Phytochemical screening and antioxidant activity of methanolic extracts of 53 antimalarial plants from Bagira in Eastern DR Congo

Valentin Bashige Chiribagula 1,2,3,*, Amuri Salvius Bakari 1, Philippe Okusa Ndjolo 2, Byanga Joh Kahumba 1 and Jean-Baptiste Lumbu Simbi 3

1 Laboratoire de Pharmacognosie - Faculté des Sciences Pharmaceutiques - Université de Lubumbashi- 27, av Kato, Commune Kampemba, Lubumbashi/ RD Congo.
2 Service de Chimie thérapeutique- Faculté des Sciences Pharmaceutiques - Université de Lubumbashi- 27, av Kato, Commune Kampemba, Lubumbashi/ RD Congo.
3 Laboratoire de chimie Organique - Faculté des Sciences Université de Lubumbashi- 2 av de la Maternité, Commune de Lubumbashi /RD Congo.

Publication history: Received on 02 August 2020; revised on 10 August 2020; accepted on 11 August 2020

Article DOI: https://doi.org/10.30574/gscbps.2020.12.2.0250

Abstract

A previous study inventoried 53 plants used in traditional medicine in Bagira in Eastern Democratic Republic of Congo (DRC) in the management of malaria. During malaria disease, oxidative stress is responsible for the worsening of the patient’s condition. This study aims to identify phytochemical groups and to evaluate antioxidant activity of 53 plants used in traditional medicine in Bagira to treat malaria. The phytochemical screening was carried out by conventional reactions in solution and antioxidant activity used in vitro method with 1,1-diphenyl-2-picrylhydrazyl radical (DPPH). Chemical screening has identified secondary metabolites with both antimalarial and antioxidant potential such as coumarins, steroids, saponins, tannins and terpenoids in more than 70% of plants. Antioxidant screening revealed for the first-time antioxidant activity of 18 plants, among which *Dalbergia katangensis*, *Dialium angolense* and *Solanecio cydoniifolius* with IC₅₀ ≤ 1.6 µg / mL having the highest activities. This study shows that among plants used as antimalarial in Bagira several possess antioxidant power and contain many of groups presumed to be both antioxidant and antimalarial. This suggests that further studies continue to isolate compounds responsible for the proven activity.

Keywords: Anti-free radical activity; DPPH; Bagira; Antimalarial; Phytochemistry
1. Introduction

Oxidative stress results from a profound imbalance between oxidative systems and the body's antioxidant capacities in favor of the former [1]. Unbalanced, it leads to irreversible cell damage [2] responsible for aging and many conditions such as obesity [3], type 2 diabetes [4], atherosclerosis [5], cancer [6] or virus diseases [7] requiring the use of antioxidants. Several synthetic antioxidants used in the past have been abandoned because of their increased risk of toxicity in favor of natural antioxidants [8], which motivates the screening of plants with antioxidant potential.

Studies have shown that during a malarial disease oxidative stress occurs which can progress to cerebral malaria or anemia [9,10]. Thus, studies have been carried out with a view to seeking both plants with antioxidant and antimalarial potential. This is the case with the work of Saliq et al [11] or Sulistyaningsih et al [12] like so many others [13–16].

Another advantage of this approach is that it allows the discovery of new antimalarial molecules with new mechanisms of action likely to overcome the resistance problems facing current antimalarials [17,18]. This approach to screening plants with dual potential has seen some studies lead to the isolation of natural molecules that are both antimalarial and antioxidant. This is the case of mammea A / AA cyclo D, a coumarin isolated from the stem bark of Mesua borneensis (P. F. Stevens), a Calophyllaceae [19] or that of Lonchocarpol A, a flavonoid isolated from the stem bark of Erythrina cristagalli L., a Fabaceae [20]. Furthermore, the isolation of a bioactive molecule is conventionally preceded by the search for secondary metabolites with the desired potential. Beyond this interest, this screening also makes it possible to provide new knowledge on the chemical composition of the plant concerned on the major phytochemical groups of secondary metabolites of plants. In the case of malaria, bibliographical reviews [21–23] have highlighted alkaloids, flavonoids, coumarins, quinones, steroids, terpenoids as phytochemical groups with antimalarial potential. Among these phytochemical groups, flavonoids, coumarins, and terpenoids are particularly reported as groups with antioxidant potential [24,25].

This study focused on 53 plants used in traditional medicine in Bagira, in the treatment of malaria, to assess their antioxidant potential in vitro and to search for phytochemical groups with antiplasmodial potential. These plants come from an ethnobotanical study carried out on antimalarial plants from Bagira, such as the city of Bukavu in the eastern DRC.

2. Material and methods

2.1. Plant material

The plant material consisted of the leaves, stems, roots, flowers, fruits, and aerial parts of 53 plant species taken from a database of a survey we conducted in Bagira in 2013-2014. These plants have been collected in Bukavu in the company of traditional healers and the herbaria created for this occasion were deposited at the IRS Lwiro herbarium where the identity of the plants was determined (Table 2). After drying at room temperature, the plant material was ground using a stainless-steel electric mill (Plymix PX-MFC 90 D, Belgium) and then kept cool before handling. The choice of organs to screen was related to availability at harvest. Thus, for the herbs, we screened the aerial parts consisting mainly of leaves and stems without discrimination.

2.2. Obtaining extracts

The extracts were obtained by maceration of 350 g of powder in 1.5 L of methanol (Sigma Aldrich, USA) for 72 hours at room temperature then filtered through paper (Whatman, USA) and concentrated on a rotary evaporator (Büchi R-210, Switzerland) at a pressure of 180 mbar and a temperature of 40 ° C.

2.3. Substrate and positive control

DPPH (Sigma Aldrich, United Kingdom) was used as a substrate for the evaluation of antioxidant activity. It was prepared at 0.002% (w / v) in methanol. L-ascorbic acid (Sigma Aldrich, China) used as a reference antioxidant substance made it possible to prepare a standard curve with 5 successive dilutions of order 2 carried out from a solution of ascorbic acid at 40 µg/mL ( y = 0.0298X +0.0071; r² = 0.9997).

2.4. Identification of secondary metabolites

The phytochemical screening was carried out using conventional reactions in solution in tubes, based on staining, precipitation, or the formation of foams. It consisted in looking for alkaloids, anthocyanins, coumarins, flavonoids, quinones, saponins, steroids, tannins and terpenoids for their antiplasmodial or antioxidant potential and cyanogenic heterosides for their toxic potential, following the protocols previously described [26–28].
2.4.1. **Alkaloids**

The detection of alkaloids consisted in precipitating them using six precipitation reagents. Briefly, 1 g of powder of dry plant material was macerated in 10 mL of methanol at room temperature for 24 hours and then in an oven at 50 °C for 4 hours. The solution obtained was filtered then the marc washed three times with portions of hot methanol. The filtrate was evaporated to dryness in an oven at 50 °C and the residue was collected twice with 2 mL of hot 1% hydrochloric acid solution (Sigma-Aldrich, USA). The acid solution obtained was basified with 1 mL of concentrated ammonia (Sigma-Aldrich, UK), placed in a separating funnel (VWR, Belgium) and then mixed with 5 mL of chloroform (Sigma-Aldrich, USA). After stirring, the two phases were separated, and the operation was repeated three times. The organic phase was evaporated to dryness in the open air, the residue obtained was taken up in 0.5 mL of chloroform and the solution, transferred to a test tube, was mixed with 0.5 mL of 1% HCl thus forming two phases. The aqueous phase, which is above, was removed using a Pasteur pipette. Six drops were placed on a microscope slide. Each of these drops was treated with one drop of one of six precipitation reagents namely Dragentoff, Mayer, Hager, Wagner, Bertrand, and Sonnenschein reagent. The presence of alkaloids was only considered certain if each of the six reagents gave a precipitate.

2.4.2. **Coumarins**

Coumarins were identified by the alkaline reaction. Briefly 0.5 g of the moistened various extracts was taken in a test tube. The mouth of the tube was covered with filter paper treated with 1 N NaOH solution. Test tube was placed for 5 minutes in boiling water and then the filter paper was removed and examined under the UV light for yellow fluorescence indicated the presence of coumarins.

2.4.3. **Flavonoids and anthocyanins**

The flavonoids have been demonstrated by the Shinoda test. Briefly, 5 g of plant material placed in an Erlenmeyer flask was infused in 50 mL of distilled water for 30 minutes. 5 mL of filtrate were then treated successively with 5 mL of concentrated HCl, 5 drops of isoamyl alcohol and 1 mg of magnesium shavings. The red-orange (flavone), red or red-violet (flavonones), cherry red (flavonol) coloration appeared in the supernatant layer if the solution contained the flavonoids. Likewise, the reaction carried out for two minutes in a water bath in the absence of magnesium chips allowed the characterization of anthocyanins with the appearance of a red color.

2.4.4. **Cyanogenic heterosides**

Cyanogenic heterosides were identified by the reaction with picric acid. Briefly, 5 g of vegetable powder was placed in an Erlenmeyer flask with 10 mL of distilled water. The container was closed with a stopper to which was attached a strip of picrosodium paper lightly moistened with water and the contents were slightly heated (to 60 °C). The yellow picrosodium paper turned orange or red if the plant extract had released hydrocyanic acid.

2.4.5. **Quinones**

Quinones were identified by the Borntrager test. Briefly, 5g of powdered plant material was macerated for 24 hours in 50mL of petroleum ether. After filtration, 10 mL of ethereal filtrate was treated with 5 mL of 10% NH₃. The appearance of a purplish red color in the aqueous phase indicated the presence of free quinones and that of yellow or orange colors, the bound quinones.

2.4.6. **Saponins**

Saponins were identified by the foaming reaction. Briefly, 10 g of coarsely ground plant material was treated with 100 mL of distilled water to make a decoction for 30 minutes and the mixture was filtered through filter paper after cooling. 15 mL of the decocts were then introduced into a test tube 16 mm in diameter and 160 mm in height. The contents of the tube were shaken tightly for one minute and then allowed to stand for 10 minutes. The appearance of a persistent foam greater than 10 mm in height indicates the presence of saponins.

2.4.7. **Steroids and terpenoids**

Both steroids and terpenoids have been defied by the reaction with sulfuric acid. Briefly, 5 g of plant material was macerated for 24 hours in 100mL of petroleum ether. After filtration, the solvent was evaporated to dryness. In the residue obtained, were added successively and with stirring, 2 mL of chloroform and three drops of concentrated sulfuric acid. The appearance of purple or green colorings indicated the presence of steroids. The identification of terpenoids followed the same pattern as that of steroids. In addition to the reagents used for steroid testing, a few drops
of Hirschson reagent (concentrated acetic anhydride) were added to 4 mL of the acidified solution. Yellow staining turning red indicated the presence of terpenoids.

2.4.8. Tannins

The tannins were identified according to the protocol below: 5 g of plant material were infused in 50 mL of water contained in an Erlenmeyer flask for 30 minutes. 5 mL of the infused was taken and mixed with 1 mL of 1% ferric chloride. The test was considered positive when either a precipitate appeared or a blue-green, dark blue or green color. 15 mL of Stiasny reagent (10 mL 40% formalin and 5 mL concentrated HCl) was mixed with 30 mL of the infused and the mixture was brought to a water bath at 90 °C. The appearance of a precipitate indicated the presence of catechetical tannins. The solution was then filtered, and the filtrate was saturated with sodium acetate before adding a few drops of ferric chloride thereto. The formation of a precipitate in this case revealed the presence of gallic tannins.

2.5. Antioxidant activity test with DPPH

Antioxidant activity was assessed using the DPPH assay [29]. Briefly, 50 µL of extract or positive control prepared at different dilutions of order 2 in methanol from a 100 µg / mL solution were interacted with 1950 µL of 0.002% DPPH in test tubes. (Nunc WVR, Germany). After mixing and incubating in the dark for 30 minutes, the absorbance of the solution was read at 492 nm (Thermo Fisher Scientific Inc. spectrophotometer, Waltham, USA). The tests were carried out in triplicate and the percentage of antioxidant activity was calculated by the formula:

\[
\%AAO = \left(\frac{Ab - Ae}{Ab}\right) \times 100
\] (equation 1)

with \(Ab\) = absorbance measured in the presence of the negative control, \(Ae\) = absorbance measured in the presence of the extract and \(\% AA0\) = Percent inhibition and expresses antioxidant activity. This percentage of activity made it possible to generate the IC\textsubscript{50} or concentration at which the extract has 50%, to categorize the extracts.

2.6. Statistical analysis of data

GraphPad Prisme version 6 software (GraphPad Software, La Jolla, USA) was used to perform statistical analysis of the data and generate the IC\textsubscript{50}s. The analysis of the variables was carried out by one-way ANOVA with the significance level set at 95%.

3. Results and discussion

3.1. Phytochemical screening

The results of the chemical screening show that each of the 53 plants contains at least 5 phytochemical groups out of the 10 sought. No plant contains cyanogenic heterosides and 3 species, Carica papaya, Entada abyssinica and Flueggea virosa, all contain the 9 groups with therapeutic potential. Each organ contains at least 4 phytochemical groups and the leaves of Azadirachta indica as well as the fruits of Lantana camara with 8 groups each, contain the greatest number of the desired phytochemical groups (Table 1). Table 1 shows that antimalarial molecules have already been isolated for 12 plants. These are the species Artemisia annua (terpenoids), Azadirachta indica (terpenoids), Bidens pilosa (flavonoids), Cajanus cajan (flavonoids), Cymbopogon citratus (terpenoids), Erythrina abyssinica (flavonoids), Euphorbia hirta (flavonoids), Lantana camara (terpenoids), Occhna schweinfurthiana (flavonoids), Phyllanthus niruri (steroids), Physalis angulata (steroids) and Tithonia diversifolia (terpenoids). It also shows that 11 plants were so far phytochemically unrecognized. These are, Aframomum laurentii, Clematis villosa, Crooscephalum montuosum, Crooscephalum picridifolium, Dalbergia catangensis, Dialium angolense, Isoberlinia angolensis, Isoberlinia tomentosa, Julbernardia paniculata, Rothmannia engleriana, and Solanecio cydonifolius.
### Table 1: Phytochemical screening of 53 plants used as antimalarial drugs in Bagira (DRC)

| Species | PU | Alkaloids | Anthocyanins | Coumarins | Flavonoids | Quinones | Saponins | Steroids | Tannins | Terpenoids | HCN | Previous chemical screening |
|---------|----|-----------|--------------|-----------|------------|----------|----------|----------|---------|------------|-----|-----------------------------|
| 1 Acacia polyacantha | De Wild (Fabaceae) | | | | | | | | | | | |
|  |  | F  | + | + | - | - | - | + | + | - | - | [30] |
|  |  | ET | + | - | + | + | + | - | + | + | - | |
|  |  | R  | + | - | + | - | - | - | + | - | + | |
|  |  | Fr  | - | + | + | - | + | - | + | + | - | |
|  |  | Flr  | - | + | + | - | + | - | + | + | - | |
| 2 Aframomum laurentii | (De Wild & T, Durand) K. Schum (Zingiberaceae) | PA  | - | - | - | + | + | - | + | + | - | |
|  |  | F  | - | - | - | + | - | + | - | + | - | [32,33] |
|  |  | R  | - | - | + | + | + | + | - | + | - | |
| 3 Ageratum conyzoides | L. (Asteraceae) | F  | + | + | - | + | + | + | - | - | - | [31] |
|  |  | ET | + | + | + | - | + | (+) | + | - | |
|  |  | ER | - | - | - | - | + | + | - | + | - | |
| 4 Artemisia annua | L. (Asteraceae) | R  | - | - | + | - | + | - | + | - | - | [32,33] |
| 5 Azadirachta indica A. Juss (Meliaceae) | | F  | + | - | + | + | + | + | - | + | - | [34,35] |
|  |  | ET | - | + | + | + | - | + | - | - | - | |
|  |  | ER | - | - | - | - | + | - | + | - | - | |
| 6 Bidens pilosa | L. (Asteraceae) | R  | + | - | + | + | + | - | - | - | - | [36,37] |
| 7 Bobgunia madagascariensis | (Desv.) J.H. Kirkbr. (Fabaceae) | ET | - | - | + | + | + | - | - | - | + | - | [38] |
| 8 Cajanus cajan | (L.) Millsp. (Fabaceae) | R  | - | - | + | + | + | + | - | - | - | |
| 9 Carica papaya | L(Caricaceae) | Fr  | - | - | + | + | + | + | - | - | - | [41] |
| 10 Cassia occidentalis | L. (Fabaceae) | Fr  | - | - | + | + | + | - | + | + | - | [42] |
| 11 Catharanthus roseus | (L.) G Don. (Apocynaceae) | Fr  | - | - | + | + | + | - | + | + | - | [43] |
| No. | Species                                                                 | F    | ET   | ER   | Fr  | PA   |
|-----|-------------------------------------------------------------------------|------|------|------|-----|------|
| 12  | Chenopodium abrosioides (Chenopodiaceae)                                | +a   | -    | +a   | -   | -    |
|     |                                                                         | ++a  | +    | -    | +   | -    |
|     |                                                                         | +a   | -    | -    | +   | +a   |
| 13  | Chenopodium opulifolium Schrad, EX Wdij. Koch (Chenopodiaceae)          | PA   | -    | +a   | +   | ++   |
|     |                                                                         | +    | +    | +    | +   | +a   |
|     |                                                                         | -    | -    | -    | +   | +    |
| 14  | Cinchona ledgeriana (Howard) Bern. Moens Ex Trimen (Rubiaceae)          | F    | +a   | -    | +a  | +a   |
|     |                                                                         | +a   | +    | +a   | -   | -    |
|     |                                                                         | ET   | ++a  | -    | +a  | -    |
|     |                                                                         | ER   | +a   | -    | +a  | -    |
|     |                                                                         | Fr   | -    | +    | -   | +    |
|     |                                                                         | +    | +    | +    | +   | +a   |
|     |                                                                         | -    | -    | -    | +   | +    |
| 15  | Clematis villosa DC (Ranunculaceae)                                     | PA   | +    | -    | +   | ++   |
|     |                                                                         | -    | +    | -    | ++  |
|     |                                                                         | +    | -    | +    | -   |
| 16  | Crassocephalum montuosum (S. Moore) Milne-Redh (Asteraceae)             | PA   | -    | +    | -   | -    |
|     |                                                                         | -    | +    | -    | +   |
|     |                                                                         | +    | -    | +    | -   |
| 17  | Crassocephalum picridefolium (DC) S More (Asteraceae)                    | PA   | -    | +    | -   | +    |
|     |                                                                         | +    | +    | -    | -   |
|     |                                                                         | +    | -    | +    | -   |
| 18  | Cymbopogon citratus (DC) Stapf. (Poaceae)                               | F    | -    | +    | -   | -    |
|     |                                                                         | +    | a    | -    | -   |
|     |                                                                         | -    | -    | -    | -   |
|     |                                                                         | +    | a    | -    | -   |
|     |                                                                         | -    | -    | -    | -   |
| 19  | Dalbergia kantangensis Lechneuad (Fabaceae)                            | F    | -    | +    | +    |
|     |                                                                         | ++   |
|     |                                                                         | ET   | -    | +    | +    |
|     |                                                                         | ER   | +    | -    | -    |
|     |                                                                         | Fr   | -    | +    | -    |
|     |                                                                         | +    |
|     |                                                                         | +    | +    | +    |
|     |                                                                         | -    | +    | -    |
| 20  | Dialium angolense (Welw EX Beth) Harms (Fabaceae)                       | F    | ++   | -    |
|     |                                                                         | +    | -    | +    |
|     |                                                                         | ER   | -    |
|     |                                                                         | Fr   |
|     |                                                                         | +    |
|     |                                                                         | +    |
| 21  | Dialopsis africana Radck (Sapindaceae)                                  | F    | -    | +    |
|     |                                                                         | ++   | +    |
|     |                                                                         | +    | -    |
|     |                                                                         | -    | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
| 22  | Ekebergia benguellensis Welw EX CDC (Meliaceae)                         | F    | ++a  |
|     |                                                                         | ++   |
|     |                                                                         | +a   |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | ++a  |
|     |                                                                         | +a   |
|     |                                                                         | a    |
|     |                                                                         | Fr   |
|     |                                                                         | ++   |
|     |                                                                         | +    |
|     |                                                                         | +    |
| 23  | Eleusine indica (L) Gaertn (Poaceae)                                    | PA   | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
| 24  | Entada abyssinica Steud. ex A. Rich. (Fabaceae)                         | F    | +a   |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
| 25  | Erythrina abyssinica Lam. Ex DC (Fabaceae)                              | F    | ++   |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
| 26  | Euphorbia hirta L. (Euphorbiaceae)                                      | F    | -    |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
|     |                                                                         | +    |
| 27  | Flueggea virosa (Roxb. Ex Willd.) Voigt (Phyllanthaceae)                | F    | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | +    |
| 28  | Hypoestes triflora (Forssk) Roem, & Schult (Acanthaceae)                | PA   | +    |
|     |                                                                         | +    |
|     |                                                                         | ++   |
|     |                                                                         | -    |
|     |                                                                         | +    |
|     |                                                                         | -    |
|     |                                                                         | -    |

[^44]: 44
[^45]: 45
[^46]: 46
|   | **Isoperlinia angolensis** (Welw. Ex Benth.) Hoyle & Brenan (Fabaceae) | PA | - | + | - | - | - | + | - | - |
|---|-----------------------------------------------------------------------|----|----|----|----|----|----|----|----|----|
|   | **Isoperlinia tomentosa** (Harms) Craib & Stapf (Fabaceae)            | PA | - | + | + | + | - | - | + | + |
| 31| **Jatropha curcas** L. (Euphorbiaceae)                                 | F  | + | + | + | - | - | + | - | - | [61] |
|   |                                                                       | T  | - | - | + | + | - | - | - | + | - |
|   |                                                                       | R  | + | - | + | - | + | + | - | - | - |
|   |                                                                       | Fr | - | + | - | - | + | + | - | - | - |
| 32| **Julbernardia paniculata** (Benth.) Troupin (Fabaceae)                | F  | - | + | + | + | + | + | + | - | - |
|   |                                                                       | ET | + | - | - | + | + | + | ++ | + | - |
|   |                                                                       | ER | - | - | + | - | + | ++ | + | - | - |
| 33| **Lantana camara** L. (Verbenaceae)                                   | F  | + | + | + | - | - | - | + | + | [62] |
|   |                                                                       | T  | - | - | + | - | + | ++ | + | - | - |
|   |                                                                       | R  | + | - | + | - | + | ++ | + | - | - |
|   |                                                                       | Fr | - | + | - | - | + | ++ | + | - | - |
| 34| **Leucas martinicensis** (Jacq.) R. BR. (Lamiaceae)                   | F  | + | + | + | - | - | - | + | + | [63] |
|   |                                                                       | R  | - | - | + | - | + | ++ | + | - | - |
| 35| **Mangifera indica** L. (Anacardiaceae)                               | F  | + | + | + | - | - | + | + | - | - |
|   |                                                                       | ET | - | - | + | - | - | + | ++ | + | - |
|   |                                                                       | ER | + | - | + | - | + | ++ | + | - | - |
|   |                                                                       | Fr | - | + | - | - | + | ++ | + | - | - |
| 36| **Moringa oleifera** Lam. (Moringaceae)                               | F  | + | + | + | - | - | - | + | + | [65,66] |
|   |                                                                       | T  | - | - | + | - | + | ++ | + | - | - |
|   |                                                                       | R  | + | - | + | - | + | ++ | + | - | - |
|   |                                                                       | Fr | - | + | - | - | + | ++ | + | - | - |
| 37| **Ochna schweinfurthiana** F Hoffm (Ochnaceae)                         | F  | + | + | + | - | - | + | + | - | - |
|   |                                                                       | ER | + | + | (++) | - | - | - | ++ | + | - |
|   |                                                                       | ET | + | - | - | - | + | ++ | + | - | - |
| 38| **Ocimum gratissimum** L. (Lamiaceae)                                 | F  | + | + | + | - | - | - | + | + | [68,69] |
|   |                                                                       | R  | + | - | + | - | + | ++ | + | - | - |
|   |                                                                       | Fr | - | + | - | - | + | ++ | + | - | - |
| 39| **Phyllanthus muellerianus** (Kuntze) Exell (Phyllanthaceae)           | F  | + | + | + | - | - | - | + | + | [70] |
|   |                                                                       | ET | - | - | + | - | + | ++ | + | - | - |
|   |                                                                       | R  | + | - | + | - | + | ++ | + | - | - |
|   |                                                                       | Fr | - | + | - | - | + | ++ | + | - | - |
| 40| **Phyllanthus niruri** L. (Phyllanthaceae)                             | F  | + | + | + | - | - | - | + | + | [71] |
|   |                                                                       | T  | - | - | + | - | + | ++ | + | - | - |
|   |                                                                       | R  | + | - | + | - | + | ++ | + | - | - |
| 41| **Physalis angulata** L. (Solanaeace)                                 | F  | - | - | + | - | + | ++ | + | - | - |
|   |                                                                       | R  | + | - | + | - | + | ++ | + | - | - |
|   |                                                                       | Fr | - | + | - | - | + | ++ | + | - | - |
| 42| **Piliostigma thonningii** (Schum.) Milne-Redh. (Fabaceae)            | F  | - | - | + | - | + | ++ | + | - | - |
|   |                                                                       | T  | + | - | + | - | + | ++ | + | - | - |
|   |                                                                       | R  | - | - | + | - | + | ++ | + | - | - |
3.1.1. Classification of species according to the number of phytochemical groups identified

Depending on the number of phytochemical groups identified within each plant, all the organs together, the 53 plant species can be grouped into 5 classes (Classes A to E). Although almost 70% of plant species contain 7 phytochemical groups, only 6% of plants contain the nine phytochemical groups with therapeutic potential (Figure 1).

Class A: species with 5 phytochemical groups; Class B: species with 6 phytochemical groups; Class C: species with 7 phytochemical groups; Class D: species with 8 phytochemical groups; class E: species with 9 phytochemical groups.
The class A includes 10 species which are *Clematis villosa*, *Crassocephalum montuosum*, *Crassocephalum picridifolium*, *Cymbopogon citratus*, *Eleusine indica*, *Hypoestes triflora*, *Isobaria anglolensis*, *Isoberiala tomentosa*, *Ocimum gratissimum* and *Solaneo cydoniifolius*. Class B includes 7 species: *Artemisia annua*, *Bidens pilosa*, *Chenopodium abrosioides*, *Chenopodium opulifolium*, *Dalbergia katangensis*, *Phyllanthus niruri*, and *Spilanthes mauritiana*. We find in class C, 17 species: *Ageratum conyzoides*, *Bobgunia madagascariensis*, *Cajanus cajan*, *Cassia occidentalis*, *Erythrina abyssinica*, *Julbernardia paniculata*, *Leucas martinicensis*, *Mangifera indica*, *Phyllis angulata*, *Rothmannia engleriana*, *Senecio cineraria*, *Syzygium cordatum*, *Tutges minuta*, *Tithonia diversifolia*, *Trema orientalis*, and *Vernonia amygdalina*. Class D has only 3 species, these are *Carica papaya*, *Entada abyssinica* and *Flueggea virosa*. In class E we find the species *Acacia polyacantha*, *Aframomum laurentii*, *Azadirachta indica*, *Catharanthus roseus*, *Cinchona ledgeriana*, *Dialium angolense*, *Diospyros africana*, *Ekebergia benguellensis*, *Euphorbia hirta*, *Jatropha curcas*, *Lantana camara*, *Magifera indica*, *Ochna schwarfinfurthiana*, *Pilostigma thonningii*, *Psidium guajava*, and *Psorospermum corymbiferum*.

**Figure 1** Classification of species according to the number of phytochemicals identified within the species, N = 53.

3.1.2. Classification of phytochemical groups identified in the 53 plants

The phytochemical groups identified can be classified either according to the overall result of the screening or according to the result within each organ. According to the overall results of the phytochemical screening, flavonoids (81.7%) and terpenoids (70.5%) are the most representative, while quinones (29.8%) and alkaloids (35.8%) are the most representative less frequent (figure 2).

**Figure 2** Frequency of phytochemical groups from 53 plants.

These frequencies observed for the entire screening (Figure 2) are not, however, in the same proportions for each organ (Figure 3). Flavonoids, for example, which are 81.7% overall, vary between 67 and 100% depending on the organ (Figure 3), thus illustrating a variability in the chemical composition of species. This variability in the composition of
secondary metabolites within the same plant may justify the difference in pharmacological properties attributable to each species depending on the organ considered.

![Figure 3](image)

**Figure 3** Frequency of secondary metabolites in different organs of plants: leaves (a), stems (b), fruits (c), flowers (d), roots (e) and aerial parts (f).

### 3.2. Antioxidant activity of methanolic extracts from 53 selected plants

Regarding the IC$_{50}$ values, the 147 extracts obtained from the 53 plants can be grouped into 4 classes. Class 1 is that of very active extracts (IC$_{50} \leq 1.6$ µg / mL), class 2 is that of active extracts (1.6 <IC$_{50} \leq 50$ µg / mL), class 3 contains weakly...
active extracts ($50 < \text{IC}_{50} \leq 200 \mu g / mL$) and class 4 contains inactive extracts ($\text{IC}_{50} > 200 \mu g / mL$). In addition, 68% of plants have already been evaluated for antioxidant activity (Table 2).

**Table 2** Antioxidant activity of methanolic extracts from 53 plants known to be antimalarial in Bagira.

| Species                        | Herbarium Code | CIso: Mean ± SD (µg/mL) N=3 | Areal part | Organ: Previous antioxidant activity |
|--------------------------------|----------------|-----------------------------|------------|--------------------------------------|
|                                |                | 1.01 ± 0.4                  |            |                                      |
| Ascorbic acid                  |                |                             |            |                                      |
|                                |                | Leaves                      | Root       | Stem                                 |
| Acacia polyacantha             | KH5128         | 48.4 ± 1.4<sup>b</sup>      | 38.8 ± 0.4<sup>b</sup> | 60.4 ± 1.1<sup>d</sup> | G : [84] |
| Aframomum laurentii            | KH4072         | >200                        | 45.1 ± 0.2<sup>b</sup> | >200 |
| Ageratum conyzoides            | KH3560         | 25.5 ± 0.1<sup>b</sup>      | 18.5 ± 0.2<sup>a</sup> | 75.5 ± 0.4<sup>d</sup> | PA : [85] |
| Artemisia annua                 | IL2045         | >200                        | >200       |                                      | F, PE : [86] |
| Azadirachta indica             | IL2451         | 13.2 ± 0.4<sup>a</sup>      | 8.1 ± 1.5<sup>a</sup> | 75.5 ± 1.7<sup>d</sup> | T : [87] |
|                                 |                |                             |            |                                      | F : [35] |
| Bidens pilosa                  | IL8431         | 1.1 ± 0.4                   | 1.2 ± 0.1  |                                      | F: [88][79] |
| Bobgunia madagascariensis      | IL4757         | 30.9 ± 0.4<sup>b</sup>      | 11.1 ± 0.4<sup>a</sup> | 13.1 ± 0.4<sup>a</sup> |                                      |
| Cajanus cajan                  | IL6158         | 30.9 ± 2.4<sup>b</sup>      | 10.1 ± 0.4<sup>a</sup> | 13.4 ± 0.4<sup>a</sup> | F : [89] |
| Carica papaya                  | III671         | 13.1 ± 1.5<sup>a</sup>      | 13.3 ± 1.4<sup>a</sup> | 14.1 ± 0.4<sup>a</sup> | F : [90] |
| Cassia occidentalis            | IL3978         | 13.1 ± 0.4<sup>a</sup>      | 13.1 ± 0.4<sup>a</sup> | 63.9 ± 1.6<sup>d</sup> | PA, F : [91] |
| Catharanthus roseus            | IL4292         | 30.8 ± 1.4<sup>b</sup>      | >200       | 7.4 ± 1.4<sup>a</sup>              | R : [92][91] |
|                                 |                |                             |            |                                      | F : [93] |
| Chenopodium abrosioides        | IL8462         | 13.1 ± 1.1<sup>b</sup>      | >200       |                                      | [94] |
| Chenopodium opulifolium        | IL4012         | 12.1 ± 0.2<sup>b</sup>      | >200       |                                      | [46] |
| Cinchona ledgeriana            | IL3076         | 30.8 ± 0.2<sup>b</sup>      | 13.1 ± 0.2<sup>a</sup> | >200 | F : [46] |
| Clematis villosa               | IL3076         | 47.7 ± 0.2<sup>c</sup>      |            |                                      | |
| Crassocephalum montuosum       | IL1546         | 60.2 ± 0.2<sup>d</sup>      |            |                                      | |
| Crassocephalum picridifolium   | IL1498         | 47.7 ± 0.2<sup>c</sup>      |            |                                      | |
| Cymbopogon citratus            | II2098         | 59.9 ± 0.2<sup>c</sup>      | 13.1 ± 0.2<sup>a</sup> |            | R, PA : [95] |
|                                 |                |                             |            |                                      | F : [96] |
| Dalbergia katangensis          | IL1025         | 1.1 ± 0.1                   |            |                                      | |
| Dialium angolense              | II1097         | 1.2 ± 0.2                   | 7.4 ± 0.2<sup>a</sup> |            | |
| Dialopsis africana             | II1091         | 1.4 ± 0.1                   | 7.4 ± 0.2<sup>a</sup> | >200 | |
| Ekebergia benguellensis        | II2076         | 1.2 ± 0.3                   | >200       | >200 | |
| Eleusine indica                | II3061         | 13.1 ± 0.2<sup>a</sup>      |            |                                      | PA : [97] |
| Entada abyssinica              | III1546        | 30.7 ± 0.2<sup>b</sup>      | 13.1 ± 0.2<sup>a</sup> | >200 | F : [98] |
| Erythrina abyssinica           | III1498        | 7.4 ± 0.2<sup>a</sup>       | 13.1 ± 0.2<sup>a</sup> | >200 | F, T, R : [99] |
| Euphorbia hirta                | II2098         | 51.8 ± 0.2<sup>c</sup>      |            |                                      | PA : [100] |
|   | Species                  | Code   | IL | 1  | 2          |        |
|---|--------------------------|--------|----|----|------------|---------|
|27 | *Flueggea virosa*        | IL1025 | >200| >200|           |         |
|28 | *Hypoestes triflora*     | IL1087 | >200|     | 58.6 ± 0.2 | c       |
|29 | *Isoberlinia angolensis* | IL1091 | >200|     | 59.6 ± 0.2 | c       |
|30 | *Isoberlinia tomentosa*  | IL2076 | >200|     | 13.1 ± 0.1 | c       |
|31 | *Jatropha curcas*        | IL3061 | >200| 7.4 ± 0.2 | >200     | F: [101]|
|32 | *Julbernardia paniculata*| IL1098 | >200| 13.1 ± 0.2|           |         |
|33 | *Lantana camara*         | IL1075 | 50.2 ± 0.2| >200| 58.9 ± 0.2 | c       |
|34 | *Leucas martinicensis*   | IL713  | >200|     |           |         |
|35 | *Mangifera indica*       | IL3026 | >200|     |           |         |
|36 | *Moringa oleifera*       | IL1233 | 30.7 ± 0.2| 7.4 ± 0.2| >200     | F: [14] |
|37 | *Ochna schweinfurthiana* | IL1063 | 7.4 ± 0.2 | >200| 13.1 ± 0.2| a       |
|38 | *Ocimum gratissimum*     | IL1087 | 30.7 ± 0.2| >200|           |         |
|39 | *Phyllanthus muellerianus*| IL4679 | 30.7 ± 0.2| 13.1 ± 0.2| >200     | PA: [107]|
|40 | *Phyllanthus niruri*     | IL1076 | 30.9 ± 0.2| 7.4 ± 0.2| >200     | F & Fr: [108]|
|41 | *Physalis angulata*      | IL4078 | 13.1 ± 0.2 | 13.1 ± 0.2| >200     | [109]   |
|42 | *Piliostigma thonningii* | IL2045 | 30.9 ± 0.2| >200| >200     | F: [110]|
|43 | *Psidium guajava*        | IL0241 | 30.9 ± 0.2| 13.1 ± 0.2 | 13.1 ± 0.2| a       |
|44 | *Psorospermum corimbiferum* | IL2089 | >200| 7.4 ± 0.2| 10.1 ± 0.2| a       |
|45 | *Rothmannia engleriana*  | IL3075 | 7.4 ± 0.2| 13.1 ± 0.2| >200     |         |
|46 | *Senecio cineraria*      | IL1065 | >200|     | 1.5 ± 0.3  | PE: [77]|
|47 | *Solanecio cydoniifolius*| IL3070 | >200|     | 1.6 ± 0.1  |         |
|48 | *Spilanthes mauritiana*  | IL7012 | >200|     | 1.6 ± 0.3  | PE: [78]|
|49 | *Syzygium cordatum*      | IL4051 | 14.1 ± 0.2| 7.4 ± 0.2| >200     | Fr: [112]|
|50 | *Tagetes minuta*         | IL2458 | 12.1 ± 0.2| >200|           | PA: [113]|
|51 | *Tithonia diversifolia*  | IL2097 | 30.7 ± 0.2| >200| 7.4 ± 0.2  | F: [102]|
|52 | *Trema orientalis*       | IL7849 | 13.1 ± 0.2| 7.4 ± 0.2| 6.4 ± 0.2 | F: [82] |
|53 | *Vernonia amygdalina*    | IL4032 | 1.5 ± 0.1| 1.4 ± 0.2| 13.1 ± 0.2| a       |

*F: leaf, Fr: fruit, Flr: flowers, T: stem, R: roots, PA: aerial parts, PE: whole plant, G: gum, The extracts are compared to the positive control which is ascorbic acid and the level of significance of the difference is expressed by letters a, b and c: a p<0.01, b p <0.001, c p<0.0001.*  

Antioxidant activity screening results show that 73.3% of extracts have antioxidant activity and the most active 5/11 extracts are leaf. The only 8% of plants that showed strong antioxidant activity are: *Bidens pilosa* (leaves and roots), *Dalbergia katingensis* (Leaves), *Dialium angolense* (leaves), *Senecio cineraria* (aerial parts), *Solanecio cydoniifolius* (aerial parts) and *Vernonia amygdalina* (leaves and roots) (figure 4).
4. Discussion

During this study, 53 plants selected from an ethnobotanical survey carried out on plants known to be antimalarial in Bagira in eastern DRC were studied. This study focused on the search for secondary metabolites in various organs of these plants, and the demonstration of the antioxidant potential of methanolic extracts from their organs used as antimalarial drugs in Bagira. The interest in evaluating the antioxidant potential of antimalarial substances comes from the fact that plants with antioxidant potential could prevent the oxidative stress which occurs in malaria disease. As for the phytochemical screening of secondary metabolites, it constitutes the first step towards the isolation and characterization of the active compounds.

This study reports, for the first time, the phytochemical knowledge of 11 plants, *Aframomum laurentii*, *Clematis villosa*, *Crassocephalum montuosum*, *Crassocephalum picridifolium*, *Dalbergia katangensis*, *Dialium angolense*, *Isoberlinia angolensis*, *Isoberlinia tomentosa*, *Julbernardia paniculata*, *Rothmannia engleriana* and *Solanecio cydoniifolius*. Among these plants, *Aframomum laurentii* and *Dialium angolense* with 8 phytochemical groups each, *Julbernardia paniculata* as well as *Rothmannia engleriana* with 7 phytochemical groups each, can be considered as the 4 most interesting species from a phytochemical point of view because of their diversity in secondary metabolites.

The results of this study show that 30 of these 53 plants are already known from a phytochemical point of view although no antimalarial molecules have been reported (Table 1). This study confirmed previous results for some of these species. This is the case with flavonoids and terpenoids in *Chenopodium opulifolium* [45] or flavonoids and terpenoids in *Ekebergia benguelensis* [51]. Furthermore, some previous phytochemical knowledge has not been confirmed by this study. This is the case of the species *Ekebergia benguelensis* where we did not find coumarins in the root bark and yet previously 4-methoxy-5-hydroxymethylcoumarin had been isolated there [50]. The fact that the plants were not harvested in the same environment is a likely explanation for these observed disparities given that the phytochemical composition of the plant in secondary metabolites depends on several factors such as climate, age of the plant or the place of harvest [115]. It could also be varieties different from those studied previously. It would therefore be interesting to carry out a simultaneous study between these different specimens to have a clear point of view.

Terpenoids and flavonoids were the most frequent alongside several metabolites with antiplasmodial and antioxidant potential (Table 1 and Figure 3). Note that several studies have reported the preponderance of these metabolites among phytochemical groups with antimalarial potential [21,22]. The identification of these phytochemical groups within these 53 plants could constitute a first orientation for a more in-depth screening possible mainly on the 11 plants which were until then little known from a phytochemical point of view.

Only 18 plants (32%) have never been assessed for prior antioxidant activity (table 2). These species are, *Aframomum laurentii*, *Bobgunia madagascariensis*, *Chenopodium opulifolium*, *Clematis villosa*, *Crassocephalum montuosum*, *Crassocephalum picridifolium*, *Dalbergia katangensis*, *Dialium angolense*, *Dialopsis africana*, *Ekebergia benguelensis*, *Flueggea virosa*, *Hypoestes triflora*, *Isoberlinia angolensis*, *Isoberlinia tomentosa*, *Julbernardia paniculata*, *Ochna
The results obtained for these plants constitute the first information concerning their antioxidant potential. In this category of plants, only Dalbergia katangensis, Dialium angolense and Solanecio cydoniifolius, with IC$_{50}$ ≤1.6 µg/mL, are very active and of which, Dialium angolense is the only species which has 8 phytochemical groups. These 3 plants could constitute interesting candidates for a more in-depth antioxidant investigation.

Among the 18 plants so far unrecognized from the point of view of antioxidant activity, 11 are also unknown from the phytochemical and antimalarial point of view [116]. These species are Aframomum laurentii, Clematis villosa, Crossocephalum montuosum, Crossocephalum picridifolium, Dalbergia katangensis, Dialium angolense, Isobelopeia angolensis, Isobelopeia tomentosa, Julbernardia paniculata, Rothmannia engleriana and Solanecio cydoniifolius. Over 80% of these plants contain coumarins (100% of plants) and terpenoids (81.2% of plants). However, it has been previously reported that coumarins [114,117] and terpenoids [118,119] constitute true groups of natural antioxidants. Their frequent presence in the plants could therefore constitute an explanation of the antioxidant activity demonstrated in the extracts examined. On the other hand, the fact that 68% of plants have already been investigated for antioxidant activity suggests that there is a high probability of encountering in the 32% of plants not studied, interesting antioxidant compounds.

5. Conclusion
This study highlights for the first time the antioxidant activity of 18 plants in which several phytochemical groups with both antioxidant and antimalarial activity such as flavonoids and terpenoids are frequently found. It shows that among these plants, 11 are also unrecognized from the phytochemical antioxidant and antimalarial point of view. She suggests that these plants, such as Dalbergia katangensis, Dialium angolense and Solanecio cydoniifolius, whose antioxidant activity has just turned out to be interesting, be further investigated in the hope of discovering compounds that are both anti-free radicals and antimalarial.

Compliance with ethical standards

Acknowledgments
The authors thank Kalonda Emery for her valuable advice during phytochemical screening.

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.

References
[1] Goudable J and Favier A. (1997). Radicaux libres oxygènes et antioxydants. Nutr Clin Metab, 11(2), 115–120.
[2] Schirmer RH, Müller JG and Krauth-Siegel RL. (1995). Disulfide-Reductase Inhibitors as Chemotherapeutic Agents: The Design of Drugs for Trypanosomiasis and Malaria. Angew Chemie Int Ed English, 34(2), 141–154.
[3] Costantino S, Paneni F, Virdis A, Hussain S, Mohammed SA, Capretti G, Akhmedov A, Dalgaard K, Chiodotto S, Pospisilik JA, Jenuwein T, Giorgio M, Volpe M, Taddei S, Lu”scher TF and Cosentino F. (2019). Interplay among H3K9-editing enzymes SUV39H1, JMJD2C and SRC-1 drives p66 Shc transcription and vascular oxidative stress in obesity. Eur Heart J, 40(4), 383–391.
[4] Hosseinpouri-Niazi S, Mirmiran P, Abd-Mishani M and Azizi F. (2019). Effect of dairy products on oxidative stress in type 2 diabetic patients: A randomized controlled clinical trial. Nutr Clin Metab, 33(3), 212–216.
[5] Beaudieux JL, Delattre J, Therond P, Bonnefont-Rousselot D, Legrand A and Peynet J. (2006). Le stress oxydant, composante physiopathologique de l’athérosclérose. Immuno-Analyse Biol Spec, 21(3), 144–150.
[6] Saha SK, Lee S Bin, Won J, Choi HY, Kim K, Yang GM, Kim K, Yang GM, Dayem AA and Cho SG. (2017). Correlation between oxidative stress, nutrition, and cancer initiation. Int J Mol Sci, 18(7).
[7] Schwarz KB. (1996). Oxidative stress during viral infection: A review. Free Radic Biol Med, 21(5), 641–649.
[8] Atta EM, Mohamed NH and Abdelgawad AAM. (2017). Antioxidants: An Overview on the Natural and Synthetic Types. Eur Chem Bull, 6(8), 365.
[9] Percário S, Moreira DR, Gomes BAQ, Ferreira MES, Gonçalves ACM, Laurindo PSOC, Vilhena TC, Dolabela MF and Green MD. (2012). Oxidative stress in Malaria. Int J Mol Sci, 13(12),16346–16372.

[10] Aguilar R, Marrocco T, Skorokhod OA, Barbosa A, Nhabomba A, Manaca MN, Guinovart C, Quintó L, Arese P, Alonso PL, Dobaño C and Schwarzer E. (2014). Blood oxidative stress markers and Plasmodium falciparum malaria in non-immune African children. Br J Haematol, 164(3), 438–450.

[11] Sadiq MB, Tharaphan P, Chotivanich K, Tarning J and Anal AK. (2017). In vitro antioxidant and antimalarial activities of leaves, pods and bark extracts of Acacia nilotica (L.) Del. BMC Complement Altern Med, 17(1), 1–8.

[12] Sulistyaningsih E, Amalia TY and Kartikasari R. (2017). Antioxidant and antimalarial activity of Leeea indica leaf extract against malaria-mice model. J Appl Pharm Sci, 7(12), 163–168.

[13] Da O, Traoré M, Yerbanga R, Koama B, Ouedraogo N, Tamboura S, Matsabisa MG and Ouédraogo JB. (2014). Antiplasmodial and antioxidant activities of Saye: A traditional herbal remedy for Malaria. Am J Biochem Mol Biol, 4(4), 155–166.

[14] Kpétèhoto HW, Madjíd A, Amoussa O, Johnson RC, Meinsan EE, Maurille F, Yédomonhan H, Loko F, Bankolé H and Lagnika L. (2019). Phytochemical analysis and antioxidant potential of Ocimum gratissimum Linn (Lamiaceae ) commonly consumed in the Republic of Benin. J Appl Biol Biotechnol, 7(04), 75–83.

[15] Kwansa-Bentum B, Agyeeman K, Larbi-Akor J, Anyigba C and Appiah-Opong R. (2019). In Vitro Assessment of Antiplasmodial Activity and Cytotoxicity of Polyalthia longifolia Leaf Extracts on Plasmodium falciparum Strain NF54. Malar Res Treat, 1–9.

[16] Nnami D, Ettebong E and Davis K. (2017). Antiplasmodial and antioxidant activities of methanolic leaf extract and fractions of Alchornea cordifolia. J HerbMed Pharmacol, 6(4), 171–177.

[17] Imwong M, Dhorda M, Myo Tun K, Thu AM, Phylo AP, Proux S, Suwannasin K, Kunasol C, Srisutham S, Duanguppana J, Vongpromek R, Prommarat C, Saijeng A, Khantikul N, Sugaram R, Thanapongpichat S, Sawangjaroen N, Sutawong K and White NFRS. (2020). Molecular epidemiology of resistance to antimalarial drugs in the Greater Mekong subregion: an observational study. Lancet Infect Dis, 3099(20), 1–11.

[18] Morita M, Hayashi K, Sato A, Hiramoto K, Kaneko O, Isogawa R, Miyoshi S, Chang KS, Wataya Y and Kim H-S. (2019). Genomic and biological features of Plasmodium falciparum resistance against antimalarial endoperoxide N-89. Gene, 716, 144016.

[19] Tanjung M, Saputri RD, Fitriati FF and Tjahjandarie TS. (2016). Antimalarial and Antioxidant Activities of Isoprenylated Coumarins from the Stem Bark of Mesua borneensis L. J Biol Act Prod from Nat, 6(2), 95–100.

[20] Tjahjandarie TS, Pudjiastuti P, Saputri RD and Tanjung M. (2014). Antimalarial and antioxidant activity of phenolic compounds isolated from Erythrina crista-galli L. J Chem Pharm Res, 6(4), 786–790.

[21] Bero J, Frédérich M and Quinet-Ledercq J ¨lle. (2009). Antimalarial compounds isolated from plants used in traditional medicine. J Pharm Pharmacol, 61, 1401–1433.

[22] Onguéné AP, Ntie-Kang F, Lifongo LL, Ndom JC, Sippl W and Mbaze LMA. (2013). The potential of anti-malarial compounds derived from African medicinal plants, part I: A pharmacological evaluation of alkaloids and terpenoids. Malar J, 12(1).

[23] Ntie-Kang F, Onguéné PA, Lifongo LL, Ndom JC, Sippl W and Mbaze LM. (2014). The potential of anti-malarial compounds derived from African medicinal plants , part II: a pharmacological evaluation of non-alkaloids and non-terpenoids. Malar J, 13(81), 1-20.

[24] Cox-Georgian D, Ramadoss N, Dona C and Basu C. (2019). Therapeutic and medicinal uses of terpenes. Med Plants From Farm to Pharm, 333–359.

[25] Khan H, Amin H, Ullah A, Saba S, Rafique J, Khan K, Ahmad N and Badshah SL. (2016). Antioxidant and Antiplasmodial Activities of Bergenin and 11-O -Galloylbergenin Isolated from Mallotus philippensis. Oxid Med Cell Longev, 2016, 1–6.

[26] Babakura M, Usman H, Gaidam YA, Halima UA and Fulata AM. (2019). Preliminary Phytochemical Screening , Analgesic and Anti-inflammatory Effects of the Hydroethanol and n -Hexane Leaf Extracts of Maytenus senegalensis Lam . Excell. ( Celestraceae ). South Asian Res J Nat Prod, 2(1), 1–9.
[27] Bashige CV, Bakari AS, Okusa PN, Kalonda EM and Lumbu JBS. (2020). Criblage phytochimique et activité antimicrobienne de six rhizomes comestibles utilisés en médecine traditionnelle à Lubumbashi (RDC). Int J Biol Chem Sci, 14(4), 1367–1380.

[28] Kumar RS, Venkateshwar C, Samuel G and Rao SG. (2013). Phytochemical Screening of some compounds from plant leaf extracts of Holoptelea integrifolia (Planch.) and Celestrus emarginata (Grah.) used by Gondu tribes at Adilabad District, Andhrapradesh, India. Int J Eng Sci Invent, 2(8), 65–70.

[29] Shekhar TC and Anju G. (2014). Antioxidant Activity by DPPH radical scavenging method of Ageratum conyzoides Linn. Leaves. Am J Ethnomedicine, 1(4), 244–249.

[30] Bashige CV, Manya-Mboni H, Ntabaza-Ndage V, Numbi Ilunga E, Bakari-Amuri S, Kalonda Mutombo E, Kahumba B and Lumbu S. (2017). Étude ethnobotanique, biologique et chimique de plantes réputées anticariogènes à Lubumbashi – RD Congo. Phytotherapie, 15(1), 2–9.

[31] Yemele M, Telefo P, LL L, Tagne S, Fodouop C, Goka, CS, Lemfack M and Moundipac FP. (2015). Ethnobotanical survey of medicinal plants used for pregnant women’s health conditions in Menoua division-West Cameroon. Int J Phytoecodermecine, 7, 235–239.

[32] Baldino L, Reverchon E and Della Porta G. (2017). An optimized process for SC-CO2 extraction of antimalarial compounds from Artemisia annua L. J Supercrit Fluids, 128, 89–93.

[33] Nigam M, Atanassova M, Mishra AP, Pezzani R, Devkota HP, Pygfun S, Bahare Salehi, Setzer WN and Sharifi-Rad J. (2019). Bioactive compounds and health benefits of Artemisia species. Nat Prod Commun, 14(7), 1–17.

[34] Fernandes L, Casal S, Pereira JA, Saraiva JA and Ramalhosa E. (2017). Edible flowers: A review of the nutritional, antioxidant, antimicrobial properties and effects on human health. J Food Compos Anal, 60, 38–50.

[35] Airaodion AI, Olatoyinbo PO, Ogbuagu EO, Akinmolayan JD, Adegboyega AA, Adu-Akpo A, Adeniji AR and Airaodion EO. (2019). Comparative Assessment of Phytochemical Content and Antioxidant Potential of Azadirachta indica and Parqueutia nigrescens Leaves. Asian Plant Res J, 2, 1–14.

[36] Oliveira FQ, Andrade-Neto V, Krettili AU and Brandão MGL. (2004). New evidences of antimalarial activity of Bidens pilosa roots extract correlated with polyacetylene and flavonoids. J Ethnopharmacol, 93(1), 39–42.

[37] Khanal DP, Rana R, Raut B and Dhakal RP. (2019). Phytochemical Screening, Biological Studies and GC-MS Analysis of Extract of Bidens pilosa L. J Mannomhan Meml Inst Heal Sci, 5(1), 75–93.

[38] Bashige CV, Manya-Mboni H, Ntabaza-Ndage V, Numbi Ilunga E, Bakari-Amuri S, Kalonda Mutombo E, Kahumba B and Lumbu S. (2017). Ethnobotany, biological and chemical study of plants used as anti-cariogenic in Lubumbashi – RD Congo. Phytotherapie, 15(1), 1-12.

[39] Sahu M, Vermaand D and Harris KK. (2014). Phytochemical analysis of the Leaf, Stem and Seed Extracts of Cajanus Cajan (Fabaceae). World J Pharm Pharm Sci, 3(8), 694–733.

[40] Pan WH, Xu XY, Shi N, Tsang SW and Zhang HJ. (2018). Antimalarial activity of plant metabolites. Int J Mol Sci, 19(5), 1–40.

[41] Singh P, Tanwar N, Saha T, Gupta A and Verma S. (2018). Phytochemical Screening and Analysis of Carica papaya, Agave americana and Piper nigrum. Int J Curr Microbiol Appl Sci, 7(2), 1786–1794.

[42] Daskum AM, Godly C and Qadeer MA. (2019). Effect of Senna occidentalis (Fabaceae) leaves extract on the formation of β - hematin and evaluation of in vitro antimalarial activity. Int J Herb Med, 7(3), 46–51.

[43] Nisar A, Mamat AS, Hatim I, Aslam MS and Syarhabil M. (2016). An Updated Review on Catharanthus Roseus: Phytochemical and Pharmacological Analysis. Indian Res J Pharm Sci, 3(2), 631–653.

[44] Shah H and Khan AA. (2017). Phytochemical characterisation of an important medicinal plant, Chenopodium ambrosioides Linn. Nat Prod Res, 31(19), 2321–2324.

[45] Bylka W and Kowalewski Z. (1997). Flavonoidy w Chenopodium album L. i Chenopodium opulifolium L. (Chenopodiaceae). Herba Pol, 43(3), 208-213.

[46] Sundowow A, Artanti N, Hanafi M, Minarti and Primahana G. (2017). Phytochemical screening, total phenolic, total flavonoids contents and antioxidant activity of Cinchona ledgeriana leaves ethanol extract. AIP Conf Proc, 1904, 1-5.
Promila and Madan V. (2018). A Review on the Phytochemistry and Pharmacology of *Cymbopogon citratus* Stapf. (Lemongrass). Pharma Innov J, 7(3), 300–304.

Oladjei OS, Adelowo FE, Ayodele DT and Odelade KA. (2019). Phytochemistry and pharmacological activities of *Cymbopogon citratus*: a review. Sci African, 6, e00137.

Dewildeman E. (1938). Sur la distribution des saponines dans le règne végétal. Institut R. Bruxelles, 1, 15–17.

Jonker SA, Nkunya MHH, Mwamtobe L, Geenevasen J and Koomen GJ. (1997). A new coumarin and polyhydroxysqualenes from *Ekebergia benguelensis*. Nat Prod Lett, 10(4), 245–248.

Chávez D, Chai HB, Chagwedera TE, Gao Q, Farnsworth NR, Cordell GA, Pezzuto JM and Kinghorn AD. (2001). Novel stilbenes isolated from the root bark of *Ekebergia benguelensis*. Tetrahedron Lett, 42(22), 3685–3688.

Morah FN and Otuk M. (2015). Antimicrobial and Anthelmintic activity of eleusine indica. Acta Sci Intellectus, 1(4), 28–31.

Desai AV, Kangralkar VA, Patil SS and Patil VM. (2017). Phytochemical Investigation of *Eleusine indica* for in-Vivo Anti-Hypertensive Activity. Int J Innov Sci Res Technol, 2(6), 405–416.

Yenesew A, Derese S, Irungu B, Midiwo JO, Waters NC, Liyala P, Akala H, Heydenreich M and Peter MG. (2003). Flavonoids and isoflavonoids with antiplasmodial activities from the root bark of *Erythrina abyssinica*. Planta Med, 67(9), 658–661.

Fahmy NM, Al-Sayed E, El-Shazly M and Nasser Singab A. (2019). Alkaloids of genus *Erythrina*: An updated review. Nat Prod Res, 1–22.

Liu Y, Murakami N, Ji H, Abreu P and Zhang S. (2007). Antimalarial flavonol glycosides from *Euphorbia hirta*. Pharm Biol, 45(4), 278–281.

Arsule CS and Sable KV. (2017). Preliminary Phytochemical Analysis of *Euphorbia hirta* Linn. Leaves. Int J Life Sci, 5(4)(4), 746–748.

Al-Rehaily AJ, Yousaf M, Ahmad MS, Samoylenko V, Li XC, Muhammad I and Tahir KEHE. (2015). Chemical and biological study of *Flueggea virosa* native to Saudi Arabia. Chem Nat Compd, 51(1), 187–188.

Bei J, Qinshi Z, Zhongwen L, Yang L, Qitai Z and Handong S. (2001). Studies on the chemical constituents of *Hypoestes triflora*. Nat Prod Res Dev, 13(6), 12–15.

Al Haidari RA. (2018). A Review of Traditional Uses, Phytochemicals and Bioactivities of the Genus *Hypoestes*. Afr J Tradit Complement Altern Med, 15(3), 1.

Oyama M, Malachi O and Oladejo A. (2016). Phytochemical Screening and Antimicrobial Activity of Leaf Extract of *Jatropha curcas*. J Adv Med Pharm Sci, 8(1), 1–6.

Ved A, Arsi T, Prakash O and Gupta A. (2018). Review On Phytochemistry And Pharmacological Activity Of *Lantana Camara* Linn. Int J Pharm Sci Res, 9(1), 37–43.

Muhammad S, Fatima A and Yahaya MM. (2012). The Phytochemical Components of *Leucas Martinicensis* that Cause Repellence of Adult Mosquito. Int J Mod Bot, 2(1), 1–5.

Nangue YD, Llorent-Martínez EJ, Fernández-de Córdova ML, Ngangou DAM, Nguelefack TB, Azebaze AGB and Dongmo AB. (2019). Phytochemical study and anti-inflammatory activity of the roots of *Mangifera indica* L. in lipopolysaccharide (LPS)-stimulated peritoneal macrophages. Trends Phytochem Res, 3(1), 53–60.

Ndung’u J, Anino E, Njuguna D, Mwangangi R, Jekporir M, Mbogu R, Chepng’etich J, Ngule CM and Mwitari P. (2018). Phytochemical Screening and Synergistic Anti-proliferative Activity against Selected Cancer Cell Lines of *Moringa oleifera* and *Indigofera arrecta* Leaf Extracts. European J Med Plants, 23(2), 1–11.

Oladeji OS, Odelade KA and Oloke J K. (2020). Phytochemical screening and antimicrobial investigation of *Moringa oleifera* leaf extracts. African J Sci Technol Innov Dev, 12(1), 79–84.

Djova S V, Nygue MA, Messi AN, Afagnini AD and Etoa F. (2019). Phytochemical Study of Aqueous Extract of *Ochna schweinfurthiana* F. Hoffm Powder Bark and Evaluation of Their Anti-Inflammatory, Cytotoxic, and Genotoxic Properties. Evidence-Based Complement Altern Med, 1(1), 1–8.

Bashige CV, Bakari-Amuri S, Mbuiyi-Kalonji S, Kahumba-Byanga J, Duez P and Lumbu-Simbi JB. (2017). Étude ethnobotanique, phytochimique et évaluation de l’activité antiplasmodiale de 13 plantes réputées antimalariennes dans la commune du Kenya (Lubumbashi, RDC). Phytotherapie, 1–10.
Annona

0. The Phytochemical and Comparative Anticancer Toxicant Activity of -

[87]

[86]

[85]

[84]

[83]

[82]

[81]

[80]

[79]

[78]

[77]

[76]

[75]

[74]

[73]

[72]

[71]

[70]

[69]

[68]

[67]

[66]

[65]

[64]

[63]

[62]

[61]

[60]

[59]

[58]

[57]

[56]

[55]

[54]

[53]

[52]

[51]

[50]

[49]

[48]

[47]

[46]

[45]

[44]

[43]

[42]

[41]

[40]

[39]

[38]

[37]

[36]

[35]

[34]

[33]

[32]

[31]

[30]

[29]

[28]

[27]

[26]

[25]

[24]

[23]

[22]

[21]

[20]

[19]

[18]

[17]

[16]

[15]

[14]

[13]

[12]

[11]

[10]

[9]

[8]

[7]

[6]

[5]

[4]

[3]

[2]

[1]
[88] Chen Y, Zhu N, Chen X, Liu G, Li Y, Guo Y, Deng M, Liu D and Sun B. (2019). Evaluation of pigeon pea leaves (Cajanus cajan) replacing alfalfa meal on growth performance, carcass trait, nutrient digestibility, antioxidant capacity and biochemical parameters of rabbits. J Anim Physiol Nutr, 1–9.

[89] Yap J, Hii C, Ong S, Lim K, Abas F and Pin K. (2020). Effects Of Drying On Total Polyphenols Contents And Antioxidant Properties Of Carica papaya Leaves. J Sci Food Agric, 100(7), 1–14.

[90] Ngombe NK, Ngolo CN, Kialengila DM, Wamba AL, Mungisthi PM, Tshibangu PT, Kalenda T. DB, Kantola PT and Kapepula PM. (2019). Cellular Antioxidant Activity and Peroxidase Inhibition of Infusions from Different Aerial Parts of Cassia occidentalis. J Biosci Med, 7, 83–94.

[91] Pham TNH, Sakoff JA, Vuong Q Van, Bowyer MC and Scarlett CJ. (2019). Phytochemical, antioxidant, anti-proliferative and antimicrobial properties of Catharanthus roseus root extract, saponin-enriched and aqueous fractions. Mol Biol Rep, 46(3), 3265–3273.

[92] Keshari AK, Srivastava A, Upadhayaya M and Srivastava R. (2018). Antioxidants and free radicals scavenging activity of Medicinal Plants. J Pharmacogn Phytochem, 7(3), 1499–1504.

[93] Villalobos-Delgado LH, González-Mondragón EG, Ramírez-Andrade J, Salazar-Govea AY and Santiago-Castro JT. (2020). Oxidative stability in raw, cooked, and frozen ground beef using Epazote (Chenopodium ambrosioides L.). Meat Sci, 168, 108187.

[94] Hartatie E, Widodo P and Wahyudi A. (2019). Bioactive Compounds of Lemongrass (Cymbopogon citratus) essential oil from different parts of the plant and distillation methods as natural antioxidant in broiler meat. IOP Conf Ser Mater Sci Eng, 532(1), 1–7.

[95] Unuigbe K, Enahoro J, Erharuyi O and Okeri H. (2019). Phytochemical analysis and Antioxidant Evaluation of Lemon Grass (Cymbopogon citratus DC.) Stapf Leaves. J Appl Sci Environ Manag, 23(2), 223–228.

[96] Galketi C, Weeraratna TS and Punchihewa JC. (2017). Screening of edible plants in Sri Lanka for antioxidant activity. J Med Plants Stud, 5(1), 91–95.

[97] Dzoyem JP, Melong R, Tsamo AT, Tchinda AT, Kapche DGWF, Ngadjui BT, McGaw LJ and Eloff JN. (2017). Activity and Antimicrobial and Antioxidant Effects Of Ethanolic Leaf Extract Of Erythrina abyssinica Lam, Ex DC. Asian J Pharm Clin Res, 11(8), 300–306.

[98] Amal D, Amal S, Saleem A, Saleem M and Furqan M. (2020). Antioxidant, anti-infl ammatory and antiarthritic potential of Moringa oleifera Lam : An ethnomedical plant of Moringaceae family. South African J Bot, 128, 246–256.

[99] Ademoye MA, Lajide L and Owolabi BJ. (2018). Phytochemical and Antioxidants Screening of. Int J Sci, 7(11), 1–11.
[107] Gayathri R and Manju S. (2020). Identification and Comparative Study of In Vitro Antioxidant Potential of Fractionated Hydroalcoholic Extract of **Phyllanthus niruri** Linn. Eur J Adv Chem Res, 1(1), 1-7.

[108] Golubkina NA, Kekina HG, Engalichev MR, Antoshkina MS, Nadezhkin SM and Caruso G. (2018). Yield, quality, antioxidants and mineral nutrients of **Physalis angulata** L. and **Physalis pubescens** L. fruits as affected by genotype under organic management. Adv Hort Sci, 32(4), 541–548.

[109] Dieng ISM, Fall AD, Diatta-badji K, Sarr A, Sene M, Sene M, Amadou M and William DIATTA. (2017). Evaluation de l’activité antioxydante des extraits hydro-ethanoloques des feuilles et écorces de **Piliostigma thonningii** Schumach. Int J Biol Chem Sci, 11(2), 768–776.

[110] Niwoye AA, Ndaman SA, Olufunmilayo AH and Evans E. (2019). GSC Biological and Pharmaceutical Sciences Antioxidants and hypoglycemic effect of some medicinal plants. GSC Biol Pharm Sci, 08(02), 70–80.

[111] Kucich DA and Wicht MM. (2016). South African indigenous fruits – Underutilized resource for boosting daily antioxidant intake among local indigent populations? South African J Clin Nutr, 29(4), 150–156.

[112] Al-zubari AS, Al-mamary MA and Al-ghasani E. (2017). The Antibacterial, Antifungal, and Antioxidant Activities of Essential Oil from Different Aromatic Plants. Glo Adv Res J Med Med Sci, 6(9), 224–233.

[113] Alara OR, Abdurahman NH and Olalere OA. (2020). Ethanolic extraction of flavonoids, phenolics and antioxidants from **Vernonia amygdalina** leaf using two-level factorial design. J King Saud Univ - Sci, 32(1), 7–16.

[114] Matos JM, Vazquez-Rodriguez S, Fonseca A, Uriarte E, Santana L and Borges F. (2017). Heterocyclic Antioxidants in Nature: Coumarins. Curr Org Chem, 21(4), 311–324.

[115] Amuri B, Maseho M, Lumbu S, Pierre D and Byanga K. (2018). Ethnobotanical survey of herbs used in the management of diabetes mellitus in Southern Katanga Area/DR Congo. Pan African Med Journal, 30(2018),1-13.

[116] Bashige C valentin, Bakari AS, Okusa N, Kahumba BJ, Duez P and Lumbu SJ-B. (2020). Antiplasmodial, inhibitor of hemozoin synthesis and antioxidant activities of some plants used as antimalarial drugs in Bagira (DR Congo). Int J Pharmacogn Clin Res, 2(1), 1–8.

[117] Kassim NK, Cee LP, Ismail A and Awang K. (2019). Isolation of antioxidative compounds from Micromelum minutum guided by preparative thin layer chromatography-2,2-Diphenyl-1-picrylhydrazyl (PTLC-DPPH) bioautography method. Food Chem, 272, 185–191.

[118] Mohandas GG and Kumaraswamy M. (2018). Antioxidant Activities of Terpenoids from **Thuidium tamariscellum** (C. Muell.) Bosch. and Sande-Lac. a Moss. Pharmacogn J, 10(4), 645–649.

[119] Wang CY, Chen YW and Hou CY. (2019). Antioxidant and antibacterial activity of seven predominant terpenoids. Int J Food Prop, 22(1), 230–238.

---

**How to cite this article**

Chiribagula VB, Bakari AS, Ndjolo PO, Kahumba BJ and Simbi JBL. (2020). Phytochemical screening and antioxidant activity of methanolic extracts of 53 antimalarial plants from Bagira in Eastern DR Congo. GSC Biological and Pharmaceutical Sciences, 12(2), 99-118.