

1 **Ethnobotany and antimicrobial potential of ethanolic extracts of plants sold** 2 **in the markets of Boundiali (Northern Ivory Coast).**

3 4 **Abstract**

5 The vegetation of northern Côte d'Ivoire is renowned for its floristic diversity, particularly its
6 medicinal plants commonly used traditionally to treat infectious diseases. However, rapid
7 urbanization and the resulting human pressures threaten the disappearance of numerous
8 species, creating an imbalance in its biodiversity. The objective of this study was to evaluate
9 the antibacterial activity of ethanolic extracts from 10 medicinal plants from this flora against
10 bacteria of the genera *Staphylococcus* and *Pseudomonas*, as well as enteric bacteria
11 (*Escherichia coli*, *Salmonella typhimurium*, and *Proteus mirabilis*), which are responsible for
12 opportunistic infections. These bacteria include both wild-type and multidrug-resistant strains.
13 Ten ethanolic extracts from 10 plant species belonging to 9 botanical families were prepared for
14 diffusion tests in agar plates. Based on their activity against germs, the extract of
15 *Funtumia africana* Stapf (Apocynaceae) was selected to determine antibacterial parameters
16 (MIC and MBC) using the macrodilution method in liquid medium. The largest inhibition
17 zone diameter (28 ± 1.2 mm) was obtained with the extract of this plant at a concentration of
18 50 mg/mL. This extract also yielded the best MIC (0.04 ± 0.0 mg/mL) and MBC (0.39 ± 0.2
19 mg/mL). Furthermore, phytochemical sorting by thin-layer chromatography detected the
20 presence of several phytoconstituents, including saponins, tannins, flavonoids, polyphenols,
21 alkaloids, and sesquiterpenes, which are likely responsible for the observed activity. The
22 results obtained would support scientific validation of the traditional use of these plants in the
23 treatment of pathologies, primarily of bacterial origin. Furthermore, the range of protections
24 for medicinal plants must be broadened to better safeguard plant biodiversity.

25 **Keywords :-**Antibacterial activity, Medicinal plants, *Funtumia africana*, Côte d'Ivoire.

26 **Introduction :-**

27 Despite the spectacular development of the pharmaceutical industry, herbal medicine remains
28 crucial, especially in developing countries where over 80% of the population relies
29 exclusively on medicinal plants to meet their primary healthcare needs (Traoré, 2013). In Côte
30 d'Ivoire, numerous researchers have conducted and continue to conduct antimicrobial tests
31 with many of these plants (Zirihi et al., 2003; Tra Bi, 2008). For a large number of ailments,
32 these plants represent an essential alternative to pharmaceutical drugs, which themselves
33 largely derive from plant secondary metabolites (N'Gaman et al., 2009).

34 However, this abundance of medicinal plants does not prevent the numerous deaths from
35 various diseases observed each year. Given this situation, the floral diversity of Côte d'Ivoire
36 should inspire further contributions to provide the population with more accessible remedies
37 capable of overcoming bacterial resistance.

38 Indeed, diseases caused by microbes remain the leading cause of death worldwide, killing
39 more than 50,000 people every day globally (Ahmad & Beg, 2001). Bacteria are responsible
40 for 70% of these deaths (Gangoué, 2007). To combat bacteria, modern medicine has
41 developed antibiotics, which have proven effective in significantly reducing the spread of
42 these diseases. However, many conventional antibiotics are increasingly encountering
43 resistance against bacteria (Ben et al., 2007).

44 In Côte d'Ivoire, numerous cases of multidrug-resistant bacteria have been reported
45 (Guessenn, 2013). This bacterial resistance, linked to the continuous or even uncontrolled
46 use of antibiotics (Ben et al., 2007), is a criterion in the selection of bacteria used in this
47 research. Furthermore, these germs are responsible for common diseases in tropical regions.
48 These include typhoid fever caused by *Salmonella Typhimurium*; *Escherichia coli*,
49 responsible for purulent meningitis and diarrhea in newborns; *Pseudomonas aeruginosa*,
50 responsible for meningitis in adults; *Staphylococcus aureus*, found in furunculosis, sinusitis,
51 otitis, urinary tract infections, and diarrhea in children; and *Proteus mirabilis*, causing urinary
52 tract infections, meningitis in infants, and diarrhea due to intestinal dysbiosis.

53 The overall objective of this study is to evaluate the antibacterial properties of ethanolic
54 extracts from 10 plants used in traditional medicine in Côte d'Ivoire in order to contribute to
55 the development of the Ivorian pharmacopoeia. This development could lead the population to
56 understand the urgency and necessity of the rational and sustainable use of these plants.

57

58 **Materials and Methods**

59 **Plant Material**

60 It is essentially composed of plant organs such as the leaves of six (6) species:

61 *Spondias mombin* (Desr.) A. Juss. (Anacardiaceae),
62 *Nauclea latifolia* Sm. (Rubiaceae),
63 *Lawsonia inermis* L. (Lythraceae),
64 *Carica papaya* L. (Caricaceae),
65 *Diospyros mespiliformis* Hochst. (Ebenaceae), and
66 *Funtumia africana* Stapf (Apocynaceae).

67 The stem barks of three (3) species were also used:

68 *Ficus iteophylla* Miq. (Moraceae),
69 *Pterocarpus erinaceus* Poir. (Fabaceae), and
70 *Lannea microcarpa* Engl. et K. Krause (Anacardiaceae).

71 In addition, the roots of one species were used:

72 *Fagara xanthoxyloides* Lam. (Rutaceae).

73

74 **Bacterial Material**

75 It consists of eleven (11) microorganisms, including three reference strains (*E. coli* ATCC
76 25922, *Pseudomonas aeruginosa* ATCC 27853, and *Staphylococcus aureus* ATCC 25923)
77 used for quality control, and eight clinical isolates categorized as resistant or wild-type
78 phenotypes (Table 1).

79 These microorganisms originate from the Pasteur Institute of Côte d'Ivoire and the University
80 Hospital Centers of Cocody and Yopougon (Abidjan).

81 **Table 1: List of different bacterial strains.**

Bacterial strains	Code	Biological origins	Phenotypes
<i>Escherichia coli</i>	CIP7624 (ATCC 25922)		
<i>Pseudomonas aeruginosa</i>	CIP 76110 (ATCC 27853)		
<i>Staphylococcus aureus</i>	CIP 7625 (ATCC 25923)		
<i>Escherichia coli</i>	1218 (BLSE)	Urine	Resistant
<i>Proteus mirabilis</i>	1048 (BLSE)	Stools	Resistant
<i>Pseudomonas aeruginosa</i>	261 (IMP ^R)	Pus	Resistant
<i>Staphylococcus aureus</i>	926 (MET ^R)	Blood	Resistant
<i>Salmonella typhimurium</i>	1176	Blood	Resistant
<i>Salmonella typhimurium</i>	1938	Blood	Savage
<i>Pseudomonas aeruginosa</i>	872	Ascite	Savage
<i>Staphylococcus aureus</i>	1227	Blood	Savage

82 **BLSE: Extended Spectrum Beta-Lactamase; IPM^R: Imipenem-resistant strain; MET^R:**
83 **Methicillin-resistant strain; ATCC: American Type Collection Culture.**

84 **Methods :-**

85 **Ethnobotanical survey :-**

86 The meticulously conducted ethnobotanical survey in the Boundiali department, involving
87 traditional medicine practitioners, identified thirty-eight (38) plants. An initial courtesy visit
88 was made to these practitioners (traditional health practitioners, traditional healers, herbalists,
89 and households) to get acquainted, establish a foundation of trust, and define a work plan.
90 After obtaining their consent, a date was set for the main survey.

91 This consisted of a semi-structured interview using an interview guide. The questions
92 concerned the names of the plants, the diseases treated (primarily those of microbial origin),
93 the local name of each plant, the parts used, and the methods of preparation and
94 administration of the remedies. This led to the identification of 38 plants traditionally used to
95 treat bacterial infections. A literature review identified 10 of these plants, which are well
96 known to the local population.

97

98 Calculation of the Proportions of Organs Used and Methods of Prescription

99 Since the preparation method is decoction, only the percentages of use of each organ and the
100 methods of prescription were calculated according to the following formulas:

101 % of organ usage =

102 % of prescription methods =

103

104 Sample Collection and Packaging

105 The selected plant samples were harvested during the dry season in the savannas of northern
106 Côte d'Ivoire. Harvesting took place at dusk, when the plants had time to secrete sufficient
107 active compounds to combat the stresses of the day.

108 The harvested plant parts were cleaned, cut into small fragments, and then dried in a well-
109 ventilated shed at ambient temperature, away from direct sunlight to prevent the loss of
110 substances sensitive to ultraviolet rays. After drying, they were ground into a powder and
111 stored in glass jars for extraction.

112

113 Preparation of the Alcoholic Extract

114 The plant samples underwent several extractions according to a method described by Zirihi et
115 al. (2003), adapted for this study. To do this, 25 g of plant powder were macerated in 250 ml
116 of hexane for 24 hours under magnetic stirring to degrease the powder.

117 The residue was dried on blotting paper and weighed, then added to 250 ml of ethanol. After
118 24 hours of maceration under stirring, the filtrate was evaporated using a rotary evaporator at
119 40 °C to remove the alcohol and dried under a fume hood to obtain the ethanolic extract.

120

121 Antibacterial Study

122 *Preparation of Inoculum for Solid-State Tests*

123 The inoculum was prepared from a 24-hour-old colony. These were emulsified in 2 ml of
124 85% NaCl suspension. The optical density was then adjusted to 0.5 McFarland using a
125 densimat.

126 The volume collected was 100 µl for Enterobacteriaceae, 1000 µl for *Staphylococcus aureus*,
127 and 10 µl for *Pseudomonas aeruginosa*. This suspension was diluted in 10 ml of
128 physiological saline (0.9% NaCl), thus constituting the bacterial inoculum estimated at 10⁶
129 bacteria/ml.

130

131 Germ Susceptibility Testing

132 Before evaluating any activity, the extracts underwent a sterility test to verify whether or not
133 they were contaminated by microorganisms.

134 The well diffusion method in agar plates and the macrodilution method in liquid medium
135 were used to perform the tests (Koné et al., 2004). Petri dishes containing Muller-Hinton agar
136 were inoculated by swabbing with the prepared inoculum.

137 Wells were then created by inserting the large end of a Pasteur pipette into the agar and filled
138 with 50 µl of the different extracts. The plates were incubated at 37 °C for 24 hours.

139 After this time, the inhibition zone diameter around each well was measured using calipers.
140 The effectiveness of the extracts was assessed according to the criteria of Poncé et al. (2003).

- 141 • A substance is considered **ineffective** if the inhibition diameter is less than 8 mm.
- 142 • It is **effective** if the diameter is between 9 and 14 mm.
- 143 • It is **very effective** when the diameter is between 15 and 19 mm.
- 144 • It is **extremely effective** if the diameter is greater than 20 mm.

145 This test is followed by the determination of antibacterial parameters.

146

147 Preparation of the Inoculum for Liquid-Based Tests

148 Two 24-hour bacterial colonies were collected using a Pasteur pipette and emulsified in a test
149 tube containing 10 ml of sterile Muller-Hinton broth. The mixture was incubated at 37 °C for
150 3 hours.

151 After incubation, a 0.3 ml suspension of this pre-culture was taken and diluted in 10 ml of
152 sterile Muller-Hinton broth, then homogenized.

153

154 Preparation of the Concentration Range

155 The concentration range was obtained by the double dilution method. The solution of each
156 extract with a concentration of 50 mg/ml underwent a series of dilutions with a ratio of 2 in
157 order to obtain concentration ranges from 50 to 0.02 mg/ml.

158

159 Determination of Antibacterial Parameters

160 The determination of antibacterial parameters was performed by dilution in liquid medium
161 according to the method used by Kouadio et al. (2015).

162 In ten experimental hemolysis tubes, 1 ml of each concentration range was mixed with 1 ml of
163 bacterial inoculum.

- 164 • The **growth control tube** received 1 ml of sterile distilled water in addition to the
165 inoculum.
166 • The **sterility control tube** received only 2 ml of sterile Muller-Hinton broth (MHB).

167 The tubes were incubated for 24 hours at 37 °C.

168 After incubation, visual observation was performed, and the lowest concentration at which no
169 bacterial growth was observed corresponds to the **Minimum Inhibitory Concentration**
170 (**MIC**).

171 The **Minimum Bactericidal Concentration (MBC)** yields 0.01% viable bacteria after 24
172 hours of incubation at 37 °C.

173 Its determination began with enumeration. This consisted of diluting the initial inoculum from
174 10^{-1} to 10^{-4} and inoculating these dilutions using a 2 µl calibrated loop in 5 cm streaks onto
175 Muller-Hinton agar, followed by incubation for 24 hours. These Petri dishes were designated
176 **A**.

177 After reading the MICs, the contents of the tubes in which no visible growth was observed
178 were used to inoculate Muller-Hinton agar in 5 cm streaks. This series of Petri dishes was
179 designated **B**.

180 The MBC was determined by comparing the bacterial growth of dishes A and B. Thus, the
181 lowest concentration in the tube that has less than 0.01% viable bacteria relative to the initial
182 inoculum is the MBC.

183 This part of the study was conducted using the ethanolic extract of *Funtumia africana*, which
184 proved to be the most active against the majority of bacteria and germs exhibiting an
185 inhibition zone diameter greater than or equal to 10 mm.

186

187 Determination of Mode of Action

188 The **MBC/MIC ratio** was used to determine the substance's mode of action (Fauchere, 2002).

189 According to Kamanzi (2002):

- 190 • The extract is **bactericidal** when the MBC is equal to the MIC or when the MBC/MIC
191 ratio ≤ 4 .
192 • It is **bacteriostatic** when the MBC is greater than the MIC or when the MBC/MIC
193 ratio > 4 .
194 • When this ratio equals 32, the strain is considered **tolerant**.

195

196 Statistical Analysis of the Results

197 Analysis of variance (**one-way ANOVA**) followed by **Tukey's test** was used to compare
198 variations in MICs and MBCs and to determine whether the activity of the extracts was
199 statistically influenced by the phenotypes (wild-type and resistant) of the bacteria.

200 The results are expressed as **means ± standard deviation**, and **P-values < 0.05** were
201 considered statistically significant.

202 The statistical analyses were performed using **R software** (R Core Team, 2013).

203

204 **Phytochemical Screening**

205 The identification of the different chemical compounds in the solutions was performed by
206 **thin-layer chromatography (TLC)** according to the method used by Kouadio et al. (2015).
207 This method allows the detection of several groups of secondary metabolites through specific
208 colorations either in the visible spectrum or at a given wavelength (N'Gaman et al., 2009).

209 Ten milligrams of extracts were dissolved in 1 ml of absolute methanol to obtain a solution
210 with a concentration of **10 mg/ml**. Ten microliters (10 µl), corresponding to **100 µg of**
211 **solution**, were spot-applied onto an **F254 silica gel plate** (stationary phase) using a
212 microcapillary tube.

213 The chromatograms were developed in tanks previously saturated with the mobile phase
214 **CHCl₃-MeOH-H₂O (65:35:5 v/v/v)** and then dried. The plates were observed before and
215 after development either in the visible spectrum or under a **UV lamp**.

216

217 **Detection of Terpenoids and Saponins**

218 These compounds are detected using **Godin's reagent**. After spraying the plate with the
219 reagent and heating it at **100 °C for 10 minutes**, various colors appear.

- 220 • Violet and red spots indicate **monoterpenes**.
- 221 • Blue spots indicate **saponins**.

222

223 **Detection of Alkaloids**

224 After spraying with **Dragendorff's reagent** and heating the chromatogram at **100 °C for 10**
225 **minutes**, alkaloids appear as **orange spots** in the visible spectrum.

226

227 **Detection of Polyphenols**

228 After spraying the chromatogram with **10% Folin-Ciocalteu reagent** and heating it at **100 °C**
229 **for 10 minutes**, **blue spots** in the visible spectrum indicate the presence of polyphenols.

230

231 Detection of Flavonoids and Sesquiterpene Lactones

232 After spraying with **5% (w/v) aluminum chloride (AlCl₃)** and heating:

- 233 • **Yellow spots** visible under UV light at **366 nm** indicate flavonoids.
- 234 • Fluorescence of various colors at **366 nm** indicates **sesquiterpene lactones**.

235

236 Detection of Coumarins

237 A **5% (w/v) basic lead acetate solution** was used to spray the chromatogram. **Green and**
238 **blue fluorescence spots** under UV light at **366 nm** indicate the presence of coumarins.

239

240 Detection of Tannins

241 The appearance of **blue, green, or black spots** in the visible spectrum after spraying the
242 chromatogram with **10% FeCl₃ solution** indicates the presence of tannins.

243 Detection of Anthraquinones and Anthrones :-

244 Detection of Anthraquinones and Anthrones

245 A 5% ethanolic solution of KOH was sprayed onto the chromatogram. The red spots visible in
246 the visible spectrum and under UV light at 366 nm confirm the presence of **anthraquinones**.
247 **Anthrones**, on the other hand, appear as yellow spots under UV light at 366 nm.

248 After heating the plate, **terpenes** appear in purple, while **saponins** appear in blue.

249

250 Results

251 Plants and Recipes

252 The identified plants are used in the treatment of several diseases such as **urinary tract**
253 **infections, headaches, diarrhea, gonorrhoea, wounds, ulcers, ringworm, pimples, cough,**
254 **fever, itching, Buruli ulcer, chronic wounds, and tuberculosis.**

255 These plants belong to **nine (9) botanical families**. The results indicate that **leaves and stem**
256 **bark** are the most commonly used plant parts in the preparation of medicinal recipes.

257 **Decoction** is the main method of preparation used. The remedies are generally **administered**
258 **orally** (Table 2).

259 Table 2: List of selected plants and their uses in traditional medicine

Scientific names	Families	Parts	Preparationmet	Method of	Traditionaltherape
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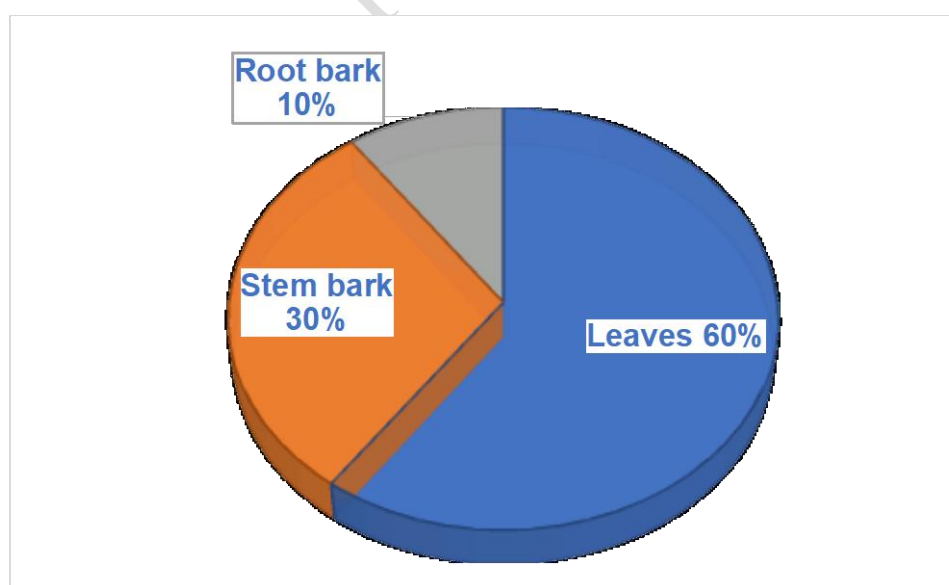
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<i>Funtumiaafricana</i>	Apocynaceae	Leav es	Decoction	Drink, Bath	Tuberculosis, urinary tract infection
<i>Spondias mombin</i>	Anacardiaceae	Leav es	Decoction	Drink, Bath	Buruliulcer, urinary tract infection
<i>Carica papaya</i>	Caricaceae	Leav es	Decoction	Drink	Headaches
<i>Diospyrosmespilifor mis</i>	Ebenaceae	Leav es	Decoction	Drink	Swelling in pregnantwomen
<i>Fagaraxanthoxyloid es</i>	Rutaceae	Root bark	Decoction	Mouthwash	Tooth decay
<i>Ficus iteophylla</i>	Moraceae	stem bark	Decoction	Drink, Bath	Ringworm, pimple
<i>Lanneamicrocarpa</i>	Anacardiace ae	stem bark	Decoction	Drink	Ulcers
<i>Lawsoniainermis</i>	Lytraceae	Leav es	Decoction	Mouthwash	Mouth sore
<i>Nauclea latifolia</i>	Rubiaceae	Leav es	Decoction	Drink, Bath	Cough, fever
<i>Pterocarpus erinaceus</i>	Fabaceae	stem bark	Décoction	Mouthwash	Gonorrhea, sore, itching

260

261 **Calculation of the proportions of organsused and methods of prescription :-**

262 **Organsused :-**

263 The most used part consists of the leaves with 55%, followed by stem bark (36%) and finally
264 root bark with 9% (Figure 1).

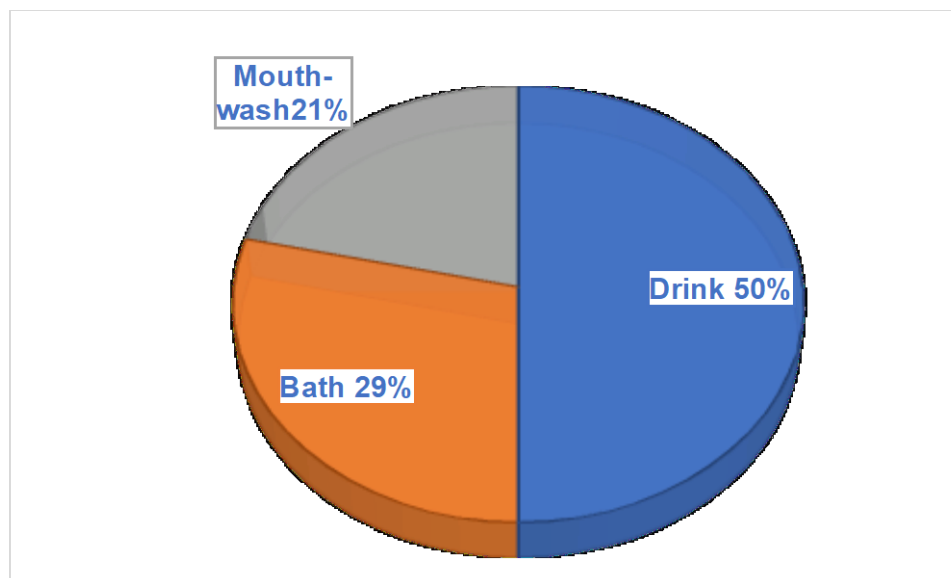


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266 **Figure 1: Proportion of organsused**

267 **Methods of prescription :-**

268 The most frequently prescribed method was oral administration (50%), followed by oral
269 administration (31%). Mouth wash, on the other hand, was less frequently prescribed,
270 representing only 15% (Figure 2).



271

272 **Figure 2: Proportion of prescription methods**

273 **Phytochemical screening :-**

274 The results of the tests for the groups of chemical compounds in the ethanolic extracts of the
275 different organs are recorded in Table 3. Thirteen (13) groups of phytochemical compounds
276 were identified. These include polyterpenes, saponins, polyphenols, flavonoids, xanthonenes,
277 naphthoquinones, alkaloids, anthrones, coumarins, and tannins, several of which are known
278 for their antibacterial potential.

279 **Table 3: Chemical compounds identified in different plant organs**

Plant species	Chemical compounds detected
<i>Funtumia africana</i> Stapf (Apocynaceae)	Saponins, catechins, flavonoids, polyterpenes, polyphenols
<i>Spondias mombin</i> (Desr.) A. Juss. (Anacardiaceae)	Saponins, catechins, flavonoids, polyphenols, coumarins, sesquiterpene lactones, terpenes, anthrones
<i>Carica papaya</i> L. (Caricaceae)	Catechic and gallic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, anthocyanins, flavonoids, alkaloids, polyterpenes
<i>Diospyros mespiliformis</i> Hochst. (Ebenaceae)	Saponins, catechins and gallic tannins, polyphenols, anthocyanins, polyterpenes
<i>Fagaraxanthoxyloides</i> Lam. (Rutaceae)	Catechic tannins, alkaloids, polyphenols, anthocyanins, flavonoids, polyterpenes

<i>Ficus iteophylla</i> Miq. (Moraceae)	Saponins, catechins and gallic tannins, anthraquinone glycosides, polyphenols, anthocyanins, polyterpenes, alkaloids
<i>Lanneamicrocarpa</i> Engl et Kr. (Anacardiaceae)	Catechic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, polyterpenes, anthocyanins
<i>Lawsoniainermis</i> L. (Lytraceae)	Gallic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, polyterpenes, anthocyanins
<i>Nauclea latifolia</i> Sm. (Rubiaceae)	Saponins, catechins and gallicacid tannins, anthraquinone glycosides, free anthraquinones, polyphenols, flavonoids, polyterpenes
<i>Pterocarpus erinaceus</i> Poir. (Fabaceae)	Saponins, catechins and gallic tannins, anthraquinone glycosides, free anthraquinones, polyphenols, flavonoids, anthocyanins

280

281 **Antibacterial activity :-**

282 **Sensitivity of germs :-**

283 **Antibacterial Activity of the Extracts**

284 The extracts were active, to varying degrees, against all bacterial strains. Of the ten ethanolic
 285 extracts tested, with the exception of that of *Carica papaya*, the other nine produced
 286 inhibition zone diameters ranging from 9 ± 0.1 to 28 ± 1.2 mm against the majority of
 287 bacterial strains (Figure 3).

288 Among these extracts, the most active was that of *Funtumia africana*, which produced the
 289 largest inhibition zone diameter (28 ± 1.2 mm) against the bacterial strain *Staphylococcus*
 290 *aureus* 1227. This strain, belonging to the **wild-type phenotype**, was obtained from the blood
 291 of a superinfected patient.

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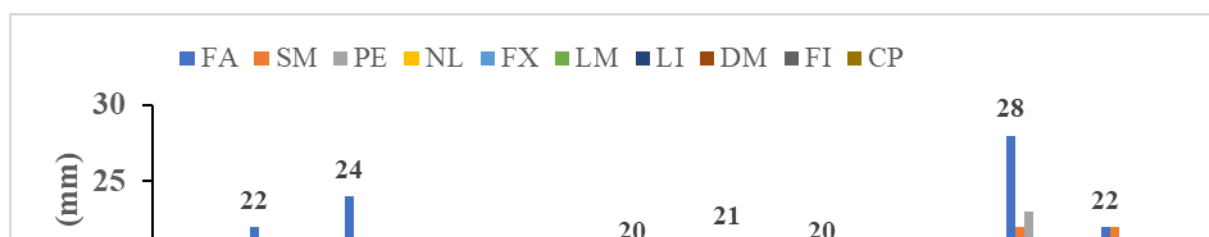
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Antibacterial Parameters

The tests revealed that the turbidity induced by bacterial growth decreased inversely with the concentration of the extracts in the test tubes. Overall, the extracts exerted a **bactericidal effect** on all selected bacteria.

The **Minimum Inhibitory Concentrations (MICs)** ranged from **0.04 ± 0.0 mg/mL to 3.12 ± 3.0 mg/mL**. The lowest MIC (**0.04 ± 0.0 mg/mL**) was observed for *Staphylococcus aureus* (METR) 926. This methicillin-resistant strain also exhibits cross-resistance to fluoroquinolones. It was collected from the blood of a patient with a urinary tract infection.

The **Minimum Bactericidal Concentrations (MBCs)** ranged from **0.39 ± 0.2 mg/mL to 6.24 ± 4.1 mg/mL**. Low MBC values were generally observed in bacterial strains exhibiting low MIC values (Table 4).

Analysis of variance showed a **non-significant difference** between the MICs of wild-type and resistant bacterial strains and the MBCs of these strains (Table 5; **P > 0.05**).

328 **Table 4 : Antibacterial parameters of the ethanolic extract of Funtumia africana**

Bacterial strains	Antibacterial parameters (mg/mL)			
	MIC	MBC	$\frac{MBC}{MIC}$	Antibacterial power
<i>S. typhi</i> 1176	1,56 ± 1,1	3,12 ± 0,2	2	Bactericide
<i>P. mirabilis</i> (BLSE) 1048	3,12 ± 3,0	6,24 ± 1,4	2	Bactericide
<i>E. coli</i> (BLSE) 1218	1,56 ± 1,0	3,12 ± 0,2	2	Bactericide
<i>S. typhi</i> 1938	0,78 ± 0,1	1,56 ± 0,2	2	Bactericide
<i>S. aureus</i> ATCC	3,12 ± 1,2	6,24 ± 0,1	2	Bactericide
<i>Ps. Aeruginosa</i> ATCC	3,12 ± 0,0	6,24 ± 0,2	2	Bactericide
<i>E. coli</i> ATCC	0,97 ± 0,0	0,39 ± 0,2	2	Bactericide
<i>Ps. aeruginosa</i> 872	1,56 ± 7,2	3,12 ± 2,4	2	Bactericide
<i>Ps. aeruginosa</i> (IMP ^R) 261	1,56 ± 0,0	6,24 ± 4,1	4	Bactericide
<i>S. aureus</i> (MET ^R) 926	0,04 ± 0,0	0,97 ± 0,0	1	Bactericide
<i>S. aureus</i> 1227	0,97 ± 0,0	0,97 ± 0,0	1	Bactericide

329
330 **Table 5: Comparison of mean MIC and MBC values of the ethanolic extract of Funtumia**
331 **africana according to bacterial phenotypes**

Antibacterial parameters	Wild bacterial strains	Resistant bacterial strains	P-value
MIC (mg/mL)	2,575 ± 2,0	2,92 ± 3,1	P (0,2365) > 0,05
MBC (mg/mL)	2,785 ± 2,1	3,478 ± 4,2	P (0,3008) > 0,05

332
333 **Discussion :-**

334 **Ethnobotanical Survey**

335 Investigations into the treatment of bacterial infections using traditional medicine in the
336 Boundiali department identified **38 medicinal plants**. A literature review highlighted **ten (10)**
337 **plants** that require further investigation. These readily available plants are regularly harvested
338 and sold in the markets of Boundiali and the surrounding areas.

339 They belong to **nine (9) botanical families**, including the **Combretaceae** family. The use of
340 Combretaceae in treating microbial infections has also been mentioned by other authors, such

341 as Koné (2005), in a survey conducted in the Ferkessédougou region. This can be explained
342 by the fact that these two study areas share similar vegetation, consisting mainly of **wooded**
343 **savannas and shrub savannas**. Furthermore, the Combretaceae family is abundant in
344 **Sahelian–Sudanian savannas**, which represent the dominant vegetation type in northern
345 Côte d'Ivoire.

346 In traditional remedies, **leaves are the most frequently used plant part**, accounting for
347 approximately **60% of medicinal preparations**. Several authors agree on the increased use of
348 this plant organ. For example, Koffi et al. (2009) reported a usage rate of **63.52%** in an
349 ethnopharmacological survey conducted in Krobou country. Similarly, in other West African
350 countries, particularly **Nigeria**, leaves remain the most commonly used plant component. This
351 high usage can be explained by their **abundance, availability, and relatively easy handling**
352 (Tra Bi, 2008).

353 Remedies are generally prepared in the form of **decoctions**. Among neighboring populations,
354 medicinal recipes vary very little from one traditional healer to another, as the same
355 formulations are often used to treat specific ailments. This may explain the similarity between
356 the results of this study and those reported by Koné (2005), who conducted research in the
357 same northern region.

358 Decoction, prepared at high temperatures, has the advantage of **neutralizing pathogenic**
359 **microorganisms and ensuring the safety of the preparation**, thus preventing
360 contamination. The **primary method of administration is oral**, accounting for
361 approximately **50% of cases**. This finding is consistent with that of Jean (2000), who reported
362 similar results in his study on plants used as **anthelmintics in traditional medicine** in the Dja
363 Biosphere Reserve in Cameroon.

364

365 Phytochemical Perspective

366 Plants identified as effective against microbial infections are often prescribed for the
367 treatment of several other common ailments. This **multipurpose use** can be explained by the
368 presence of numerous groups of **biologically active chemical compounds** they contain (Tra
369 Bi, 2008).

370 Phytochemical investigations identified **thirteen (13) groups of chemical compounds**,
371 including:

- 372 • Alkaloids
- 373 • Quinones
- 374 • Flavonoids
- 375 • Terpenes
- 376 • Saponins
- 377 • Tannins

378 These phytoconstituents are responsible for the pharmacological effects observed when these
379 plants are used and therefore determine their **therapeutic value**.

380 Among these compounds, many are recognized for their **antibacterial effects**. Alkaloids play
381 an important role in biological structures and appear to possess **potent anticholinergic**
382 **properties** (Muster, 2004). Their presence in the various plant organs could explain the use of
383 these species in treating **headaches, tooth decay, colds, and coughs**. According to Jacques
384 (2000), certain alkaloids have a direct physiological effect by **reducing spasms and relieving**
385 **pain**.

386 Similarly, the presence of **funtumine**, an alkaloid extracted from *Funtumia africana*, has been
387 reported along with **flavonoids, coumarins, tannins, and terpenes**, demonstrating that this
388 plant possesses **bactericidal and fungicidal properties** (Thanyani, 2010).

389 Anthraquinone-containing compounds are frequently used in the treatment of **itching and**
390 **dermatological conditions** (Sanogo et al., 2016). These compounds are present in most of the
391 plant species studied, which could justify their use in treating **acne, itching, gonorrhea, and**
392 **wounds**.

393 Flavonoids, particularly **flavones and flavonols**, were also detected in most plant species.
394 These secondary metabolites are known for their **protective effects against hormone-**
395 **dependent diseases** (Cimanga et al., 2006). Their presence may explain the **anti-edematous**
396 **effects** observed in pregnant women using the leaves of *Diospyros mespiliformis*.

397 Polyterpenes possess **anti-allergic and anti-inflammatory properties**. The anti-
398 inflammatory effects observed in the treatment of **wounds, fever, and headaches** may be
399 associated with these compounds, since such conditions often involve inflammatory
400 processes. This could particularly explain the **anti-inflammatory capacity of Funtumia**
401 **africana leaves** (Thanyani, 2010).

402 Saponins are also recognized for their **anti-inflammatory, anti-edematous, analgesic, and**
403 **antibacterial properties** (Sanogo et al., 2016). Their presence in most of the plants studied
404 justifies their use in treating conditions such as **ulcers, tooth decay, headaches, and**
405 **gonorrhea**, which are often associated with severe pain.

406 Tannins are known for their **antiseptic, bactericidal, and astringent properties**. The
407 treatment of **skin blemishes** using the stem bark of *Ficus iteophylla*, **itching** using the stem
408 bark of *Pterocarpus erinaceus*, and **mouth sores** using the leaves of *Lawsonia inermis* may
409 be attributed to the presence of **catecholic and gallic tannins**.

410

411 Antibacterial Activity

412 The results of this study demonstrated that the extracts exhibit **varying degrees of**
413 **antibacterial activity** against the tested bacterial strains. This is reflected in the differences
414 observed in **inhibition zone diameters**.

415 Among all the plant species tested, *Funtumia africana* showed the **highest antibacterial**
416 **activity**, producing the largest inhibition zones. Its activity was particularly evident against
417 *Staphylococcus aureus* (METR) 926, a strain resistant to **methicillin and fluoroquinolones**
418 that was isolated from the blood of a patient suffering from a urinary tract infection.

419 These findings corroborate those reported by **Kouadio et al. (2015)**, who also highlighted the
420 use of this plant in the treatment of bacterial infections.

421 Regarding antibacterial parameters, the **lowest concentration at which the inhibitory action**
422 **of the *Funtumia africana* extract was observed was 0.04 mg/mL** against *Staphylococcus*
423 *aureus* (METR) 926. This result demonstrates the **strong antibacterial efficacy of the**
424 **extract against this resistant strain.**

425 These findings are comparable to those reported by **Baba-Moussa et al. (2013)**, who
426 demonstrated significant antibacterial activity using a decoction of *F. africana* leaves against
427 susceptible strains of *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus*
428 *aureus*, which are responsible for opportunistic infections. The same authors also reported
429 **fungicidal properties** for this plant.

430 The **one-way ANOVA test** indicated that the differences observed in the MICs and MBCs
431 between the two bacterial strain categories (**wild-type and resistant**) were **not statistically**
432 **significant**. Therefore, the antibacterial activity of the extracts **was not statistically**
433 **influenced by the bacterial phenotype.**

434 Furthermore, the **MBC/MIC ratios**, which were all **less than or equal to 4**, indicate that the
435 extracts exhibit a **bactericidal effect against all bacterial strains tested in this study.**

436 **Conclusion :-**

437 Research conducted in northern Côte d'Ivoire on medicinal plants used to treat bacterial
438 infections and many other pathologies identified **38 plant species**, of which **10 were selected**
439 **following a literature review**. Ethnobotanical surveys confirmed their **traditional**
440 **therapeutic uses.**

441 Phytochemical screening of these plants revealed the presence of several major groups of
442 **secondary metabolites**, including **alkaloids, quinones, flavonoids, terpenes, saponins, and**
443 **tannins**, all of which are known for their **antimicrobial activity.**

444 Furthermore, the evaluation of their antibacterial potential confirmed that **all the selected**
445 **plants exhibit antibacterial effects**. Among them, the species *Funtumia africana* was the
446 most active, and its extract was selected for the determination of the **Minimum Inhibitory**
447 **Concentrations (MICs) and Minimum Bactericidal Concentrations (MBCs).**

448 This research demonstrates that these plants offer **promising prospects for combating**
449 **microbial infections**, which remain a major public health concern. Therefore, it is necessary
450 to **strengthen conservation strategies for endangered plant species** in order to ensure the
451 preservation and protection of plant biodiversity, which represents a **valuable resource of**
452 **Ivorian flora.**

453

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457

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459 This work was carried out in collaboration with all the authors listed. Each author participated
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461 writing, and final revision of the manuscript. All authors have **read and approved the final**
462 **version of the manuscript.**

463

464 Competing Interests

465 The authors declare that **there are no competing interests regarding the publication of this**
466 **study.**

467

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