Mini Review

Secondary metabolites and biological activity of *Pentas* species: A minireview

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**Graphical abstract**

**Abstract**

The genus *Pentas* belongs to the Rubiaceae family, which contains approximately 40 species. Several *Pentas* species were reported to be used as a folk treatment by African indigenous people in treating some diseases such as malaria, tapeworms, dysentery, gonorrhea, syphilis and snake poisoning. This article covers the period from 1962 to 2017 and presents an overview of the biological activity of different biological activities.

**Keywords**

-Pentas-; Secondary metabolites; Biological activity-
Introductions

The genus *Pentas* belongs to the botanical plant family Rubiaceae. It consists of about 40 species, many of them used widely by indigenous people in Africa as medicinal plants. It is a flowering plant found mainly as an herb or shrub (*P. bussi* and *P. nobilis*), herb or subshrub (*P. lanceolata* and *P. zanibarica*) or subshrub only (*P. paviflora*). The stem length varies between 60 and 2 m in the case of subshrubs and between 2 and 4 m if a shrub. The shape of the leaves is ovate, oblong, lanceolate or elliptic, while the flower shape is dismorphus, subsessile or unisemiporous [1]. This genus is commonly used in the treatment of tropical and other diseases such as malaria (*P. micrantha* and *P. longiflora*) [2-3], tapeworms (*P. longiflora*), itchy rashes and pimples [4] (*P. longiflora* and *P. decora*), gonorrhea, syphilis and dysentery (*P. brussei*), cough (*P. micrantha*) [4], dysmenorrhea, headache and pyrexia (*P. purpurea*) [5], hepatitis B [6], mental illness and epilepsy (*P. trichophyton*) [7], lymphadenitis, abdominal cramps, ascariasis, snake poisoning, retained placenta and some veterinary diseases (*P. lanceolata*) [8,9].

Iridoids and highly oxygenated compounds have been shown to be the most common secondary metabolites of this genus. These plants have not been intensively studied to determine their biological characteristics. Several reports have found that some of their biological activity is antimalarial and antimicrobial [10-13]. However, *P. lanceolata* is the only species that has been tested for analgesic and wound-healing properties, whereas very few examples were studied as having antitumor characteristics [11,14-16]. The secondary metabolites that were identified in this genus are a common feature of the Rubiaceae family; however, there are some examples that have only been expressed in this genus [17]. This review endeavors to provide a comprehensive and up-to-date compilation of documented biological activities and the phytochemistry of the *Pentas* genus.

Phytochemical screening of *Pentas* species

The chemistry of *Pentas* species does not exhibit great diversity. The common active constituents of *Pentas* species can be considered chemotaxonomic markers. The main groups of secondary metabolites that were isolated are simple phenolic compounds, naphthoquinones, naphthohydroquinones, anthraquinones, and iridoids. Furthermore, few examples of alkaloids, triterpenes, sterols, and chromenes were identified. The isolated compounds, structures, species, solvents of extraction and extracted organs are compiled in the Tables 1–8 which are displayed below.

Simple phenolic compounds

Two examples of simple phenolics (1 and 2) were identified in the colletes of *P. lanceolata* by GC–Ms chromatography in a greater amount than in the stipules without collettes (Table 1) [18].

Naphthoquinones

*P. longiflora* was the only source among the genus *Pentas* from which naphthoquinones (3–7) were separated. Pantagolin 3 [19] and isagarin 5 were identified for the first time in the roots of *P. longiflora*, whereas psychorubrin 4 is a common constituent of other Rubiaceae species: Psychotria camponutans [20] and Mitracarpus frigidus (Table 2) [17].

Naphthohydroquinones

Busseihydroquinone A 8 [23] and the very recently discovered parvinaphthols A 10 and B 11 [24] were named after *P. bussei* and *P. parvifolia*, respectively. They are as well as the naphthohydroquinones (9 and 11) have been identified only in *Pentas* species (Table 3).

Chromene-based structures

This class of compounds is widespread in different species of *Pentas* as well as the other members of Rubiaceae. Compounds 14–17, 25 and 28 were discovered as novel compounds in 2003 in *P. longiflora*, *P. bussei*, and *P. parvifolia*. Additionally, an isolation of known compounds 21–24 from the root of *P. longiflora* [22,25] was reported; these were similarly identified in another plant of Rubiaceae (*Rubia cordifolia*) [26]. Scopoletin 13 is a very common coumarin found broadly in many genera of Rubiaceae [17] (Table 4).

Anthraquinones

The anthraquinones are the major class of secondary metabolites in *Pentas*. They are also commonly found as mixtures of closely related pigments in the Rubiaceae family. Some members of this family have been used for centuries as a source of natural dye for textiles [17]. Many *Pentas* species produced anthraquinones in the form of aglycone (30–42) (Table 5) [10,11,22,25,21] or as glycosides (43–46) (Table 6) [24,25,29]. Two dimeric structures of anthraquinone named schimperiquinones, A 47 and schimperiquinones B 48 (Table 6), were isolated from *P. schimperi* as novel structures in 2014 [30]. Anthraquinones seem to be very important to the antiplasmodial activity expressed by *Pentas* [10].

Iridoids

Iridoids are monoterpenoid cyclopentanopyran type glycosides [31], which are common constituents of *P. lanceolata*. The first study to identify iridoids in *P. lanceolata* was performed by Schripsema and his coworkers in 2007 [32]. In this study, seven iridoid glycosides were identified from the aerial parts of *P. lanceolata*. Furthermore, asperuloside 49 and asperulosidic acid 50, which are characteristic iridoids of Rubiaceae, and five iridoids 51–55 were isolated (Table 7) [32]. The ethanolic extract of *P. lanceolata
Deflers was analyzed. A total of 12 compounds were identified, and ten of them were iridoid glucosides. Among these, compounds 57–60 were identified for the first time in *P. lanceolata* in addition to a new iridoid 61 (Table 7) [28]. Recently, two new iridoids, namely, 13R-methoxy-epi-gaertneroside 56 and 13S-methoxy-epi-gaertneroside 57, were identified by way of bio-guided sub-fractionation. They were identified in the immunomodulatory active sub-fractions of *P. lanceolata* (Table 7) [35].

**Table 2**
Naphthoquinones (3–7) isolated from *P. longiflora*.

| Isolated compound          | Structure | Species   | Extract/Organ          | Refs. |
|---------------------------|-----------|-----------|------------------------|-------|
| Pentalongin 3             | ![Structure](image1) | *P. longiflora* | Hexane, (DCM/MeOH)/Root | [19]  |
| Psychorubrin 4            | ![Structure](image2) |                     |                        | [10]  |
| Isagarin 5                | ![Structure](image3) |                     |                        | [21]  |
| Methyl 2,3-epoxy-3-prenyl-1,4-naphthoquinone-2-carboxylate 6 | ![Structure](image4) |                     |                        | [22]  |
| Methyl 3-prenyl-1,4-naphthoquinone-2-carboxylate 7 | ![Structure](image5) |                     |                        |       |

**Table 3**
Naphthohydroquinones (8–12) isolated from *Pentas* species.

| Isolated compound          | Structure | Species     | Extract/Organ          | Refs. |
|---------------------------|-----------|-------------|------------------------|-------|
| Busseihydroquinone A 8    | ![Structure](image6) | *P. bussei* | Crystallized out as needles from (DCM/MeOH)/Root | [23]  |
| Methyl 8-hydroxy-1,4,6,7-tetramethoxy-2-naphthoate 9 | ![Structure](image7) | *P. parvifolia* | (DCM/MeOH)/Root | [24]  |
| Parvinaphthols A 10       | ![Structure](image8) |                    |                        |       |
| Parvinaphthols B 11       | ![Structure](image9) |                    |                        |       |
| 1,4,5-Trihydroxy-3-methoxy-6-(3,7,11,15,19-pentamethyleicosa-2, 6,10,14,18-pentaenyl)naphthalene 12 | ![Structure](image10) | EtOAc/Root | [25]  |

(Forssk.) Deflers was analyzed. A total of 12 compounds were identified, and ten of them were iridoid glucosides. Among these, compounds 57–60 were identified for the first time in *P. lanceolata* in addition to a new iridoid 61 (Table 7) [28]. Recently, two new iridoids, namely, 13R-methoxy-epi-gaertneroside 56 and 13S-methoxy-epi-gaertneroside 57, were identified by way of bio-guided sub-fractionation. They were identified in the immunomodulatory active sub-fractions of *P. lanceolata* (Table 7) [35].

**Table 1**
Simple phenolics identified in *P. lanceolata*.

| Isolated compound          | Structure | Species | Extract/Organ     | Refs. |
|---------------------------|-----------|---------|-------------------|-------|
| 4-Hydroxycinnamic acid 1  | ![Structure](image11) | *P. lanceolata* | MeOH/Colleters   | [18]  |
| Thymol 2                  | ![Structure](image12) |                     |                        |       |

**Table 2**
Naphthoquinones (3–7) isolated from *P. longiflora*.

**Table 3**
Naphthohydroquinones (8–12) isolated from *Pentas* species.

**Terpenes, sterols, saponins, and alkaloids**

These classes of secondary metabolites are not common in *Pentas* species. They have only been isolated from *P. lanceolata*. These are triterpenes (oleanolic 58 and ursolic acids 59), sterols (campesterol 60, β-stigmasterol 61) and sesquiterpene (caryophyllene 62) was found in the colleters of *P. lanceolata* (Table 8) [17,18]. The identified alkaloids 71 and 72 were oxindole skeleton (Table 8) [36].
| Isolated compound | Structure | Species            | Extract/Organ              | Refs. |
|-------------------|-----------|--------------------|----------------------------|-------|
| Scopoletin 13     | ![Structure](image1) | *P. longiflora* | EtOAc/Root [22] |       |
| Methyl 5,10-dihydroxy-7-methoxy-3-methyl-3-(4-methyl-3-pentenyl)-3H-benzo[f]chromene-9-carboxylate 14 | ![Structure](image2) | *P. bussei* | Hexane/Root [27] |       |
| Methyl 5,10-dihydroxy-7-methoxy-1,1,3a-trimethyl-1a,2,3,3a,10c,10d-hexahydro-1H-4-oxacyclobuta[1,4]indeno[5,6-\textit{a}]naphthalene-9-carboxylate 15 | ![Structure](image3) | *P. bussei* |                   |       |
| 9-Methoxy-2-methyl-2-(4-methyl-3-pentenyl)-2H-benzo[h]-chromene-7,10-diol 16 | ![Structure](image4) | *P. bussei, P. parvifolia* |                   |       |
| 9-Methoxy-2,2-dimethyl-2H-benzo[h]chromene-7,10-diol 17 | ![Structure](image5) |                   |                   |       |
| Busseihydroquinone B 18 | ![Structure](image6) | *P. bussei* | (DCM/MeOH)/Root [23] |       |
| Busseihydroquinone C 19 | ![Structure](image7) | *P. bussei* | (DCM/MeOH)/Root [23] |       |
| Busseihydroquinone D 20 | ![Structure](image8) |                   |                   |       |
| Mollugin 21        | ![Structure](image9) | *P. longiflora* | Hexane, (DCM/MeOH)/Root [22,28] |       |
| 3-Hydroxymollugin 22 | ![Structure](image10) | *P. longiflora* | Hexane/Root [22] |       |
| 3-Methoxymollugin 23 | ![Structure](image11) |                   | DCM/Root |       |
| trans-3,4-Dihydroxy-3,4-dihydromollugin 24 | ![Structure](image12) |                   | Hexane/Root |       |
| cis-3,4-Dihydroxy-3,4-dihydromollugin 25 | ![Structure](image13) |                   |                   |       |
| Parvinaphthols C 26 | ![Structure](image14) | *P. parvifolia* | (DCM/MeOH)/Root [23] |       |
| Busseihydroquinone E 27 | ![Structure](image15) | *P. bussei* |                   |       |

**Table 4**

Chromene-based structures (13–29) separated from *Pentas* species.
Biological activities of Pentas species

**Antiplasmodial activity**

Endale and his coworker discussed the antiplasmodial activities of *P. longiflora* and *P. lanceolata*. They mentioned that the dichloromethane/methanol (1:1) extract of the roots indicated in vitro antiplasmodial activity against chloroquine-resistant (W2) (IC$_{50}$: 0.93 ± 0.16 µg/mL) and chloroquine-sensitive (D6) strains (IC$_{50}$: 0.99 ± 0.09 µg/mL) of *Plasmodium falciparum* [10]. Pentalongin 3 and psychorubrin 4 (Table 2) were tested against the same strains, W2 and D6, in the same study. The IC$_{50}$ values of the first were 0.27 ± 0.09 and 0.23 ± 0.08 µg/mL, respectively, and for compound 4 (Table 2) were 0.91 ± 0.15 and 0.82 ± 0.24 µg/mL, respectively [10]. However, all of the previous results were lower than the reference compounds, which were chloroquine and mefloquine [10]. In 2013, those researchers found that the crude methanol root extract of *P. micrantha*, which is used as an antimalarial in East Africa, exhibited moderate antiplasmodial activity against W2 (IC$_{50}$: 3.37 ± 0.74 µg/mL) and D6 (IC$_{50}$: 4.00 ± 1.86 µg/mL) strains. Anthraquinones 30–36 (Table 5) were examined for the same strains, but they were not active [11].

**Antimicrobial properties**

*P. decorata* was used traditionally in Western Uganda as an antifungal [12]. This common medicinal usage encouraged Ahumuza et al. to analyze the plant to determine whether this traditional use has a scientific basis or not. The ethanolic extract...
of P. decora leaves was studied for four fungal strains: Epidermophyton floccosum, Microsporum canis, Trichophyton rubrum and Candida albicans. The inhibitory zone of 2000 mg/mL of the plant extract was 4.8 ± 0.4 and 3.7 ± 0.2 mm against C. albicans and M. canis, respectively, while the other two fungal strains were not sensitive. Both results were greater than that of clotrimazole. They attributed the results to the presence of alkaloids and terpenoids, which are well-known to be biologically active in the treatment of fungal infections [12].

Wound healing

The ethanol flower extract of P. lanceolata was evaluated for its effect on wound healing. This was assessed using an excision wound model. Significant increments in granulation tissue weight, tensile strength, glycosaminoglycan, and hydroxyproline content were found. A group of rats treated with the extract at 150 mg/kg/day for 10 days via the oral route showed incremental improvement in the wound contraction relative to the untreated one, which may be due to increased collagen deposition, alignment, and maturation [14].

Immunomodulatory activity

Ethyl acetate and n-butanol extracts of P. lanceolata and 13R-epi-gaertneroside 52 (Table 7) were discovered to be immunostimulants at both the humoral and cellular levels. This evaluation was performed on specific-pathogen-free chickens vaccinated against Newcastle disease (ND) virus. Increases in lymphocytes and macrophages were observed in the blood of poultry. These fractions (Ethyl acetate and n-butanol extracts of P. lanceolata), in addition to compound 52 (Table 7), appeared to decrease the mortality from ND in chickens [35].

Antitumor activity

Minimal literature has found a cytotoxic effect in the Pentas species. The methanolic root extract of P. micrantha and anthraquinones 30–36 and 38–39 (Table 5) revealed low cytotoxicity on the breast cancer cell line MCF-7 [11]. The compounds busselhydroquinone E 29 (Table 4), busselhydroquinone C 19 (Table 4), and rubiadin-1-methyl ether 32 (Table 5) exhibited the most potent cytotoxic activity within a survey done for some quinones separated from the roots of P. parvifolia and P. bussei. They had IC50 values of 62.3, 48.4 and 54.4 µM against the MDA-MB-231 ER-negative human breast cancer cell line, respectively [24]. Damnacanthal 34 (Table 5) proved to have a moderate influence on CCRF-CEM leukemia cells (IC50: 3.12 ± 0.27 µM) and against the drug-resistant cell line MDA-MB-231-BCRP (IC50: 7.02 ± 0.51 µM) by apoptosis in comparison with doxorubicin. This antiproliferative activity was attributed to reactive oxygen species (ROS) production and mitochondrial membrane potential (MMP) disruption [16].

Conclusions and future perspective

The main active constituents that were purified from Pentas are quinones, highly oxygenated chromene-based structures, and Table 6

Anthraquinones glycosides (43–46) and anthraquinone dimers (47, 48) that are distributed in different Pentas species.

| Isolated compound                  | Derivatives | Species          | Extract/Organ | Refs. |
|-----------------------------------|-------------|------------------|---------------|-------|
| Rubadin-1-methylether-3-O-β-primeveroside 43 | OCH3 | CH3 | P. bussei | EtOAc/Root | [25] |
| Rubadin-3-O-β-primeveroside 44    | OH | CH3 | P. zanzibarica | MeOH/Root, 50% EtOH/Leaves | [29] |
| Damnacanthol-3-O-β-primeveroside 45 | OCH3 | CH2OH | P. parvifolia | MeOH/Root | [25] |
| Lucidin-3-O-β-primeveroside 46    | OH | CH2OH | P. bussei | MeOH/Root | [25] |
| Schimperiquinones A 47            | R1 = OH, R2 = CH3 | P. zanzibarica | MeOH/Stem | [29] |
| Schimperiquinones B 48            | R1 = H, R2 = OH | P. schimperi | EtOAc/Stem bark | [30] |
Table 7
Iridoids from P. lanceolata.

| Isolated compound   | Structure | Species     | Extract/Organ      | Refs.  |
|---------------------|-----------|-------------|--------------------|--------|
| Asperuloside 49     | ![Asperuloside 49](image) | *P. lanceolata* | MeOH/Aerial parts  | [32]    |
|                     |           |             | MeOH/Colletier     | [18]    |
|                     |           |             | EtOH/Entire plant  | [33,34] |
| Asperulosidic acid 50| ![Asperulosidic acid 50](image) |            | MeOH/Stem and leaves | [32]    |
|                     |           |             | EtOH/Entire plant  | [33,34] |
| Tuodoside 51        | ![Tuodoside 51](image) |            | MeOH/Colletier     | [18]    |
|                     |           |             | EtOH/Entire plant  | [28]    |
| 13R-epi-Gaertneroside 52 | ![13R-epi-Gaertneroside 52](image) | *P. lanceolate* | MeOH/Aerial parts | [32]    |
| 13R-epi-Epoxygaertneroside 53 | ![13R-epi-Epoxygaertneroside 53](image) | | EtOH/Entire plant | [28]    |
| E-Uenfoside 54      | ![E-Uenfoside 54](image) |            | MeOH/Aerial parts  | [32]    |
| Z-Uenfoside 55      | ![Z-Uenfoside 55](image) |            | EtOH/Entire plant  | [28]    |
| Loganin 56          | ![Loganin 56](image) |            | MeOH/Colletier     | [18]    |
| Deacetyl-asperulosidic acid 57 | ![Deacetyl-asperulosidic acid 57](image) | | EtOH/Entire plant | [28]    |
| Ixoside 58          | ![Ixoside 58](image) |            |                    |         |
| Griselinoside 59    | ![Griselinoside 59](image) |            |                    |         |
| 6β,7β-Epoxyplendoside 60 | ![6β,7β-Epoxyplendoside 60](image) | | EtOH/Entire plant | [28]    |
| 61                  | ![61](image) |            |                    |         |

(continued on next page)
iridoids. *P. lanceolata* has represented the sole source of iridoids, whereas the naphthoquinones have been attributed exclusively to *P. longiflora* until now. *Pentas* species are widely used in folk medicine in many tropical regions. However, more attention should be paid to this plant in terms of its medicinal properties. The most interesting medicinal use of *Pentas* is antimalarial (which is attributed to the anthraquinones) and wound-healing activity; however, it did not show very promising antitumor activity. Further investigation should be conducted to evaluate this plant group with biological assays to address this research gap.

Table 7 (continued)

| Isolated compound                 | Structure | Species | Extract/Organ          | Refs. |
|-----------------------------------|-----------|---------|------------------------|-------|
| 13R-Methoxy-epi-gaertneroside 62  | [Chemical structure] | *P. lanceolata* | 80% Aqueous MeOH/Aerial parts | [35]  |
| 13S-Methoxy-epi-gaertneroside 63  | [Chemical structure] | *P. lanceolata* | [Chemical structure] | [ ] |

Table 8

Terpenes, sterols, Saponin and Oxindole alkaloids identified in *P. lanceolata*.

| Isolated compound                 | Structure | Species | Extract/Organ | Refs. |
|-----------------------------------|-----------|---------|---------------|-------|
| Oleanolic acid 64, R<sub>1</sub>, R<sub>2</sub> = CH<sub>3</sub> | [Chemical structure] | *P. lanceolata* | MeOH/Colleter | [17,18] |
| Ursolic acid 65, R<sub>1</sub> = H, R<sub>2</sub>, R<sub>3</sub> = CH<sub>3</sub> | [Chemical structure] | *P. lanceolata* | MeOH/Colleter | [17,18] |
| Campesterol 66                    | [Chemical structure] | *P. lanceolata* | MeOH/Colleter | [17,18] |
| β-Stigmasterol 67                 | [Chemical structure] | *P. lanceolata* | MeOH/Colleter | [17,18] |
| Caryophyllene 68                  | [Chemical structure] | *P. lanceolata* | MeOH/Colleter | [17,18] |
| 3-O-β-fucosyl-quinovic acid 69    | [Chemical structure] | *P. lanceolata* | 50% EtOH/Leaves | [36] |
| Quermiside 70                     | [Chemical structure] | *P. lanceolata* | 100% EtOH/Leaves | |
| Speciophylline 71                 | [Chemical structure] | *P. lanceolata* | 100% EtOH/Leaves | |
Hortorium LHB. Hortus third: a concise dictionary of plants cultivated in the United States and Canada, Macmillan; 1976.

Njorge GN, Bussmann RW. Diversity and utilization of antimalarial ethnophytotherapeutic remedies among the Kikuyus (Central Kenya). J Ethnobiol Ethnomedicine 2006;2:8.

Kokwaro JO. Medicinal plants of East Africa. University of Nairobi Press; 2009.

Kokwaro JO. Medicinal plants of East Africa, East African Literature Bureau, Nairobi; 1976. p. 223.

Nutt JM, Breyer-Brandwijk MG. The medicinal and poisonous plants of southern and eastern Africa: being an account of their medicinal and other uses, chemical composition, pharmacological effects and toxicology in man and animal. E. & S Livingstone; 1962.

Facho DA, Ndam WT, Fonge BA. Medicinal plants of Aguambu-Bamumbu in the Lebalem highlands, southwest province of Cameroon. Afr J Pharm Pharmacol 2009;3:1–13.

Mesfin F, Demissew S, Teklehaymanot T. An ethnobotanical study of medicinal plants in Wonago Woreda, SNNP, Ethiopia. J Ethnobiol Ethnomedicine 2009;5:28.

Giday M, Asfaw Z, Woldu Z. Medicinal plants of the Meinit ethnic group of Ethiopia: an ethnobotanical study. J Ethnopharmacol 2009;124:513–21.

Bekalo TII, Woodmats S, Woldemariam ZA. An ethnobotanical study of medicinal plants used by local people in the lowlands of Konta Special Woreda, southern nations, nationalities and peoples regional state, Ethiopia. J Ethnobiol Ethnomedicine 2009;5:22.

Endale M, Alao JP, Akala HM, Rono NK, Eyase FL, Derene S, et al. Antiplasmodial quinones from Pentas longiflora and Pentas lanceolata. Planta Med 2012;78:31–5.

Endale M, Alberg A, Alao JP, Akala HM, Ndakala A, Sunnerhagen P, et al. Anthraquinones of the Roots of Pentas micrantha. Molecules 2013;18:311–21.

Ahumuza T, Kizirumuzya C. Qualitative (phytochemical) analysis and antifungal activity of Pentas decora (De Wild), a plant used traditionally to treat skin fungal infections in Western Uganda. Res Pharm Biotechnol 2017;26:2196–204.

Kamurthy H, Dontha S, Duggi S, Sudhakar M. Phytochemical screening on Pentas lanceolata leaves: Isolation of saponin and anthracene glycosides and alkaloids. Am J Ethnopharmacology 2014;1:206–15.
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