (Ae) is the absorbance measured in the presence of the extract, and (AAO) is the calculated percentage of inhibition. The experiment was performed in triplicate.

In this study, the antioxidant activity of the extracts was categorized as follows: very strong when IC_{50} < 50 µg/mL, strong when 50 µg/mL ≤ IC_{50} ≤ 100 µg/mL, moderate when 100 µg/mL < IC_{50} < 250 µg/mL, weak: 250 µg/mL < IC_{50} < 500 µg/mL, and absent when IC_{50} ≥ 500 µg/mL [27,28].

2.8. Anti-bacterial activity test

Antibacterial activity was assessed by the macrodilution test in a tube, by determining MIC, and by macrodiffusion on a disk, by determining DZI [28–31].

The bacterial strains included in this study were *Escherichia coli (E coli)* ATCC 25922*, Salmonella typhi (S typhi)* ATCC 14028*, Shigella sonnei (S sonnei)* ATCC 25931*, Staphylococcus aureus (S aureus)* ATCC 6538*, Klebsiella pneumoniae (K*

pneumoniae) ATCC 13883 et *Streptococcus pneumoniae (S pneumoniae)* ATCC 49619. The bacterial strains were obtained from the Lubumbashi Provincial Laboratory, where tests were conducted using an agar diffusion method to ascertain the diameter of the zone of inhibition (DZI). Additionally, the broth dilution method was employed in triplicate to ascertain the minimum inhibitory concentration (MIC), and the minimum bactericidal concentration (MBC) of the extract [28].

These distinct parameters (DZI, MIC, and MBC) were utilized to delineate the antimicrobial activity of the extracts. The microorganisms selected for this study were based on their prevalence in locally observed instances of bacterial gastroenteritis.

For susceptibility testing, 20 mL of Muller-Hinton agar was poured into sterile Petri dishes, and allowed to stand for 20 minutes. Subsequently, 1 mL of a bacterial suspension containing 10^8 CFU (colony-forming units) per mL was evenly distributed over the entire surface of each culture medium. Blotting paper discs (with a diameter of 6 mm) were impregnated with 5 µL of extracts (with a concentration of 50 µg. mL^{-1}), and placed on the surface of the solidified, infected medium. Subsequently, the Petri dishes were incubated at 37°C for 48 hours in an oven. The susceptibility of the germs to the extracts was estimated by measuring the diameter (in millimeters) of the zone of inhibition induced by different concentrations of plant extracts around the discs. Each experiment was repeated three times. The Extracts were categorized as follows according to their MIC values: very active (MIC < 100 µg/mL), moderately active (100 ≤ MIC < 500 µg/mL), weakly active (500 ≤ MIC ≤ 1000 µg/mL), and inactive (MIC > 1000 µg/mL)[29,30].

To determine MIC, 100 µL of each extract at a concentration of 1 mg/mL, dissolved in methanol (petroleum ether), was combined with 1900 µL of culture medium. Subsequently, eight successive dilutions of order 2 (ranging from 500 µg. mL^{-1} to 1.9 µg. mL^{-1}) were prepared for each extract and placed in different 5 mL aseptic tubes. After that, 1000 µL of standard inoculum was added to each tube, and the mixture was incubated for 24 h at 37°C. The growth of microorganisms was observed visually. The minimum inhibitory concentration (MIC) was determined as the lowest concentration at which the extract prevented visible bacterial growth [32]. Extracts were categorized as follows according to their MIC values: very active (MIC < 100 µg. mL^{-1}), moderately active (100 ≤ MIC < 500 µg. mL^{-1}), weakly active (500 ≤ MIC ≤ 1000 µg . mL^{-1}), and inactive (MIC > 1000 µg.mL^{-1}).

To determine the minimum bactericidal concentration (MBC), samples were taken from tubes that exhibited no visible growth, as had been used to determine the minimum inhibitory concentration (MIC). Inoculation was conducted in Petri dishes on Mueller Hinton agar medium, and incubation was performed at 37°C for 24 hours. The growth of microorganisms was monitored visually, and the minimum bactericidal concentration (MBC), defined as the lowest concentration at which the extract prevented visible bacterial growth after transplantation, was determined [33]. The effect of the extract was determined according to the ratio between the minimum bactericidal concentration (MBC), and the minimum inhibitory concentration (MIC). A bactericidal effect was considered present when the ratio was ≤ 2, while a bacteriostatic effect was observed when the ratio was >2 [30]. The experiment was performed in triplicate.

2.9. Statistical analysis

All the tests were carried out in triplicate and the results are expressed as mean ± Standard deviation. In bivariate analysis, the T Student Test was used and in multivariate analysis, the one-way ANOVA test. The significance level of the test was set at 95%.

3. Results

3.1. Sensitivity of bacteria to different extracts

The extracts showed a diameter of inhibition zone (DZI) ranging from 12.7 ± 0.1 mm (DAED on *S. typhi*) to 21.1 ± 0.2 mm (LICH on *E. coli*) on the different germs studied in solid medium. According to the classification system previously proposed [28,32], all the extracts showed activity (DZI > 10 mm). It is noteworthy that *E. coli, S. pneumoniae* and *K. pneumoniae* exhibited susceptibility to all tested extracts, with inhibition zone diameters (IZD) exceeding 20 mm. Additionally, the LICH demonstrated broad-spectrum activity, effectively inhibiting all evaluated microbial strains with IZDs > 19 mm (Table 1).

Table 1 Inhibition zone diameter of methanolic extracts of fruit of *Dacryodes edulis* and *Litchi chinensis* at 50 µg. mL^{-1}.

Simple	*E. coli*	*S. typhi*	*S. sonnei*	*K. pneumoniae*	*S. aureus*	*S. pneumoniae*
CIP	26.0 ± 1.2	24.1 ± 0.4	18.1 ± 0.2	23.0 ± 0.1	23.1 ± 0.4	23.1 ± 0.4
DAED	20.1 ± 0.2	12.7 ± 0.1	21.1 ± 0.2	20.2 ± 0.2	19.2 ± 0.6	20.2 ± 0.8
LICH	21.4 ± 0.2	19.3 ± 0.2	20.1 ± 0.4	20.1 ± 0.2	19.1 ± 0.2	20.1 ± 0.2

Legend - DAED: *Dacryodes edulis*, LICH : *Litchi chinensis*; Results expressed as mean ± standard deviation with n= 3; Ciprofloxacin (CIP) was used as a positive control (DZI: 18-28 mm) and the dilution solvent (5%) from each extract was used as negative control. No zone of inhibition was observed in the negative control.

3.2. Minimum inhibitory concentration, minimum bactericidal concentration and effect of extracts

The minimum inhibitory concentrations (MICs) of all evaluated extracts spanned a wide range (3.1–12.5 µg/mL), underscoring their diverse antibacterial potencies. Each extract suppressed the growth of *K pneumoniae* at concentrations of 3.1 µg/mL, highlighting a uniformly strong antipneumonial effect. The LICH extract proved especially compelling, inhibiting every tested bacterial strain at MICs no greater than 6.3 µg/mL, and thus demonstrating true broad-spectrum efficacy. Complementary bactericidal assays confirmed that these formulations not only arrest bacterial proliferation but actively kill pathogens at their respective MICs (Table 2).

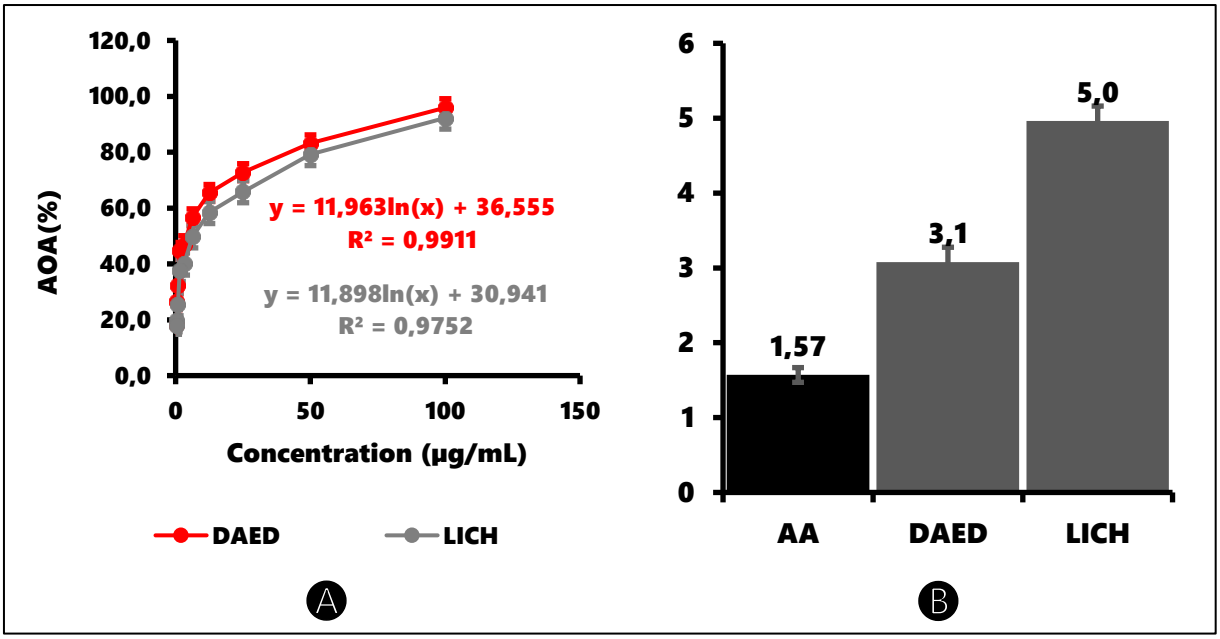
Table 2 Minimum inhibitory concentration (MIC in µg. mL-1) and minimum bactericidal concentration (MBC in µg/mL) of organic extracts of *Dacryodes edulis* and *Litchi chinensis*.

Extraits	Bacterial Strain	CMI (µg/mL)	CMB (µg/mL)	CMB/CMI	Effects
DAED	*E. coli*	6.3	6.3	1	BC
	S. typhi	12.5	25	2	BC
	S. sonnei	12.5	12.5	1	BC
	K. pneumoniae	3.1	6.3	2	BC
	S. aureus	6.3	6.3	1	BC
	S. pneumoniae	12.5	12.5	1	BC
LICH	*E. coli*	3.1	3.1	1	BC
	S. typhi	3.1	6.3	2	BC
	S. sonnei	6.3	6.3	1	BC
	K. pneumoniae	3.1	3.1	1	BC
	S. aureus	3.1	3.1	1	BC
	S. pneumoniae	3.1	3.1	1	BC

Legend - CIP : Ciprofloxacin, DAED: *Dacryodes edulis*, LICH : *Litchi chinensis*; BC: Bactericide; Ciprofloxacin was employed as a positive control, demonstrating MIC values below 5 µg/mL, whereas the uninoculated culture medium and the 5% methanol vehicle served as negative controls and showed no detectable antibacterial activity.

3.3. Antioxidant activity

The antioxidant activity of the extracts was found to vary significantly, with values ranging from 17% to 96% in accordance with the concentration, and exponential model employed. In accordance with the aforementioned classification (2.7), the extracts demonstrated high antioxidant activity, as evidenced by their IC_{50} values (3.1 and 4.9 µg. mL^{-1}). However, this activity was observed to be at a lower level than that of ascorbic acid (IC_{50} = 1.6 µg. mL^{-1}), which served as a positive control. DAED exhibited the highest antioxidant activity (Figure 1).



Legend – DAED: *Dacryodes edulis*, LICH : *Litchi chinensis*, AA: Ascorbic acid used as positive control; AOA: Antioxidant activity.

Figure 1 Antioxidant activity of methanolic extracts of the fruit of *Dacryodes edulis* and *Litchi chinensis* expressed as percentage DPPH inhibition ⓐ and as IC_{50} ⓑ; ($\bar{X}$ ± S, n=3)

3.4. Phytochemical groups identified

Excluding alkaloids, anthraquinones, and saponins, every other class of secondary metabolites—including coumarins, flavonoids, polyphenols, steroids, tannins, and terpenoids—was detected in both fruit of *Dacryodes edulis and Litchi chinensis* (Table 3).

Table 3 Phytochemical groups of antibacterial interest identified in fruit of *Dacryodes edulis* and *Litchi chinensis*.

Phytochemicals group	Tube Solution Test	DAED	LICH
Alkaloids	Dragendorff	-	-
	Mayer	-	-
	Hager	-	-
	Bertrand	-	-
	Sonnenschein	-	-
Anthraquinones	Bornträger	-	-
Coumarins	sodium hydroxide solution test	+	+
Flavonoids	Shinoda	+	+
Polyphenols	Ferric Chloride Test	+	+
Saponins	Foam test	-	-
Steroids	Liebermann-Burchard	+	+
Tannins	Braemer	+	+
Terpenoids	Liebermann-Burchard	+	+
	Hirschson	+	+

Legend - Present: + ; Absent: - ; *Dragendorff's reagent*: $Bi(NO_3)_3$ + KI + tartaric acid ($C_4H_6O_6$) ; *Mayer's reagent*: $HgCl_2$ + KI ; *Bertrand's reagent*: potassium sodium tartrate ($KNaC_4H_4O_6$) + $CuSO_4{\cdot}5H_2O$ + $Fe_2(SO_4)_3/H_2SO_4$ + $KMnO_4$; *Sonnenschein's reagent*: phosphomolybdic acid $H_3PMo_{12}O_{40}$) ; *Shinoda reagent*: Mg + HCl ; *Bornträger's reagent*: $FeCl_3$ + HCl ; *Liebermann–Burchard reagent*: acetic anhydride ($C_4H_6O_3$) + H_2SO_4 ; *Braemer's reagent*: $FeCl_3$; *Hirschhorn's reagent*: trichloroacetic acid (CCl_3CO_2H) ; Bate–Smith test: conc. HCl.

3.5. Total phenolic, flavonoids and total tannins content

The total phenolic and tannin contents were determined against gallic acid standards and are reported as mg GAE·g^{-1}. Phenolic levels ranged from 471 to 978 mg GAE·g^{-1}, while tannin concentrations varied between 3 and 41 mg GAE·g^{-1}. Total flavonoids, quantified as quercetin equivalents (mg QE·g^{-1}), spanned 3 to 230 mg QE·g^{-1}. Among the two species, *Litchi chinensis* displayed the highest flavonoid and tannin contents, whereas *Dacryodes edulis* exhibited the greatest total phenolic accumulation (Table 4).

Table 4 Total phenols, flavonoids and tannins content in fruit of *Dacryodes edulis* and *Litchi chinensis*

Simple	Total Flavonoids (mg EQC/100g)	Total polyphenols (mg EAG/100g)	Total tannins (mg EAG/100g)	Ratio TPC/TTC
DAED	3.51 ± 0.41d	978.21 ± 0.11d	3.77 ± 0.12d	259.5
LICH	230.12 ± 0,41	471.21 ± 0.12	40.30 ± 0.11	11.7

3.5.1. Proximate Nutritional Value

Across all nutritional parameters evaluated in this study—aside from total carbohydrate content, Reducing sugars content and Crude fiber content—*Dacryodes edulis* consistently exhibited higher values than *Litchi chinensis*. Notably, however, *L. chinensis* fruits contained carbohydrate levels approximately three times those of *D. edulis*, which translated into a superior overall energy content (Table 5).

Table 5 Nutritional value content in fruit of *Dacryodes edulis* and *Litchi chinensis*

Simple	CFC	FC	PT	SRC	TCT	EV
Unit	g/100g	g/100g	g/100g	g/100g	g/100g	Kcal/100g
DAED	20.2 ± 0.40a	53.4 ± 0.43a	21.3 ± 0.11a	18.06 ± 0.31a	23.21 ± 0.42a	519.1 ± 0.2
LICH	27.60 ± 0.13	12.5 ± 0.42	07.21 ± 0.41	50.71 ± 0.40	76.01 ± 0.43	480.6 ± 0.2

Legend - Crude fiber content (CFC), Fat content (FC), Protein content (PT), Reducing sugars content (SRC), Total Carbohydrate Content (TCT), Energetic Value (EV). Results expressed as mean ± standard deviation; n = 3; 95% confidence interval; analysis of variances: a if p <0.01; b if p <0.001; c if p <0.0001; Carbohydrates: 4 kcal / g; Polyol: 2.4 kcal / g; proteins: 4 kcal / g; lipids: 9 kcal / g; Ac. Organic: 3 kcal / g; dietary fiber: 2 kcal / g according to the standard: ECEC0925387A; 1Kcal = 4.184 KJ; N = 3.

3.6. Macro and micro elements

Table 6 Macro-elements in fruits of *Dacryodes edulis* and *Litchi chinensis*

Macro-elements (mg)	Na	Ca	P	K	Mg
AJR	2500	800	700	2	375
DAED	6.13 ± 0.1	64.3 ± 0.2^{d}	68.1 ± 0.2^{d}	543.6 ± 0.3^{c}	140.2 ± 0.1^{d}
LICH	9.12 ± 0.1	300.58 ± 0.1	12.3 ± 0.1	171.8 ± 0.2	010.5 ± 0.2
Micro-elements	**Fe**	**Cu**	**Zn**	**Mn**	**Cr**
AJR (mg)	14	1	10	2	0,03-0,1
DAED	00.80 ± 0.1^{d}	0.93 ± 0.3^{c}	18.4 ± 0.2^{d}	4.1 ± 0.02^{d}	0.0041 ± 0.1^{b}
LICH	30.47 ± 0.2	0.14 ± 0.3	11.67 ± 0.1	2.35 ± 0.04	0.0026 ± 0.2

Legend - AJR: daily intake in an individual of 70 kg, Results expressed as Average ± SD, n = 3, comparison between leaves and fruits by T test with a if p <0.01, b if p <0.001, c if p <0.0001 , d if p <0.00001.

Regarding macro-elements, the fruits of *Dacryodes edulis* (D. edulis) contain higher levels of phosphorus, potassium, and magnesium than those of *Litchi chinensis* (L. chinensis). Conversely, the fruits of *L. chinensis* exhibit greater sodium and calcium contents than those of *D. edulis*. For micro-elements, *D. edulis* is richer in all analyzed elements except iron. However, when expressed per 100 g of dry matter, the mineral concentrations generally fall below the recommended

daily intakes for humans—except in the cases of potassium, zinc, and magnesium, which meet or exceed those dietary requirements (Table 6).

3.7. Vitamins

For vitamins A and C, *Dacryodes edulis* contains values roughly sevenfold higher than those of *Litchi chinensis*, although both fruits supply only about one-tenth of the recommended daily intake for humans per 100 g of dry matter. In contrast, the vitamin E content of both species is similar and meets the daily requirement on a 100 g dry-matter basis (Table 7).

Table 7 Vitamin A,C and E in fruit of *Dacryodes edulis* and *Litchi chinensis*

Vitamins	DR	MDD mg/70 kg	DAED (mg/100g de MS)	LICH(mg/100g de MS)
A	0.8	4.68	00.71 ± 0.03^{d}	00.10 ± 0.21
C	80	1900	01.70 ± 0.10^{d}	00.10 ± 0.31
E	10	0100	10.40 ± 0.10	13.92 ± 0.30

Legend - DR: daily requirements; MDD: maximum daily dose; Results expressed as Average ± SD, n = 3, comparison between leaves and fruits by T test with a if p <0.01, b if p <0.001, c if p <0.0001 , d if p <0.00001.

3.8. Dry matter, Ash, total acidity, pH

In general, *Litchi chinensis* fruit exhibits slightly higher titratable acidity, ash content, and dry matter than *Dacryodes edulis*, in which these parameters remain below 10%. The pH of their 10% (w/v) aqueous solutions spans from 4.7 to 4.9 (Table 8).

Table 8 Moisture, ash and acidity in fruit of *Dacryodes edulis* and *Litchi chinensis*

Parameters	Titratable acidity	Ash HCl	Ash H_2SO_4	Total Ash	Dry matter	pH
	$mol.L^{-1}$	%	%	%	%	$mol.L^{-1}$
DAED	2.3 ± 0.1^{a}	0.6 ± 0.1	1.7 ± 0.4	6.1 ± 0.1^{d}	95.9 ± 0.4^{c}	4.7 ± 0.4
LICH	2.6 ± 0.1	0.6 ± 0.1	1.8 ± 0.1	8.7 ± 0.4	97.2 ± 0.1	4.8 ± 0.1

Legend - Results expressed as mean ± standard deviation; n = 3; 95% confidence interval; analysis of variances: a if p <0.01; b if p <0.001; c if p <0.0001; IS: saponification index; MS: dry matter; AT: Titratable acid.

4. Discussion

Beyond their nutritional properties, the fruits of *Dacryodes edulis* (DAED) and *Litchi chinensis* (LICH) harbor bioactive compounds whose therapeutic potential remains largely unexplored. In this study, we demonstrate for the first time the antibacterial activity of DAED and LICH extracts against a spectrum of pathogens—chiefly *Escherichia coli*, and *Klebsiella pneumoniae*—thereby scientifically validating their traditional applications in treating gastroenteritis, urinary tract infections, and respiratory disorders. Moreover, integrated phytochemical and nutritional profiling elucidates how specific constituents contribute to these antimicrobial effects.

4.1. Nutritional values

Analysis of *Dacryodes edulis* in the present study revealed an exceptional fiber content of 20.2 ± 0.40 % (Table 5), a pivotal nutritional attribute implicated in the enhancement of intestinal transit, the modulation of glycemic response, and the promotion of satiety. This value markedly exceeds the fiber levels reported for the pulp of *Landolphia kirkii* Dyer ex Hook.f. (Apocynaceae)—a Katangese medicinal plant—where fibers comprise only 4.6 ± 0.1 to 5.8 ± 1.2 % of dry matter [34], as well as those of *Musa paradisiaca* L (Musaceae) , banana pulp (2.56 %) [35] and *Adansonia digitata* L (Malvaceae) pulp, another Congolese medicinal species whose fiber composition spans 5.7 to 6.0 % [36].

Quantitative analysis revealed that *Litchi chinensis* fruit contains an exceptionally high carbohydrate fraction, representing 71 % of its dry weight, of which 51 % are reducing sugars (Table 5). These carbohydrates constitute the primary energy substrate in humans, undergoing hydrolysis to glucose—a vital metabolic fuel for neuronal, muscular, and erythrocytic cells—and are subsequently stored as hepatic and muscular glycogen to serve as a readily mobilizable energy reserve. The carbohydrate content of *L. chinensis* are low than that reported for *Ziziphus mauritiana* Lam

(Rhamnaceae) fruit : 82.4 ± 1.95 % dry weight [37] but high than *Musa paradisiaca* L, Musaceae : 66-70 % [38], and equivalent to the levels of *Syzygium guineense* (Willd.) DC (Myrtaceae) fruit : 76.7 ± 001 % [39], other species employed in Congolese traditional medicine.

Our study revealed that the potassium content in the pulp of *Dacryodes edulis* is 543.6 ± 0.3 mg per gram of dry matter. This finding aligns with data reported in accessible literature, which—based on analyses of various pulp samples collected from different locations across southern Nigeria—estimated potassium concentrations ranging from 527 to 921 mg per 100 grams [40]. This level is markedly lower than the concentrations reported for *Adansonia digitata* fruit—1890 mg/100 g dry weight [41], *Tamarindus indica* L (Fabaceae) — 790 mg/100 g [42] and *Parinari curatellifolia* Planch. ex Benth (Chrysobalanaceae) — 1053 mg/100 g [43], yet marginally higher than that of *Tetrapleura tetraptera* pulp, which contains 251.22–288.62 mg/100g [44]. Physiologically, potassium serves as a principal electrolyte, orchestrating fluid and osmotic homeostasis, nerve impulse transmission, and muscle contractility [45,46]. Adequate potassium intake is critical for rectifying electrolyte imbalances, preventing muscular cramps and fatigue, and sustaining cardiovascular, and renal function by stabilizing arterial blood pressure and optimizing renal perfusion [47].

In this study, the pulp of *Dacryodes edulis,* and *Litchi chinensis* provided 18.4 mg and 11.7 mg of zinc per 100 g dry weight, respectively—amounts sufficient to meet the daily zinc requirement for a 70 kg adult. These values exceed those reported for *Psidium guajava* L. (0.24 ± 0.17 mg/100 g) [48], *Tamarindus indica* pulp : 4.22 mg/100 g [42], and *Dialium guineense* (1.68 ± 0.02 mg/100 g) [49], and are comparable to those found in *Mangifera indica* L pulp : 9–14 mg/100 g, and *Syzygium guineense* (Willd.) DC (Myrtaceae) :13–19 mg/100 g from samples collected in Lubumbashi [50], but remain lower than the level reported for *Adansonia digitata* pulp : 31.2 mg/100 g [41].

Zinc is an essential trace element that functions as a cofactor for over 300 enzymes, supports protein and DNA synthesis, and protects cells against oxidative stress; because it cannot be stored endogenously, a varied diet providing the recommended daily intake (10 mg for men, 8 mg for women) is critical—deficiency leads to growth retardation in children, delayed wound healing and increased infection susceptibility [51]. Therapeutically, zinc supplementation reduces the duration and severity of the common cold by inhibiting viral replication and modulating inflammatory responses, prevents and ameliorates acute pediatric diarrheal episodes—thereby lowering morbidity, and mortality from gastrointestinal infections—and, when applied topically, promotes wound healing while limiting cutaneous infections [52,53].

The present study shows that the fruits of *Dacryodes edulis* and *Litchi chinensis* contain appreciable amounts of vitamin E: 12.4–13.9 mg/100 g dry weight, sufficient to meet the recommended daily intake. Notably, previous work reported markedly higher values for *D. edulis* pulp collected in Anambra State, South-Eastern Nigeria : 54.17 mg/100 g [7], whereas a separate investigation found substantially lower concentrations in samples from Luanda, Angola : 0.59 ± 0.03 mg/100 g [54]. Such variation may reflect differences in soil composition, harvest timing, or analytical methods used to quantify vitamin E. To clarify these discrepancies, it would be valuable to collect fruit samples from all three sites under identical conditions and analyze them concurrently, enabling a robust comparison and a more precise assessment of the vitamin E content in *D. edulis* pulp from Lubumbashi.

Vitamin E is an essential liposoluble antioxidant that protects cellular membranes from oxidative damage, thereby contributing to the prevention of chronic diseases. Nutritionally, it plays pivotal roles in cardiovascular health, reproductive function, immune competence, and the mitigation of cellular aging. Clinically, vitamin E is employed to promote skin health, reduce the risk of certain cancers, and support neurological and ocular function. Recent investigations have further substantiated its protective effects against cancer, neurodegenerative disorders, and cardiovascular disease [55,56].

These nutritional constituents identified in this study may partly underpin the empirical use of *Dacryodes edulis*, and *Litchi chinensis* fruits in Katanga's traditional medicine for managing cutaneous disorders, promoting wound healing, and alleviating dysentery, febrile illnesses, and gastroenteritis. Furthermore, their rich micronutrient and antioxidant profiles could contribute to the reported benefits against neoplastic conditions, persistent cough, hyperglycemia, viral infections, and various neurological dysfunctions.

4.2. Antibacterial and antioxidant potential of *Dacryodes edulis* and *Litchi chinensis* fruits.

The fruit extracts of *Dacryodes edulis,* and *Litchi chinensis* displayed pronounced antibacterial activity against all tested strains, with particularly strong effects on *Escherichia coli* (inhibition zones of 20 and 21 mm; MICs of 6.3 and 3.1 µg/mL, respectively) and *Klebsiella pneumoniae* (20 mm inhibition zones; MICs of 3.1 µg/mL for both extracts). These activities markedly exceed those reported for other revered African medicinal fruits. For instance, ethanolic pulp extracts of

Tamarindus indica yielded MICs of 18.75 mg/mL against *E. coli* and 9.38 mg/mL against *K. pneumoniae* [57]. Similarly, *Phyllanthus emblica* L, Phyllanthaceae (amla) fruit extracts—rich in gallic acid and quercetin—exhibited strong synergy with chloramphenicol, enhancing its efficacy up to 166.7-fold against *E. coli* and 17.9-fold against *K. pneumoniae* [58,59].

Escherichia coli is a leading cause of both community-acquired and nosocomial urinary tract infections (UTIs), and also contributes to gastroenteritis, septicemia and meningitis, whereas *Klebsiella pneumoniae* predominates in hospital-acquired pneumonia, bacteremia, UTIs and hepatic abscesses, collectively driving substantial inpatient morbidity and mortality [60]. Both pathogens commonly produce extended-spectrum β-lactamases (ESBLs) and carbapenemases, severely constraining β-lactam and fluoroquinolone therapeutic options and promoting the emergence of multidrug-resistant strains [61]. Moreover, *K. pneumoniae*'s ability to form biofilms on indwelling medical devices exacerbates bacterial persistence and complicates eradication efforts [60]. A one health perspective underscores the intersectoral dissemination of ESBL-producing strains among humans, animals and the environment, highlighting the urgent need for integrated surveillance and intervention strategies [62,63]. In this context, fruit extracts of *Dacryodes edulis* and *Litchi chinensis* have demonstrated significant antimicrobial activity, thereby validating their traditional use in Lubumbashi (Democratic Republic of Congo) for the management of gastroenteritis and UTIs.

Several investigations have demonstrated a clear association between antioxidant capacity and antibacterial activity in indigenous medicinal plants. D*ialium angolense* Welw. ex Oliv, Fabaceae [30], *Rothmannia engleriana* (K.Schum.) Keay, and *Ochna schweinfurthiana* F Hoffm [31], as well as *Crassocephalum montuosum* (S.Moore) Milne-Redh., *Crassocephalum picridifolium* (DC.) S.Moore, Asteraceae [28], *Tetradenia discolor* Phillipson , and *Tetradenia riparia* (Hochst.) Codd, Lamiaceae [64], exhibit pronounced radical-scavenging potential and are rich in flavonoids, attributes that directly contribute to their antibacterial efficacy.

These bioactive compounds neutralize reactive oxygen species, inducing oxidative damage to lipids, proteins, and DNA; chelate Fe^{2+} and Cu^{2+} ions; and compromise membrane integrity, resulting in cytoplasmic leakage, inhibition of essential enzymes, and disruption of DNA replication [65]. Moreover, flavonoids and tannins impede biofilm formation and quorum-sensing pathways, thereby attenuating bacterial virulence, persistence, and the development of resistance, particularly in *Escherichia coli* and *Klebsiella pneumoniae* [66,67].

5. Conclusion

For the first time, this study demonstrates the antibacterial efficacy of *Dacryodes edulis,* and *Litchi chinensis* fruit extracts against *Escherichia coli* and *Klebsiella pneumoniae*, and delineates their nutritional and phytochemical profiles—including dietary fibers, reducing sugars, potassium, zinc, vitamin E, flavonoids, and tannins—thereby validating their traditional use in treating gastroenteritis and urinary tract infections. These findings establish a groundwork for future investigations focused on the standardization of these fruits and the isolation and characterization of the bioactive compounds responsible for their antimicrobial activity.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have not known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions

Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software and Writing - original draft: Bashige Chiribagula valentin, Ngoie Kyampoyo Laurette *Supervision:* Bakari Amuri Salvius, Okusa Ndjolo Philippe, *Writing - review & editing*: Bakari Amuri Salvius, Manya Mboni Henri, Okusa Ndjolo Philippe.

References

[1] Miller V, Reedy J, Cudhea F, Zhang J, Shi P, Erndt-Marino J, et al. Global, regional, and national consumption of animal-source foods between 1990 and 2018: findings from the Global Dietary Database. *Lancet Planet Heal* 2022;**6**(3):e243–e256.

[2] Manyong V, Nguezet PMD, Nyamuhirwa DMA, Osabohien R, Bokanga M, Mignouna J, et al. Drivers and magnitude of food insecurity among rural households in southern Democratic Republic of Congo. *Heliyon*

2024;**10**(21):e40207.

[3] Petrariu OA, Barbu IC, Niculescu AG, Constantin M, Grigore GA, Cristian RE, et al. Role of probiotics in managing various human diseases, from oral pathology to cancer and gastrointestinal diseases. *Front Microbiol* 2023;**14**(January):1–23.

[4] Marino L, Valla F, Beattie R, Verbruggen S. Micronutrient status during paediatric critical illness: a scoping review. *Clin Nutr* 2020;**1**(12):3571–93.

[5] N'guessan KA, Kambou S, N'zi NP, Gbégbé DA, Angaman DM. Ethnobotanical study of medicinal plants used for the treatment of urinary tract infections in the Haut-Sassandra region (Central-West, Côte d'Ivoire). *Ethnobot Res Appl* 2025;**30**(25):1–25.

[6] Mboujda FMM, Rimlinger A, Tientcheu M-LA, Boupoya A, Moupela C, Tankou C, et al. Diversity of Uses and Local Knowledge Associated with Wild African Plum Trees, *Dacryodes edulis*, Among Different Ethnic Groups in the Congo Basin. *Econ Bot* 2024;**78**:308–329.

[7] Swana L, Tsakem B, Tembu J V., Teponno RB, Folahan JT, Kalinski J-C, et al. The Genus Dacryodes Vahl.: Ethnobotany, Phytochemistry and Biological Activities. *Pharmaceuticals* 2023;**16**(12):775.

[8] Bano A, Singh UP. A Review on Pharmacognosy, Phytochemistry and Pharmacological Properties of *Lychee chinensis*. *Int J Pharm Sci Med* 2024;**9**(6):119–140.

[9] Sun W, Shahrajabian MH, Shen H, Cheng Q. Lychee (*Litchi chinensis* Sonn.), the King of Fruits, with Both Traditional and Modern Pharmacological Health Benefits. *Pharmacogn Commun* 2021;**11**(1):22–25.

[10] Ondo-Azi AS, Missang CE, Silou T. Physicochemical Properties and Antioxidant Activity of Mixed Oil of Safou (*Dacryodes edulis* (G. Don) H.J. Lam) from Several Trees. *J Food Res* 2020;**9**(4):50.

[11] Hassan-Olajokun RE, Deji-Agboola AM, Olasunkanmi OO, Banjo TA, Olaniran O, Awoyeni AE, et al. Phytochemical Analysis, In vitro Antibacterial Activity and Rate of Kill of Different Fractions of *Dacryodes edulis* Leaf. *Microbiol Res J Int* 2020;**30**(6):23–35.

[12] Yao P, Gao Y, Simal-Gandara J, Farag M, Chen W, Yao D, et al. Litchi (*Litchi chinensis* Sonn.): A comprehensive review of phytochemistry, medicinal properties, and product development. *Food Funct* 2021;**12**(20):9527–48.

[13] Lu Y, Qin L, Mao Y, Lnong X, Wei Q, Su J, et al. Antibacterial activity of a polysaccharide isolated from litchi (*Litchi chinensis* Sonn.) pericarp against *Staphylococcus aureus* and the mechanism investigation. *Int J Biol Macromol* 2024;**279**(P1):134788.

[14] AOAC. *Official method of Analysis, 11th Edition*. 19th Editi. Arlington, Virginia, USA, 2004.

[15] Masuko T, Minami A, Iwasaki N, Majima T, Nishimura SI, Lee YC. Carbohydrate analysis by a phenol-sulfuric acid method in microplate format. *Anal Biochem* 2005;**339**(1):69–72.

[16] Adinortey M, Sarfo J, Quayson E, Weremfo A, Adinortey C, Ekloh W, et al. Phytochemical screening, proximate and Mineral Composition of *Launaea taraxacifolia* leaves. *Res J Med Plant* 2012;**6**(2):171–179.

[17] Bashige VC, Bakari SA, Okusa PN, Kahumba JB, Lumbu JS. Potential Nutrition Of Leaves And Fruits Of *Dialium Angolense* Welw. Ex Oliv. (Fabaceae) An Antimalarial Plant From The Eastern Of Dr Congo. *Int J Adv Res* 2020;**8**(06):336–345.

[18] Aremu S, Nweze C. Determination of vitamin A content from selected Nigerian fruits using spectrophotometric method. *Bangladesh J Sci Ind Res* 2017;**52**(2):153–158.

[19] Alagendran S, Puspha N, Senthil A, Valarmathi M. Spectrophotometric method of Ascorbic acid in *Carica papaya* L . extracts : An in vitro study. *J Pharmacogn Phytochem* 2019;**8**(6):119–123.

[20] Devi OA, Das M, Saikia A, Das P. Ascorbic acid and tocopherol content of ten medicinal plant extracts of Manipur having anti-inflammatory properties. *Int J Home Sci* 2016;**2**(1):308–312.

[21] Bashige C V, Bakari AS, Numbi IE, Kalonda ME, Okusa NP, Kahumba BJ, et al. Criblage Phytochimique et activité antimicrobienne de sept fleurs comestibles utilisées en médecine traditionnelle à Lubumbashi (RDC). *J Appl Biosci* 2018;**124**:12455–12467.

[22] Bashige C V, Bakari AS, Kahumba BJ, Lumbu SJ. Activité antioxydante de 53 plantes réputées antimalariques en République Démocratique du Congo. *Phytothérapie* 2021;**19**(5–6):355–371.

[23] Bashige chiribagula V, Bakari AS, Okusa NP, Kahumba BJ, Lumbu SJ. Phytochemical screening and antioxidant

activity of methanolic extracts of 53 antimalarial plants from Bagira in Eastern DR Congo. *GSC Biol Pharm Sci* 2020;**12**(02):99–118.

[24] Aryal S, Baniya MK, Danekhu K, Kunwar P, Gurung R, Koirala N. Total Phenolic content, Flavonoid content and antioxidant potential of wild vegetables from western Nepal. *Plants* 2019;**8**(4):1–12.

[25] Muthia R, Wati H, Jamaludin W Bin, Kartini, Setiawan F, Fikri M, et al. Standardization of *Eleutherine bulbosa* urb. bulbs and total flavonoid content from three locations in Kalimantan, Indonesia. *Pharmacogn J* 2021;**13**(1):73–80.

[26] De Britto Policarpi P, Turcatto L, Demoliner F, Ferrari RA, Bascuñan VLAF, Ramos JC, et al. Nutritional potential, chemical profile and antioxidant activity of Chichá (*Sterculia striata*) nuts and its by-products. *Food Res Int* 2018;**106**:736–744.

[27] Bashige C. *Étude ethnobotanique, phytochimique et pharmacologique de plantes médicinales antimalariques de Bukavu: Intérêt majeur de Dialium angolense Welw ex Oliv (Fabaceae).* 2021. http://applications.umons.ac.be.

[28] Valentin BC, Salvius BA, Simbi LJ-B. Antibacterial and Antioxidant Activities, Toxicity, and Physicochemical Properties of *Crassocephalum montuosum* (S Moore) Milne-Redh and *Crassocephalum picridifolium* (DC) S Moore. *Adv Pharmacol Pharm Sci* 2024;**24**:9954073.

[29] Santos AF, Brotto DF, Favarin LRV, Cabeza NA, Andrade GR, Batistote M, et al. Study of the antimicrobial activity of metal complexes and their ligands through bioassays applied to plant extracts. *Rev Bras Farmacogn* 2014;**24**(3):309–315.

[30] Bashige C V, Bakari AS, Okusa NP, Kahumba BJ, Duez P, Lumbu SJ. Antimicrobial, antioxidant activities and toxicity on Cavia porcellus of *Dialium angolense* Welw. Ex Oliv, a traditional medicinal plant from Bagira in Eastern of DR Congo. *GSC Biol Pharm Sci* 2020;**13**(2):166–180.

[31] Bashige CV, Amuri SB, Ndjolo PO, Longanga OA, Duez P, Lumbu J-BS. Activités antibactérienne et antioxydante , toxicités orales aiguë et subaiguë des extraits des feuilles d ' *Ochna schweinfurthiana* F Hoffm (Ochnaceae) et *Rothmannia engleriana* (K . Schum) Keay (Rubiaceae). *Phytothérapie* 2024;**22**(1):37–39.

[32] Bashige C V, Bakari AS, Okusa NP, Kalonda ME, Lumbu SJ. Phytochemical Screening and Antimicrobial Activity of Six Edible Rhizomes Used in Traditional Medicine in Lubumbashi (DRC). *Int J Biol Chem Sci* 2020;**14**(4):1367–1380.

[33] Soifoini T, Donno D, Jeannoda V, Rakoto DD, Msahazi A, Farhat SMM, et al. Phytochemical composition, antibacterial activity, and antioxidant properties of the *Artocarpus altilis* fruits to promote their consumption in the comoros islands as potential health-promoting food or a source of bioactive molecules for the food industry. *Foods* 2021;**10**(9):1–22.

[34] Dewan A, Avuakoghene G. A Comprehensive Study of Nutrients and Anti-Nutrients Constituents of *Landolphia Owariensis* Fruit. *Res J Food Sci Qual Control* 2025;**11**(3):1–11.

[35] Rejman K, Górska-Warsewicz H, Kaczorowska J, Laskowski W. Nutritional Significance of Fruit and Fruit Products in the Average Polish Diet. *Nutrients* 2020;**13**:2079.

[36] Narendar R, Venkatachary N, Vishalakshi R, Kumar Dokuparthi S, Sujatha Edupuganti A, Edupuganti S. Nutritional and immunological significance of *Adansonia digitata* L. fruit pulp. *J Phytonanotechnology Pharm Sci* 2025;**5**(1):41–46.

[37] Adilah HN, Saleh MI, Az-Zahra NDA, Cho E, Sinaga E. Total Phenolic and Total Flavonoid Content, Antioxidant Activity, and Nutritional Profile of *Ziziphus mauritiana* Fruit Juice. *Int J Biol Phys Chem Stud* 2023;**5**(1):01–08.

[38] Oyeyinka BO, Afolayan AJ. Comparative evaluation of the nutritive, mineral, and antinutritive composition of musa sinensis l. (banana) and *Musa paradisiaca* L. (plantain) fruit compartments. *Plants* 2019;**8**(12). doi:10.3390/plants8120598.

[39] Wassie KB. Nutrient Composition and Antinutritional Evaluation of Selected Wild Edible Plants Grown in Agroforestry of Simada District, Ethiopia. *Sci World J* 2025;**25**(1):3545895.

[40] Ene-Obong H, Igile G, Ekpo A, Egbung E, Agbo M. Variations in the nutrients and bioactive compounds of different accessions of the West African pear (*Dacryodes edulis*): Implications for dietary intake assessment and health. *J Food Compos Anal* 2019;**79**(19):80–86.

[41] Abdulwaliyu I, Arekemase SO, Batari ML, Oshodin JO, Mustapha RA, Ibrahim D, et al. Nutritional and pharmacological attributes of baobab fruit pulp. *Food Prod Process Nutr* 2024;**6**(98):1–16.

[42] Kanfon RE, Fandohan AB, Agbangnan PDC, Chadare FJ. Ethnobotanical and Nutritional value of Pulps , Leaves , Seeds and Kernels of *Tamarindus indica* L . : A review. *Agron Africaine* 2023;**35**(2):297–322.

[43] Sibiya NP, Kayitesi E, Moteetee A. Mineral composition of selected indigenous wild southern African fruits. *South African J Bot* 2020;**132**:87–94.

[44] Mensah RQ, Adusei S, Azupio S, Kwakye R. Nutritive value, biological properties, health benefits and applications of *Tetrapleura tetraptera* : An updated comprehensive review. *Heliyon* 2024;**10**(6):e27834.

[45] Farag MA, Abib B, Qin Z, Ze X, Ali SE. Current Research in Food Science Dietary macrominerals : Updated review of their role and orchestration in human nutrition throughout the life cycle with sex differences. *Curr Res Food Sci* 2023;**6**(23):100450.

[46] Homeostasis P, Stress O, Disease H. Potassium Homeostasis, Oxidative Stress, and Human Disease. *Int J Clin Exp Physiol* 2017;**4**(3):111–122.

[47] Terker AS, Zhang C, Mccormick JA, Lazelle RA, Zhang C, Meermeier NP, et al. Potassium Modulates Electrolyte Balance and Blood Pressure through Effects on Distal Cell Voltage and Chloride. *Cell Metab* 2015;**21**(1):39–50.

[48] Oguazu CE, Japhet NJ, Azuka AB, Odiegwu OE. Phytochemical and Mineral Content in Flesh of *Psidium guajava* Fruit. *Reseach J Phytochem* 2022;**6081**:88–96.

[49] Danzomo IM, Yunusa A, Adamu AU, Danjaji HI, Dalhatu MM, Usman IM, et al. Phytochemicals, Mineral Elements and Antioxidants Evaluation of Some Commonly Consumed Desert Fruits. *Sahel J Life Sci FUDMA* 2024;**2**(1):118–131.

[50] Langunu S, Mpia P, Imabo I, Fwanda BB, Mwanasomwe JK, Colinet G, et al. Accumulation of Trace Metals in Fruits from Mango and *Syzygium guineense* Growing in Residential Households from a Contaminated District of Lubumbashi (DR Congo): Is Fruit Consumption at Risk ? *Toxics* 2023;**11**:620.

[51] Patil R, Sontakke T, Biradar A, Nalage D. Zinc: an essential trace element for human health and beyond. *Food Heal* 2023;**5**(3):13.

[52] Stiles LI, Ferrao K, Mehta KJ. Role of zinc in health and disease. *Clin Exp Med* 2024;**24**(1):1–19.

[53] Chao H. Zinc Deficiency and Therapeutic Value of Zinc Supplementation in Pediatric Gastrointestinal Diseases. *Nutrients* 2023;:1–18.

[54] Vinha AF, Costa ASG, Pimentel FB, Espírito Santo L, Sousa C, Freitas M, et al. Bioactive Compounds and Scavenging Capacity of *Adansonia digitata* L. (Baobab Fruit) Pulp Extracts against ROS and RNS of Physiological Relevance. *Appl Sci* 2024;**14**(8):3408.

[55] Torquato P, Marinelli R, Bartolini D, Galli F. Vitamin E: nutritional aspects. In Molecular nutrition. *Acad Press* 2020;:447–485.

[56] Shahidi F, Pinaffi-Langley A, Fuentes J, Speisky H, De Camargo A. Vitamin E as an essential micronutrient for human health: Common, novel, and unexplored dietary sources. *Free Radic Biol Med* 2021;**176**:312–321.

[57] Goanar G, Tafesse G, Fereja WM. In vitro antibacterial activity of fruit pulp extracts of Tamarindus indica against Staphylococcus aureus and *Klebsiella pneumoniae*. *BMC Complement Med Ther* 2024;**6**:1–7.

[58] Saini R, Kumar V, Sourirajan A, Dev K. Fruit Extract and Phenolic Compounds of Phyllanthus emblica Fruits as Bioactivity Enhancer of Chloramphenicol Against Bacterial Species. *Plant Foods Hum Nutr* 2024;**79**:656–661.

[59] Tiwana G, Cock IE, Cheesman MJ. *Phyllanthus emblica* : Phytochemistry , Antimicrobial Potential with Antibiotic Enhancement , and Toxicity Insights. *Microorganisms* 2025;:1–18.

[60] Maczynska B, Frej-Madrzak M, Sarowska J, Woronowicz K, Choroszy-Król I, Jama-Kmiecik A. Evolution of Antibiotic Resistance in *Escherichia coli* and *Klebsiella pneumoniae* Clinical Isolates in a Multi-Profile Hospital over 5 Years (2017 – 2021). *J Clin Med* 2023;**12**:2414.

[61] Ramatla T, Tawana M, Lekota KE, Thekisoe O. Antimicrobial resistance genes of *Escherichia coli* , a bacterium of " One Health " importance in South Africa : Systematic review and meta- analysis. *AIMS Microbiol* 2023;**9**(1):75–89.

[62] Cella E, Giovanetti M, Benedetti F, Scarpa F, Johnston C, Borsetti A, et al. Joining Forces against Antibiotic Resistance : The One Health Solution. *Pathogens* 2023;**12**:1074.

[63] Li Y, Fu Y, Qiu Y, Liu Q, Yin M, Zhang L. Genomic characterization of tigecycline-resistant *Escherichia coli* and

Klebsiella pneumoniae isolates from hospital sewage. *Front Microbiol* 2023;(14):1282988.

[64] Valentin BC, Mélissa IK, Henri MM, Salvius BA, Philippe ON. Antibacterial and antioxidant activities , toxicity and physicochemical properties of *Tetradenia discolor* Phillipson and *Tetradenia riparia* (Hochst) Cood (Lamiaceae). *Magna Sci Adv Biol Pharm* 2025;**15**(2):037–053.

[65] Dussert E, Tourret M, Dupuis C, Noblecourt A, Flahaut C, Ravallec R, et al. Evaluation of Antiradical and Antioxidant Activities of Lipopeptides Produced by *Bacillus subtilis* Strains. *Front Microbiol* 2023;**13**:914713.

[66] Patel K, Panchal R, Sakariya B, Gevariya M, Raiyani R, Soni R, et al. Combatting antibiotic resistance by exploring the promise of Quorum Quenching in targeting bacterial virulence. *The Microbe* 2025;**6**(25):100224.

[67] Mulat M, Banicod RJS, Tabassum N, Javaid A, Karthikeyan A, Jeong G, et al. Multiple Strategies for the Application of Medicinal Plant-Derived Bioactive Compounds in Controlling Microbial Biofilm and Virulence Properties. *Antibiotics* 2025;**14**:555.