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REVIEW ARTICLE

# Pharmacology and phytochemistry studies in *Peltophorum africanum*

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**KEYWORDS**

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**Abstract** *Peltophorum africanum* Sond is an ethnomedicinal plant in the family Fabaceae. This literature report captures information about the ethnomedical uses, pharmacology and phytochemistry of *P. africanum* within the last four decades. The literature surveyed revealed the presence of different types of polyphenols whose content was higher in the bark and roots than the leaves. The plant polar extracts are rich in phenolic compounds and shows high antioxidant properties. The root and stem extracts are active against bacteria, parasites and HIV. There were no reports on the quality control of *P. africanum* as a herbal drug, nor a systematic identification of which phytochemicals are responsible for most of the pharmacological activities. Betulinic acid found in the bark is a known anti HIV agent. The reports on the pharmacological functions and the phytochemical studies which were started based on the traditional uses and botanical information justify the ethnomedicinal uses of the tree.



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## 1. Introduction

*Peltophorum africanum* Sond belongs to the Fabaceae family and is among the most extensively studied of all angiosperm families with extensive research on the phylogenetic, phytochemical and medicinal research. The *Peltophorum* genus is one of the eight groups within the tribe Caesalpinieae in the Leguminosae or Fabaceae family.[1,2] The *Peltophorum* group has been characterized to be polyphyletic by molecular studies on the chloroplast genome.[3–5] A large number of scientific articles dealing with the pharmacology and phytochemistry of *P. africanum* have been published. The present review aims to compile this scattered research information on the botany, ethnomedicinal uses, phytochemistry and pharmacology of *P. africanum*. This gathered information should show what are the perspectives and directions for future research and potential applications, what is the relationship between the traditional uses and pharmacological studies on *P. africanum*.

## 2. Botanical descriptions

The *Peltrophorum* genus is found throughout the tropics while *P. africanum* (chromosome number $2n = 26$) is the only *Peltophorum* specie native to southern Africa.[6,7] It is a deciduous/semi deciduous woody tree growing 9–15 m tall, mostly with grey-brown branches emanating from the base. The hairy dull green leaves are bipinnate with 8–22 pairs of leaflets per pinna. The leaflets are oblong with an asymmetric base and a rounded apex.[8,9] The bright yellow flowers are bisexual with crinkled petals at the ends of the branches during November to February. The dark brown fruit is a flat, elliptical pod containing ovoid dark brown to black seeds, which is dispersed by birds, wild and domestic animals.[7,8,10] *P. africanum* is successfully propagated from seeds and grows fast during the summer season in well-drained soil types including sandy soils.[7,10] The young leaves and pods are eaten by cattle and goats. The leaves and twigs are also eaten by elephant, black rhino, giraffe, kudu and impala. The tree is important for beekeepers, as it is a good source of nectar and pollen.[11–13] A common name for this tree is 'Weeping wattle' which refers to the moisture that drips from the branches which is caused by the bug, *Ptyelus grossa*, that suck up the tree sap and excretes almost pure water.[10]

## 3. Ethnomedicinal uses

The leaves, bark and roots of *P. africanum* are used in the African traditional medicine. The root and bark decoctions are used to treat eye infections, joints and back pains, toothache, ascites and abdominal disorders, diarrhea, dysentery, infertility, skin rashes and blisters, venereal diseases, depression, anthelmintic, coughs and gargled to treat sore throat.[7,9,10,12,14,15,17–19] The bark and root decoctions are used for cleansing by women after bereavement.[20] The bark is a cure for fever, induces vomiting and cleanses the liver.[21,22] In Zimbabwe, the root decoctions and infusions detoxify blood, cures infertility [21,23] and are applied against the painful kicking of the foetus in pregnant women, but only if the problem lasts for at least 2–3 days.[24] The bark and root powders are a treatment for wounds or improves healing.[20,24] The leaves steam vapors are inhaled to relieve toothache.[7,20] The plant also finds applications against major diseases, HIV/AIDS and tuberculosis.[14–16]

In ethnoveterinary usages, *P. africanum* is used to treat almost similar disease conditions in domesticated animals as in man. In livestock, the plant is used against diarrhea, dysentery, colic and as a general tonic.[25] The root is a component in the '*Kgatla doctors*' mixture to promote well-being, resistance to diseases and fertility.[24,25] The crushed soaked bark is rubbed into the skin of pets to repel fleas and maggots and is used to treat helminthosis and diarrhea.[25]

The above ethnomedicinal information groups the pharmacological properties of *P. africanum* as being antibacterial, antifungal, anthelmintic, anti-inflammatory, anti-HIV, tonic and having antioxidant properties.

## 4. Phytochemistry

### 4.1. Mineral composition

The micro minerals reported are Fe, Mn and Zn while the macro minerals are Ca, Mg, Na, P and K. The mineral concentrations decrease as the plant nutritional value decreased or as plants lose their green color and dry off.[26]

### 4.2. Phytochemicals

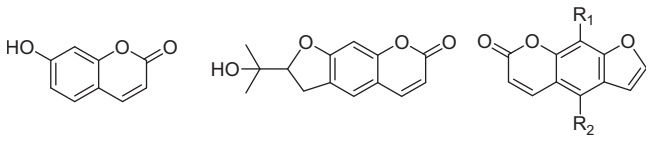
The surveyed reports on the isolation and characterization of secondary metabolites from *P. africanum* have revealed the presence of benzenoids, flavanols, flavonols, condensed flavonoids, gallotannins and δ-lactones in the flowers, bark, roots and heart wood. Terpenes, xanthone and coumarins were identified in the bark and leaves, while the seeds contain amino acids. The secondary metabolites isolated from the *P. africanum* are listed in Table 1, while their chemical structures are shown in Figs. 1–6.

Secondary metabolites isolated from *P. africanum*. Table 1.
Coumarins reported from *P. africanum* Fig. 1.
Benzenoids reported from *P. africanum* Fig. 2.

**Table 1** Secondary metabolites identified from the *P. africanum*.

| Plant part | Phytochemical class | Phytochemicals reported | Refs. |
|---|---|---|---|
| Leaves | Coumarins | **1** Umbelliferone | 27 |
| | | **2** Marmesin | |
| | | **3** Bergaptin | |
| | | **4** Xanthonin | |
| | | **5** Xanthotoxol | |
| | | **6** Imperatonin | |
| Bark, heart wood roots | Benzenoids | **7** Berginin | 28 |
| | | **8** Norbegenin | 29 |
| | | **9** 11-*O*-(*E*)-*p*-coumaroylbergin | 30 |
| | | **10** 11-*O*-galloylbegenin | 31 |
| | | **11** Gallic acid | 32 |
| | | **12** Methylgallate | 33 |
| | | **13** 3-*O*-methylgallic acid | |
| | | **14** Chlorogenic acid | |
| Heart wood, bark and flowers | Flavonols | **15** Fisetin | 28 |
| | | **16** Kaempferol | 32 |
| | | **17** Myricetin | 31 |
| | | **18** Quercetin | 33 |
| | | **19** Astralagin | 32 |
| | | **20** Isoquercitrin | 33 |
| | | **21** Kaempferol-3-galactoside | 30 |
| | | **22** Quercetin-3-galactoside | |
| | | **23** Herbacetin 3-galactoside | |
| | | **24** Rutin | 32 |
| | | **25** Nicotiflorin | 33 |
| | | **26** Myricetin-3-rutinoside | |
| | | **27** Quercetin-3- rhamnosylgalactoside | 30 |
| | | **28** Kaempferol-3- rhamnosylgalactoside | 33 |
| | | **29** Kaempferol 3-rhamnosylglucosylgalactoside | 30 |
| | | **30** Kaempferol-3-*O*-(6″-*O*-galloyl)-β-D-galactopyranoside | 33 |
| | | **31** Quercetin-3-*O*-(6″-*O*-galloyl)-β-D-galactopyranoside | |
| | | **32** Myricetin-3-*O*-(6″-*O*-galloyl)-β-D-galactopyranoside | |
| Heart wood bark flowers and leaves | Flavanol | **33** Flava-3-ol | 31 |
| | | **34** Fisetinidol | |
| | | **35** Robinetinidol | |
| | | **36** Catechin | 34 |
| | | **37** 4a-(2,4-Dihydroxy-3-methoxyphenyl)-flava-3-ol type | 31 |
| | | **38** 4b-(2,4-Dihydroxy-3-methoxyphenyl)-flava-3-ol type | |
| | | **39** (4α,6)-Bisfisetinidol | 30 |
| | | **40** (4β,6)-Bisfisetinidol | |
| | | **41** Epigallocatechin-3-*O*-gallate | 30 |
| | | **42** (+)-Gallocatechin-3-*O*-gallate | |
| | | **43** Robinetinidol-3-*O*-gallate | 31 |
| | | **44** Catechin-3-*O*-rhamnoside | 34 |
| Bark and roots | Gallotannin | **45** Red coloured gallotannin | 34 |
| Heart wood | δ-Lactone | **46** 2-(3,4-Dihydroxyphenyl) δ-lactone | 31 |
| | | **47** 2-(3,4,5-Trihydroxyphenyl) δ-lactone | |
| Heart wood | Condensed-flavonoids | **48** Bissextol (isomers) | 28 |
| | | **49** Cyanomaclurin | |
| | | **50** Cyanomaclurin analog | |
| Leaves | Xanthone | **51** Mangiferin | 33 |
| Seeds | Amino acid | **52** *Trans*-4-hydroxypipecolic acid | 35 |
| | | **53** Sulfate ester of *Trans*-4-hydroxypipecolic acid | |
| Leaves and bark | Terpenoids | **54** Betulinic acid | 15 |
| | | **55** β-Amyrin | 27 |
| | | **56** β-Sitosterol | 29 |
| | | **57** Stigmasterol | |

NB: Compound numbering refers to chemical structure shown in Figs. 1–6.
Chemistry, Vol. 5, 2133–2143, 1997.



| | $R_1$ | $R_2$ |
|---|---|---|
| **3** | H | OMe |
| **4** | OH | H |
| **5** | OMe | H |
| **6** | Prenyl | H |

**1** **2**

**Figure 1** Coumarins reported from *P. africanum*.

Flavonols reported from *P. africanum* Fig. 3.
Flavan-3-ols reported from *P. africanum* Fig. 4.
Gallotanin, δ-lactone and condensed flavanols reported from *P. africanum* Fig. 5.
Xanthone, amino acids and terpenoids reported from *P. africanum* Fig. 6.

## 5. Pharmacological reports

### 5.1. Total phenolic content and antioxidant activities

The total phenolic content of *P. africanum* is 34–49% in the bark and root acetone or ethanol extracts, 23–34% in the leaf acetone and ethanol extracts.[28,36] The plant is rich in polar extractives which should be an indicator on the type of bioassay to pursue. Traditional healers mostly use water for herbal preparations and thus the elucidation of the radical scavenging activity of water and alcoholic extracts mode of action and their quality control parameters would add value to the existing literature. The root and bark polar extracts have shown high antioxidant activity.[36] The DPPH $EC_{50}$ criteria for the acetone extracts of the leaf, bark and root are 6.54, 4.37 and 3.82 μg/mL respectively, compared to $EC_{50}$ = 5.04 μg/mL for the standard ascorbic acid.[36,37]

### 5.2. Antibacterial activity

The common problem on the surveyed reports is the reported high extract concentrations that were tabulated for the antibacterial activities. Here, the point raised by Gertsch [38] that high extract concentration is often used to attest for pharmacological response/activity is valid. Are the reported mL/g, mg/mL and zone of inhibition concentrations meaningful to human health or are the reported activities a result of the in vitro non-specific protein interaction shown as less toxic multiple antibacterial activities.[38]

The antibacterial activities of the root and bark extracts were reported against standard strains (MIC = 0.08–6 mg/mL): *Staphylococcus aureus* (ATCC.12600), *Enterococcus faecalis* (ATCC 29219), *Enterobacter cloacae* (ATCC), *Escherichia coli* (ATCC 1175), *Pantoea agglomerans*, *Pseudomonas aeruginosa* (ATCC 15442 & 9027), *Helicobacter pylori* (ATCC 43526), *Streptococcus pyogenes* (ATCC 49399), *Aeromonas hydrophila* (ATCC 35654) and clinical bacterial isolates (MIC = 1.5–12 mg/mL): *E. faecalis*, *E. coli*, *Proteus mirabilis*, *Klebsiella pneumonia*, *Salmonella choleraesuis* and *Serratia marcescens*.[17,36,39,40]

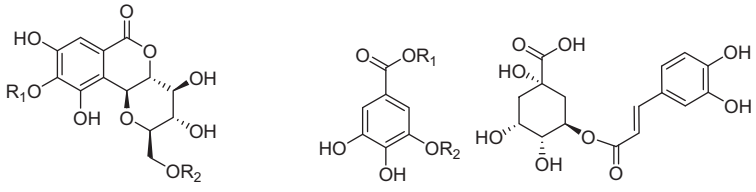
The leaves ethanol, acetone, dichloromethane and hexane extracts were active (MIC = 0.16–2.5 mg/mL) against *S. aureus* (ATCC 29213), *E. faecalis* (ATCC 29219), *P. aeruginosa* (ATCC 27853) and *E. coli* (ATCC 25922).[36] The 0–23 mm zones of inhibition were recorded for the stem bark antimicrobial activity of the ethyl acetate, acetone, ethanol, methanol and water extracts on 31 clinical strains of *H. pylori*.[16] The ethyl acetate extract was reported to be both bactericidal and bacteriostatic in activity against *Plesiomonas shigelloides* (ATCC 51903).[40] Ethnomedicinally, *P. africanum* has been used for wound healing and anti-inflammation, and since it has been established that the wound healing process is affected by the presence of microbial and free radical,[41,42] perhaps the presence of polar extractives and the antibacterial properties explains this traditional use. An *in vitro* study on the polar extracts wound healing properties would be a worthwhile venture.

### 5.3. Antifungal activity

The bark and root extracts were inactive against clinical isolates of *Candida albicans*, *Cryptococcus neoformans*, *Candida krusei*[43,44] and *Trichomonas vaginalis*.[45] The stem bark and roots ethyl acetate, methanol and water extracts antifungal activities were recently reported against *C. albicans* (ATCC 2091 and 10231) and *C. neoformans* (ATCC 66031) as fungistatic activities (5 mg/mL).[40,44] The fungal activity is thus dependent upon the fungal strains used and not the assay method used. The bark and root extracts are inactive against clinical isolates while active against standard strains using the agar diffusion method.

### 5.4. Anti-HIV activity

The aqueous and methanol extracts of the roots and stem bark were shown to inhibit RNA-dependent-DNA polymerase activity of HIV-1 reverse transcriptase and ribonuclease H activity of reverse transcriptase, which was ascribed to the gallotanin 45.[32] The ethylacetate stem bark extract contained



| | $R_1$ | $R_2$ |
|---|---|---|
| **7** | Me | H |
| **8** | H | H |
| **9** | H | *p*-Hydroxycinnamoyl |
| **10** | H | Galloyl |

| | $R_1$ | $R_2$ |
|---|---|---|
| **11** | H | H |
| **12** | Me | H |
| **13** | H | Me |

**14**

**Figure 2** Benzenoids reported from *P. africanum*.

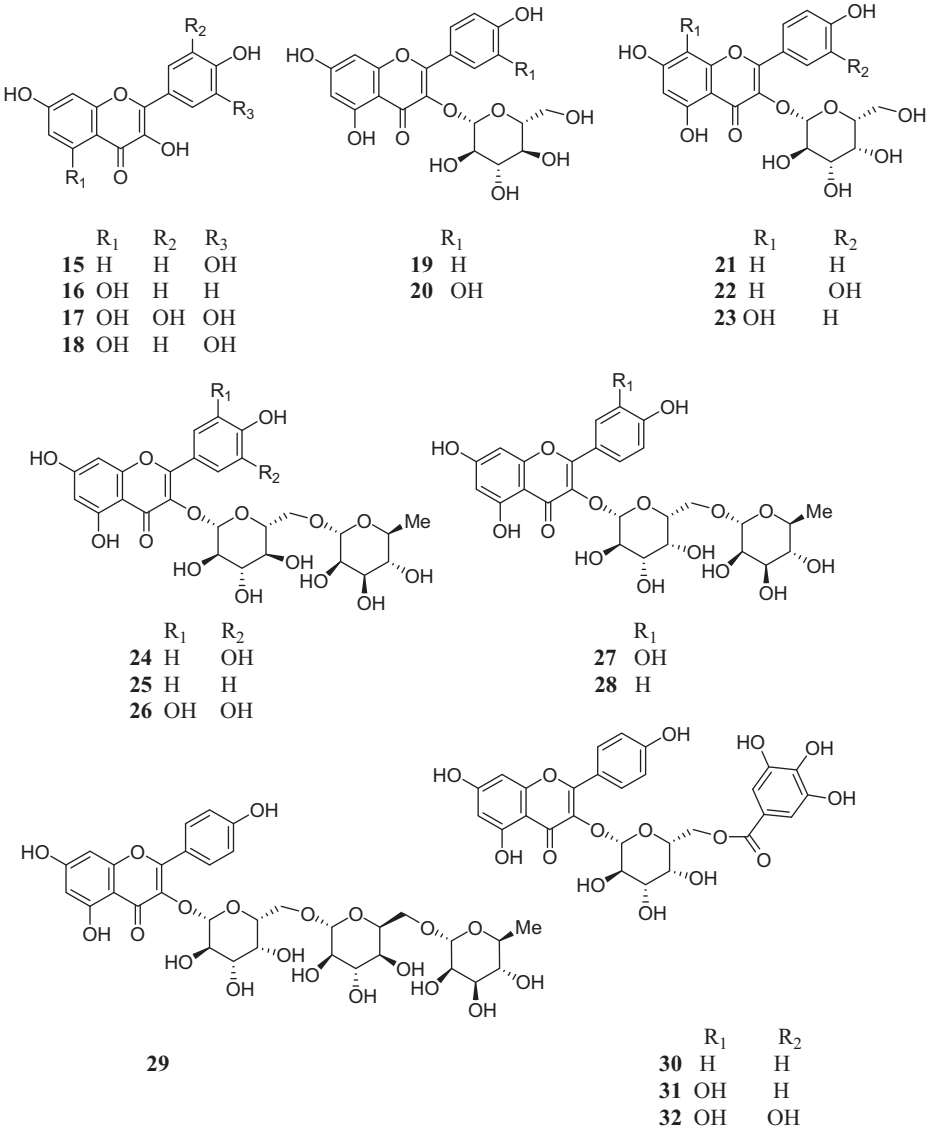



**Figure 3** Flavonols reported from *P. africanum*.

an anti-HIV-1 agent betunilic acid 54. Betunilic acid activity against HIV-1 was indicated by an $IC_{50}$ value of 0.002 μg/mL and $CC_{50}$ value > 0.09 μg/mL compared to the standard glycyrrhizin, $IC_{50}$ = 0.58 and $CC_{50}$ = 1.65 μg/mL.[15] Betunilic acid and its derivatives have been shown elsewhere to be anti HIV agents.[46–48]

### 5.5. α-Glucosidase inhibition

The leaf acetone extract inhibited α-glucosidase from rat intestinal ($IC_{50}$ = 2.5 mg/mL) and Baker's yeast ($IC_{50}$ = 0.04 mg/mL). The extract high antioxidant activity ($IC_{50}$ = 0.03 mg/mL) has a negative correlation with the enzyme inhibition.[49] The extracts mode of action and secondary metabolites responsible for the α-glucosidase were not identified.

### 5.6. Anthelmintic activity

The Mølgaard group has reported that the leaf, bark and root extracts showed anticestodial activity (0.5 mg/mL) on the parasitic worm *Hymenolepis diminutia*.[50] The extracts had a concentration dependant inhibition of *Haemonchus contortus* and *Trichostrongylus colubriformis* larval development which was attributed to larval motility.[51–53] The anthelmintic activities of the water extracts were not established, while the active secondary metabolites of the crude extracts are not known.

### 5.7. Toxicity

The toxicity of the ethylacetate stem bark extract on normal human liver cell was 82.6 μg/mL lethal dose after 24 h.[39] The acetone leaf, bark and root extracts did not show toxicity on the Vero monkey cell line and the brine shrimp larval mortality assays.[54] The root and leaf non-toxicity were also indicated by inhibition of HelaP4 cell growth at a concentration of 400 μg/mL.[33] The bark water, methanol, butanol and ethylacetate extracts have lower cytotoxicity against MAGI CCR5+ cells (CC50 > 110 μg/mL).[15] The lack of *P. africanum* extracts toxicity was further shown on sheep infected with parasites

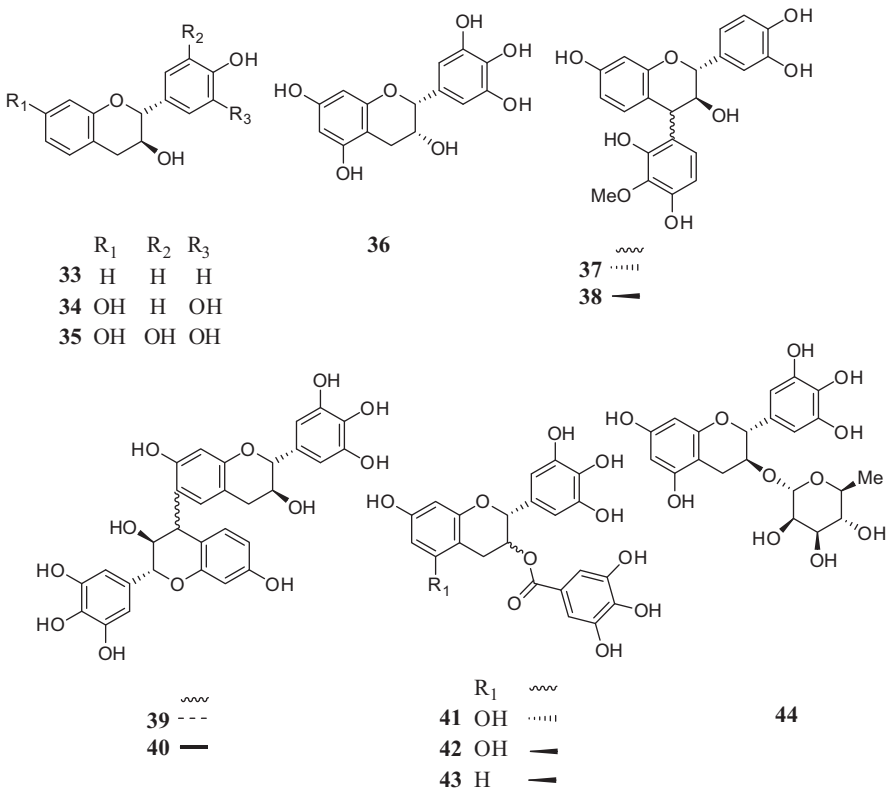



**Figure 4** Flavan-3-ols reported from *P. africanum*.

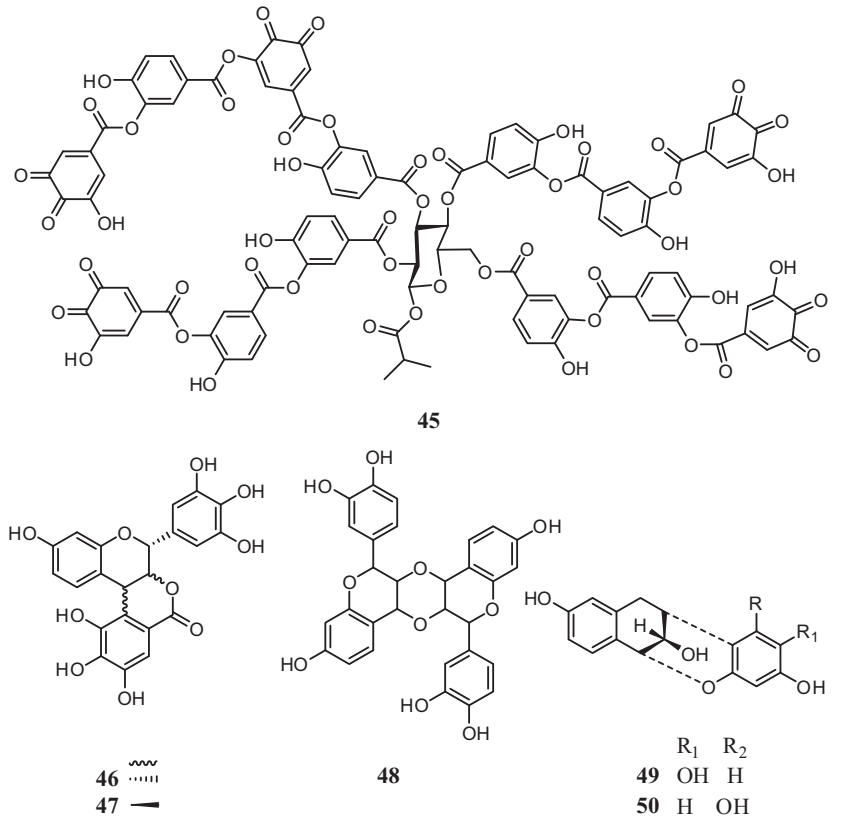



**Figure 5** Gallotanin, δ-lactone and condensed flavanols reported from *P. africanum*.

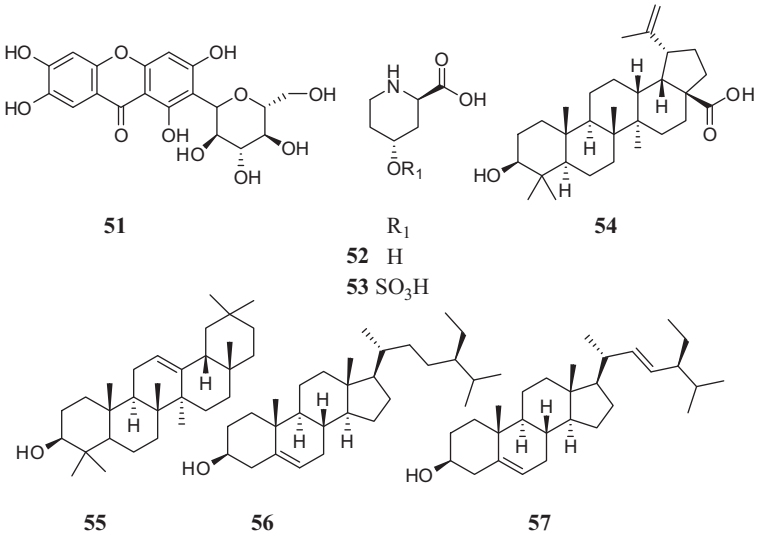



**Figure 6** Xanthone, amino acids and terpenoids reported from *P. africanum*.

*H. contortus* and *T. colubriformis*.[54] But despite this lack of toxicity the extracts rich in phenolic compounds would need to be used carefully as phenolic compounds have useful application as well as toxicity properties.[55,56]

## 6. Conclusion and future prospects

This review reports on the ethnomedical uses, pharmacology and phytochemistry of *P. africanum* Sond seed, leaf, bark, heartwood and root extracts. *P. africanum* tree is found in southern Africa with many purported ethnomedical uses. The literature surveyed revealed that the plant contains phenolics such as benzenoids, flavonoids and gallotannins. The key pharmacological activities of *P. africanum* are antioxidants, antibacterial, anthelmintic and ant-HIV-1 activities. It would be worthwhile to carry-out studies following the suggested rules of thumb for defining anti-infective potential in natural products [42], while taking into account the issues of the concentration–effect paradigm and avoiding the over-interpretation of the obtained data.[37] This would help in determining the bioassays lower active concentrations in nM, μg/mL to make a fair comparable interpretation against other very active herbal drugs, avoid superficial analysis of results, rule out the role of artefacts and non-physiological activities. Furthermore *in vivo* activities of the polar extracts need to be established since only preliminary *in vitro* activities are reported. A quality control assurance study for *P africanum* herbal medicine is necessary starting from the harvest, extraction and through the assaying processes.

Phytochemicals responsible for many of the reported extracts bioactivities have not been identified. Hence, the synergistic effect of both the major and minor extract constituents cannot be ruled out. A small scale clinical trial based on the traditional uses and claims would clarify some of the plant uses and be used to set-up extracts preparation standards. The reports on the pharmacology and phytochemistry of *P. africanum* justify its ethonomedicinal uses.

## 7. Declaration of interest

The author declares no conflict of interest and assumes the responsibility for the content of the manuscript.

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