Plectranthus barbatus: A Review of Phytochemistry, Ethnobotanical Uses and Pharmacology – Part 1

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- Plectranthus barbatus
- Lamiaceae
- forskolin
- ethnobotanical uses
- pharmacology
- 6-(3-dimethylaminopropionyl)forskolin hydrochloride (NKH477)

Abstract

Plectranthus barbatus Andr. is one of the most important species of the genus Plectranthus L’ Herit. (Lamiaceae), with a wide variety of traditional medicinal uses in Hindu and Ayurvedic traditional medicine as well as in the folk medicine of Brazil, tropical Africa and China. The plant has therefore been an attractive target for intensive chemical and pharmacological studies up to now. This review presents data about the phytochemistry, ethnobotanical uses and pharmacology of Plectranthus barbatus as well as the pharmacology of its constituents. In addition to essential oil, abietane diterpenoids and 8,13-epoxy-labd-14-en-11-one diterpenoids are the main constituents found in Plectranthus barbatus. The major ethnobotanical uses are for intestinal disturbance and liver fatigue, respiratory disorders, heart diseases and certain nervous system disorders. Forskolin as one of the major constituents with its unique adenylyl cyclase activation that underlies the wide range of pharmacological properties could explain the different traditional uses of Plectranthus barbatus. Forskolin is involved in a number of patented pharmaceutical preparations used as over-the-counter drugs for the treatment of several ailments. However, the water-insoluble nature of forskolin limits its clinical usefulness. Forskolin thus served as a prototype for the development of 6-(3-dimethylaminopropionyl)forskolin hydrochloride (NKH477) as a potent water-soluble forskolin derivative that finds use in the therapy for a number of diseases especially of the cardiovascular system.

Introduction

Plectranthus L’ Herit., is a complex genus of the family Lamiaceae (Labiatae) that contains about 300 species distributed in tropical Africa, Asia and Australia [1]. Taxonomically the genera Coleus and Plectranthus are recombined by the Japanese authors to the genus Plectranthus [2]. One of the most important species of this genus is Plectranthus barbatus Andr., which is commonly referred to by a number of synonyms such as Plectranthus forskohlii Briq., Plectranthus forskalaei Wild., Plectranthus kilimandschari (Gürke) H.L. Maass., Plectranthus grandis (Cramer) R.H. Willemse, Coleus forskohlii Briq., Coleus kilimandschari Gürke ex Engl., Coleus coerulescens Gürke, Coleus comosus A. Rich., and Coleus barbatus (Andr.) Benth [1]. Plectranthus barbatus grows perennially over the tropical and subtropical regions of the Indian subcontinent and is cultivated commercially for its use in pickles. It is also distributed over parts of Pakistan, Sri Lanka, tropical East Africa, Asia (South of Arabian Peninsula, China) and Brazil [3–5].

P. barbatus is one of the most commonly used medicinal species of the genus Plectranthus. A diversity of traditional medicinal uses of P. barbatus in India (Hindu and Ayurvedic medicine), East and Central Africa, China, and Brazil have been reported. The majority of uses are for intestinal disturbance and liver fatigue, respiratory disorders, heart diseases and certain central nervous system disorders [1,3,4,6,7]. P. barbatus root extracts, such as the 50% ethanolic and methanolic extracts were therefore, in the middle of the 1970s, independently involved in screening programs for biological activities such as cardiovascular properties in the Central Drug Research Institute (CDRI), Lucknow, India, and by the group at Hoechst India Limited in Bombay, India. Reports from both research groups revealed the hypotensive and antispasmodic effects of the root extracts as well as the isolation of the major active principle which was named coleonol by CDRI [6,8,9],...
Table 1  Diterpenoids isolated from Plectranthus barbatus.

<table>
<thead>
<tr>
<th>No. of the compound</th>
<th>Name of the compound</th>
<th>Part* used</th>
<th>P. barbatus location</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abietane diterpenoids</strong></td>
<td></td>
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<tr>
<td>2</td>
<td>Coleon S</td>
<td>L</td>
<td>China</td>
<td>[16, 17]</td>
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<tr>
<td>3</td>
<td>Coleon O</td>
<td>L</td>
<td>East Africa – Kenya</td>
<td>[18]</td>
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<tr>
<td>4</td>
<td>Coleon T</td>
<td>L</td>
<td>China</td>
<td>[16, 17]</td>
</tr>
<tr>
<td>5</td>
<td>Plectrin</td>
<td>L</td>
<td>East Africa – Kenya</td>
<td>[15, 18]</td>
</tr>
<tr>
<td>6</td>
<td>Barbatusin</td>
<td>L</td>
<td>Brazil</td>
<td>[7, 19, 20]</td>
</tr>
<tr>
<td>7</td>
<td>3β-Hydroxy-3-deoxybarbatusin</td>
<td>L</td>
<td>Brazil</td>
<td>[7]</td>
</tr>
<tr>
<td>8</td>
<td>Cyclobutatin</td>
<td>L</td>
<td>Brazil</td>
<td>[7, 19, 21]</td>
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<tr>
<td>9</td>
<td>7β-Acetyl-12-deacetoxy-cyclobutatin</td>
<td>L</td>
<td>Brazil</td>
<td>[19]</td>
</tr>
<tr>
<td>10</td>
<td>(16β)-Coleon E</td>
<td>L</td>
<td>East Africa – Kenya</td>
<td>[15, 22]</td>
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<tr>
<td>11</td>
<td>Plectrinon A</td>
<td>L</td>
<td>East Africa – Kenya</td>
<td>[15, 23]</td>
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<tr>
<td><strong>6, 7-Secoabietane diterpenes</strong></td>
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<tr>
<td>12</td>
<td>14-Deoxycoleon</td>
<td>S</td>
<td>Brazil</td>
<td>[24]</td>
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<tr>
<td>13</td>
<td>14-Deoxycoleon U</td>
<td>S</td>
<td>Brazil</td>
<td>[25]</td>
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<tr>
<td>14</td>
<td>6,7-Secoaetabietane diterpene I</td>
<td>S</td>
<td>Brazil</td>
<td>[26]</td>
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<tr>
<td>15</td>
<td>6,7-Secoabietane diterpene II</td>
<td>S</td>
<td>Brazil</td>
<td>[26]</td>
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<tr>
<td>16</td>
<td>Sugiolo</td>
<td>S</td>
<td>Brazil</td>
<td>[27]</td>
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<tr>
<td>17</td>
<td>Abietatriene (dehydroabietane)</td>
<td>S</td>
<td>Brazil</td>
<td>[28]</td>
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<td>18</td>
<td>Demethylycyclopropanol (11-hydroxy-sugiolo)</td>
<td>R</td>
<td>China</td>
<td>[24]</td>
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<tr>
<td>19</td>
<td>Ferruginol</td>
<td>S</td>
<td>Brazil</td>
<td>[29]</td>
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<td>20</td>
<td>Sugiolo</td>
<td>WP</td>
<td>China</td>
<td>[30]</td>
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<td>21</td>
<td>20-Deoxycarnosol</td>
<td>S</td>
<td>Brazil</td>
<td>[31, 32]</td>
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<td>22</td>
<td>6β-Hydroxycarnosol</td>
<td>S</td>
<td>Brazil</td>
<td>[33]</td>
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<td>23</td>
<td>Barbatusol</td>
<td>S</td>
<td>Brazil</td>
<td>[29]</td>
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<tr>
<td><strong>8,13-Epoxylabd-14-en-11-one diterpenoids</strong></td>
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<td>26</td>
<td>Forskolin (7β-acetoxy-1α,6β,9α-trihydroxy-8,13-epoxy-labd-14-en-11-one; coleonol; collorsin; 1-deacetylforskolin B, 6-deacetylforskolin J)</td>
<td>R, R</td>
<td>India, China</td>
<td>[5, 10, 34–37]</td>
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<td>27</td>
<td>9-Deoxyforskolin (7β-acetoxy-1α,6β-dihydroxy-8,13-epoxy-labd-14-en-11-one)</td>
<td>R</td>
<td>India</td>
<td>[5, 35, 38]</td>
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<td>28</td>
<td>1,9-Dideoxyforskolin (7β-acetoxy-6β-hydroxy-8,13-epoxy-labd-14-en-11-one)</td>
<td>R</td>
<td>India</td>
<td>[5, 10, 35]</td>
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<td>29</td>
<td>1,9-Dideoxy-7-deacetylforskolin (6β,7β-dihydroxy-8,13-epoxy-labd-14-en-11-one)</td>
<td>R</td>
<td>India</td>
<td>[5, 10, 35]</td>
</tr>
<tr>
<td>30</td>
<td>Deacetyl-1-deacetylforskolin (6β,7β,9α-trihydroxy-8,13-epoxy-labd-14-en-11-one)</td>
<td>R</td>
<td>India</td>
<td>[35]</td>
</tr>
<tr>
<td>31</td>
<td>6-Acetyl-1-deacetylforskolin</td>
<td>WP</td>
<td>China</td>
<td>[39]</td>
</tr>
<tr>
<td>32</td>
<td>6-Acetyl-1,9-dideoxyforskolin</td>
<td>WP</td>
<td>China</td>
<td>[39]</td>
</tr>
<tr>
<td>33</td>
<td>1,6-Di-O-acetylforskolin (1α,6β,7β-triacetoxy-9α-hydroxy-8,13-epoxy-labd-14-en-11-one; forskolin A; 1,7-diacetoxyisosforskolin)</td>
<td>R, WP</td>
<td>China</td>
<td>[4, 40, 41]</td>
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<td>34</td>
<td>1-Acetylforskolin (1α,7β-diacetoxy-6β,9α-dihydroxy-8,13-epoxy-labd-14-en-11-one; forskolin B)</td>
<td>R, WP</td>
<td>China</td>
<td>[4, 40, 41]</td>
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<td>35</td>
<td>Isosforskolin (6β-acetoxy-1α,7β,9α-trihydroxy-8,13-epoxy-labd-14-en-11-one; coleonol B; forskolin C; 1-deacetylforskolin)</td>
<td>R, R, L, WP</td>
<td>India, China</td>
<td>[4, 10, 16, 37, 40–45]</td>
</tr>
<tr>
<td>37</td>
<td>7-Deacetylforskolin (1α,6β,9α-tetrahydroxy-8,13-epoxy-labd-14-en-11-one; deacetylforskolin; 6-deacetylisoforskolin; forskolin D)</td>
<td>R, WP</td>
<td>India</td>
<td>[4, 5, 10, 35, 40, 41]</td>
</tr>
<tr>
<td>38</td>
<td>Forskolin E (1α,7β-diacetoxy-6β-hydroxy-8,13-epoxy-labd-14-en-11-one; 9-dehydroforskolin B)</td>
<td>R, WP</td>
<td>China</td>
<td>[4, 47]</td>
</tr>
<tr>
<td>39</td>
<td>Forskolin F (7β-acetoxy-6β,9α-dihydroxy-8,13-epoxy-labd-14-en-11-one; 1-deacetylforskolin B; deacetylforskolin B; coleonol D)</td>
<td>R, WP</td>
<td>India, China</td>
<td>[4, 35, 43, 47, 48]</td>
</tr>
<tr>
<td>40</td>
<td>Forskolin G (1α-hydroxy-6β,7β-diacetoxy-8,13-epoxy-labd-14-en-11-one; 1-deacetylforskolin A; 9-dehydroforskolin E; 1-deacetoxy-9-dehydroforskolin A; 6-acetoxy-9-dehydroforskolin A; 7-dehydroforskolin C)</td>
<td>R, WP</td>
<td>China</td>
<td>[44, 45, 47, 49, 50]</td>
</tr>
<tr>
<td>41</td>
<td>Forskolin H (1α,6β-diacetoxy-8,13-epoxy-labd-14-en-11-one; 7-deacetoxy-9-dehydroforskolin A; plectromatin C)</td>
<td>R, WP</td>
<td>China</td>
<td>[44, 45, 47, 49]</td>
</tr>
<tr>
<td>42</td>
<td>Forskolin I (1α,6β-diacetoxy-7β,9α-dihydroxy-8,13-epoxy-labd-14-en-11-one; 7-deacetoxyforskolin A; 1-acetylforskolin C)</td>
<td>R, WP</td>
<td>China</td>
<td>[44, 45, 51, 52]</td>
</tr>
<tr>
<td>43</td>
<td>Forskolin J (1α,9α-dihydroxy-6β,7β-diacetoxy-8,13-epoxy-labd-14-en-11-one; 6-O-acetylisoforskolin C; 1-deacetylforskolin A; 7-acetylforskolin C)</td>
<td>R</td>
<td>China</td>
<td>[44, 51, 52]</td>
</tr>
<tr>
<td>44</td>
<td>1,6-Diacetoxy-9-dehydroforskolin (1α,6β,7β-triacetoxy-8,13-epoxy-labd-14-en-11-one; forskolin K; 9-dehydroforskolin A)</td>
<td>R, WP</td>
<td>China</td>
<td>[30, 44, 52]</td>
</tr>
<tr>
<td>45</td>
<td>6β-Hydroxy-8,13-epoxy-labd-14-en-11-one (forskolin L)</td>
<td>R, R</td>
<td>China, India</td>
<td>[35, 44, 52]</td>
</tr>
</tbody>
</table>

*Continued...*
and forskolin (26) (see Fig. 2) by Hoechst India Limited [5,10]. Subsequent chemical analysis and NMR spectral studies revealed the identity of both compounds [11–13]. Additionally, a great number of constituents of P. barbatus were isolated and the pharmacology of some of them was unraveled.

The unique ability of forskolin (26) to stimulate adenylyl cyclase directly, not through β-adrenoreceptors, in different broken cell preparations as well as in intact tissues, with a consequently increasing level of adenosine 3′,5′-cyclic monophosphate (cAMP) [5,14], still motivates a great deal of scientific investigations of forskolin, forskolin derivatives and other constituents of P. barbatus. The biological profile, mechanism of action as well as the biochemical properties of forskolin have been revealed through a great number of studies worldwide. Although forskolin has been used in diverse studies for over 30 years, it will most likely continue to be an important tool to study the variety of cellular processes.

Due to the importance of P. barbatus in traditional medicine and as a source of forskolin, a general adenylyl cyclase activator with a great variety of pharmacological effects, the increasing use of the plant extracts standardized with certain amounts of forskolin as well as forskolin as over-the-counter drugs in spite of its clinical uselessness because of its nonspecific general activation of adenylyl cyclase and low water solubility, and the distribution of information regarding P. barbatus under a number of synonymous Latin names, the purpose of this review is to provide data about the phytochemistry, ethnotabonous uses and pharmacology of P. barbatus and its major constituents such as forskolin (26) (see Fig. 2) and to delineate the potential of forskolin for the development of the novel water-soluble forskolin derivate, the 6-(3-dimethylaminopropionyl)forskolin hydrochloride (NKH477) (79) (see Fig. 7) as a substantial therapeutic agent.

**Phytochemistry**

*P. barbatus*, especially that grown in India, Brazil, East Africa (Kenya) and China has been an attractive target for intensive chemical and pharmacological studies for novel biologically active constituents. The main constituents isolated from different parts of *P. barbatus* are diterpenoids and essential oil.
Diterpenoids

Two main groups of diterpenoids, the abietane diterpenoids (abieta-
noids) and the 8,13-epoxy-labd-14-en-11-one diterpenoids were identified in \textit{P. barbatus}. \textit{Table 1} demonstrates the diterpenoids isolated from different parts of \textit{P. barbatus}.

Although the majority of abietane diterpenoids were isolated from the leaves and stems of \textit{P. barbatus} growing in Brazil and from the leaves of \textit{P. barbatus} distributed in East Africa (Kenya), some of them were also obtained from the leaves, roots and whole plant as well as from the roots of \textit{P. barbatus} growing in China and India respectively (\textit{Table 1}). The identified abietanes are of various structures which could be classified accordingly into royleanones (\(+\)-allylroyleanone (1) [15] and coleon S (2) [16,17]), spirolecenes (coleon O (3) [18], coleon T (4) [16,17], plectrin (5) [15,18], barbatusin (6) [7,19,20], 3β-hydroxy-3-deoxybarbatusin (7) [7], cyclobutatin (8) [7,19,21] and 7β-acetyl-12-deacetoxy-cyclobutatin (9) [19]), vinylogous quinones (16R)-coleon E (10) [15,22] and coleon F (11) [15,23]), acylhydroquinones (16R)-plectrinon A (12) [3,15], plectrinon B (13) [15], 14-deoxycoleon U (14) [24] and coleon C (15) [25]), 6,7-secoabietanoids (6,7-secoabietane diterpene I (16), 6,7-secoabietane diterpene II (17) [26] and carbocyclic (18) [27]), aromatic abietanoids such as abietatriene (19) [28], phenolic abietanoids (demethylcryptojaponol (20) [24], fervuginol (21) [29], sugiol (22) [30], 20-deoxocarnosol (23) [31,32] and 6β-hydroxycarnosol (24) [33]), including that with a rearranged abietane skeleton (barbaturol (25) [29]) (\textit{Fig. 1}).

A series of labdane diterpenoids with the typical 8,13-epoxy-labd-14-en-11-one skeleton, differentiated in the substituent groups at C-1, C-6, C-7, and C-9 (structures 26–52) (\textit{Fig. 2}) were isolated mainly from the roots of \textit{P. barbatus} grown in India as well as from the whole plant, roots, leaves of \textit{P. barbatus} grown in China [4,5,10,16,30–57] (\textit{Table 1}). Forskolin (26) (\textit{Fig. 2}) is the first main labdane diterpenoid isolated from the roots of the Indian \textit{P. barbatus}. Some 8,13-epoxy-labdane diterpenoids with some deviations from the basic structure were identified, for example, those containing an additional hydroxy substituent at C-3 such as 3-hydroxyforskolin (53) and 3-hydroxyisoforskolin (54) [58], those with a β-axial orientation of the C-13/C-14 bond and α-equatorial orientation of the methyl group at C-16 such as 13-epi-9-deoxycoleonol (55) [59] and coleonol C (56) [57], or with the carbonyl function at C-12 or without carbonyl function such as coleonic acid (54) [58], those with a β-axial orientation of the C-13/C-14 bond and α-equatorial orientation of the methyl group at C-16 such as 13-epi-9-deoxycoleonol (55) [59] and coleonol C (56) [57], or with the carbonyl function at C-12 or without carbonyl function such as coleonic acid (54) [58], and manool oxide (58) [28] respectively (\textit{Table 1}, \textit{Fig. 3}). Further labdane diterpenoids such as 13-epi-sclareol (59) [60], forskoditerpene A (60) [61], 12-hydroxy-8,13E-labdadien-15-oic acid (61) [39], coleolic acid (62) and coleonic acid (63) [62] were also isolated from different parts of \textit{P. barbatus} (\textit{Table 1}, \textit{Fig. 4}). Moreover, five mi-

\begin{figure}
\centering
\includegraphics[width=\textwidth]{chemical_structures.png}
\caption{Abietane diterpenoids.}
\end{figure}
nor 8,13-epoxy-labd-14-en-11-one diterpene glycosides such as forskoditerpenosides A (64), B (65), C (66), D (67), and E (68) were isolated from the whole plant of P. barbatus grown in China [61, 63] (Table 1, Fig. 5).

### Essential oils

The chemical composition of the essential oils of P. barbatus varied according to location and date of harvest, and contained mainly mono- and sesquiterpenes. The main constituents of the essential oil distilled from the leaves of P. barbatus grown in Brazil were α-pinene, eremophyllene, myrcene, humulene, β-caryophyllene, β-o-cymene, limonene, nerolidol and farnesol [64, 65]. In addition, the diterpene manool (1.0%) was reported for the first time to be contained in the essential oil of the leaves [64]. In all, 91 components were detected in the essential oil obtained from the leaves of Rwandan P. barbatus. The main compounds were aromadendrene, bornol, α-fenchyl acetate, α-co-paene, γ-2-cadinene, caryophyllene oxide, T-cadinol, calamenene hydrate, and hydroxycalamene [66, 67]. Steam distillation of the roots of P. barbatus grown in India and Brazil afforded an essential oil, the main constituents of which were found to be β-o-cymene, bornyl acetate, 3-decanone, α-santalene, α-pinene, β-pinene, β-caryophyllene, camphene, sabinene, β-ionone, (E,E)-farnesol, α-cis-bergamotene and γ-curcumene [28, 64]. Furthermore, the presence of the diterpene abietastrine (0.7%) (dehydroabietastrine) (19) (Fig. 1) was reported for the first time in the essential oil extracted from the roots of P. barbatus grown in Brazil [64]. Moreover, the essential oil of the stems of this plant afforded the major constituents, β-phellandrene, α-pinene, α-co-paene, sabinene, caryophyllene oxide, limonene, β-caryophyllene, and α-humulene [64].

### Miscellaneous constituents

The monoterpene glycoside coleside (cuminyl-O-β-D-glucopyranosyl-(1→2)-β-D-galactopyranoside) (69) [68], the sesquiterpenoids α-cedrol [16, 24] and 4β,7β,11-enantioeudesmantriol (70) [63], a number of pentacyclic triterpenoids of the ursane type such as α-amyrin [24], coleonolic acid (2-hydroxymethyl-A-(19α)-hydroxy-2(3),12(13)-dien-28-oic acid) (71) [69], euscaphic acid (2α,3α,19α-trihydroxyurs-12-ene-28-oic acid) (72) [58], myrianthic acid (2α,3α,19α,23-tetrahydroxyurs-12-ene-28-oic acid) (73) [58], and uvaol (urs-12-ene-3β,28-diol) (74) [30], of the lupane type such as betulic acid [24], of the oleanane type such as arjunic acid (olean-12-en-28-oic acid,2α,3β,19α) (75) [58] and arjungenin [2,3,19,23-tetrahydroxy-olean-12-en-28-oic acid (2α,3β,4α,19α)] (76) [58] (Fig. 6) as well as the tetraterpenoids...
penoid crocetin dialdehyde [70] and the sterols (ergosterol endoperoxide \{5α,6α-epidioxy-ergosta-6,22-dien-3β-ol\} [30], 5α,6α-epidioxy-ergosta-6,9(11),22-trien-3β-ol [30], stigmasterol [16, 71], and β-sitosterol [16, 24, 30]) were isolated from different tissues of \textit{P. barbatus} distributed in India and China. Only one flavonoid and one phenylpropanoid, namely genkwanin (7-O-methylapigenin) and guaiacol glycerin ether, respectively, [16] as well as the phenolic compounds caffeic acid [68], coeleuside B (\(p\)-isopropylatechol-4-O-β-D-glucopyranosyl(1 → 2)-β-D-galactopyranoside) (77) [72] and colexanthone (1-oxymethyl-3,5-dihydroxy-7-methyl-xanthone) (78) [62] (\(\bullet\) Fig. 6) were isolated from different parts of the Chinese and Indian \textit{P. barbatus}. In addition three tetramethyl-substituted higher alkanes namely 2,6,10,14-tetramethylpentadecane, 2,6,10,14-tetramethylhexadecane, and 2,6,10,14-tetramethylheptadecane were isolated from the roots of the Indian \textit{P. barbatus} [28]. Moreover, five glycolipids, such as monogalactosyl diacylglycerol, digalactosyl diacylglycerol, trigalactosyl diacylglycerol, tetragalactosyl diacylglycerol, and sulfoquinovosyl diacylglycerol were detected in the leaves of \textit{P. barbatus} grown in Brazil [73].

### Uses

#### Ethnobotanical uses

\textit{P. barbatus} has been used for centuries in Hindu and Ayurvedic traditional medicine as well as in the folk medicine of Brazil, tropical Africa and China for the treatment of various diseases [1, 3, 4, 6, 29, 45, 66, 74–78] (\(\square\) Table 2). In addition, \textit{P. barbatus} is used to alleviate fever in East Africa and India, as a children’s tonic and also as an emetic utilized by the Samburu of Kenya for strength [1]. In Uganda the plant is used to treat spiritual ailments [79]. In Africa, the plant is applied in ethnoveterinary medicine, for instance in Kenya, it is used to treat Coast Fever in cattle [1]. \textit{P. barbatus} is used against snakebites in India, Gabon and Kenya, and as insecticide to protect grain stores [1, 66].

#### Non-medicinal uses

As reported by Lukhoba et al. [1], \textit{P. barbatus} is planted as an ornamental and as a hedge, fence or boundary marker as well as soil improver for growing grains such as cowpeas, green grains and maize; it is also planted on the hillsides to prevent soil erosion and is used for making manure. The leaves of \textit{P. barbatus} are cooked as a vegetable in Kenya and Yemen; it is fed to sheep, goats and cattle. In Kenya, the soft velvety leaves are used as sanitary tissue to clean milk guards and both the leaves and stems are used to hasten the ripening of bananas.

### Table 2 Ethnobotanical uses of \textit{Plectranthus barbatus}.

<table>
<thead>
<tr>
<th>Digestive system</th>
<th>Respiratory system</th>
<th>Cardiovascular system</th>
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</thead>
<tbody>
<tr>
<td>In India for abdominal colic [6]. For stomachache and as purgative in Kenya and for nausea in Southern Uganda [1, 74]. In Brazil, as a substitute for boldo (\textit{Peumus boldus}) to treat gastric disturbances (e.g., gastritis and intestinal spasms) and hepatic disorders [1, 3, 29, 75]. Teeth and gum disorders [1].</td>
<td>Asthma, bronchitis, cold, cough and pneumonia [1, 4, 45, 66]. General respiratory ailments [1, 6, 74].</td>
<td>Angina, hemorrhage and hypertension [1, 6].</td>
</tr>
<tr>
<td>Nervous system</td>
<td>Pain, inflammation, muscularkeletal</td>
<td>Sensory</td>
</tr>
<tr>
<td>In Asia, for insomnia, convulsion [1, 6] and against dizziness and fluster [45]. In Tanzania for psychiatric problems [1].</td>
<td>Inflammation, abdominal and spasmodic pain, and painful micturition [1, 6]. Muscular, generalized pain, stiff neck, backache, bone dislocation, and rheumatism [1].</td>
<td>For conjunctivitis in Congo and earache in Kenya [1].</td>
</tr>
<tr>
<td>Skin</td>
<td>Metabolic &amp; endocrine system</td>
<td>Infection</td>
</tr>
<tr>
<td>In East Africa (Kenya, Congo), for wounds and ringworms, to reduce swelling on bruises and as a bath for babies with measles [1, 74].</td>
<td>In Ayurvedic medicine for hypothyroidism [76]. As an emmenagogue, oral abortifacient [1, 77]. In Somalia as an aphrodisiac [1].</td>
<td>Throat and mouth infections, tonsillitis, gastrointestinal infections, genitourinary infections (e.g., syphilis in Central Africa) and eye and ear infections [1]. In Rwanda, Kenya, French Guiana and Brazil to treat malaria [1, 66, 78]. In Kenya for measles [74].</td>
</tr>
</tbody>
</table>

### References

9 Tandon JS, Dhar MM, Ramakumar S, Venkatesan K. Structure of coleo- 
nol, a biologically active diterpene from Coleus forskohlii. Indian 

10 Bhat SV, Bajwa BS, Dornauer H, de Souza NJ. Fehlhaber HW. Structures 
and stereochemistry of new labdane diterpenoids from Coleus forskoh-

11 Ramakumar S, Venkatesen K, Tandon JS, Dhar MM. Molecular and crys-
tal structure of coleonol, C_{29}H_{34}O_{6}. Z Kristallogr 1985; 173: 81–86

12 Vivaswanath M, Gowad DH. Identity of forskolin with coleonol. Indian 
J Chem Sect B Org Chem Incl Med Chem 1985; 24B: 583

13 Saksena AK, Green MJ, Shue HJ, Wong JK, McPhail AT. Identity of coleonol 
with forskolin: structure revision of a base-catalysed rearrangement 

14 Ammon HP, Müller AB. Forskolin: from an ayurvedic remedy to a 

15 Ruedi P, Noggle A. Diterpenoids from leaf glands of Plectranthus barbatus 
(Labiatae). The absolute configuration of the 2-hydroxypropyl group 

16 Yao CS, Shen YH, Xu YL. The chemical constituents of Coleus forskohlii.
Nat Prod Res Dev 2002; 14: 1–6

17 Yao CS, Xu YL. The diterpenequinone from Coleus forskohlii. Chin 

18 Kato I, Matsumoto T, Tori M, Asakawa Y. Structure of plectrin, an aphid 
anti-feedant diterpene from Plectranthus barbatus. Chem Lett 1984; 9: 
1531–1516

19 de Albuquerque RL, Kemptoff MR, Machado MLI, Silva MGV, Matos FJ de A, 
Moraes SM, Bresso F. Abietane diterpenoids isolated from Plectran-

20 Wang AHJ, Paul IC, Zelnik R, Lavie D, Levy EC. Spectral characteristics of forsko-
lin and stereochemistry of new labdane diterpenoids from 
Coleus forskohlii. Phytochemistry 1993; 34: 1577–1580

21 Xu YL, Lin JD, Liu J. Spectral characteristics of forskolins (3). Nat 
Prod Res Dev 2008; 18 (Suppl.): 79–81, 97

22 Patrikowial Nj, Waterhouse P, Inmanor PK, de Souza NJ, Rupp RH. Structural 
study, elucidation, and synthesis of 1-deoxyforskolin. Tetrahedron 
1989; 45: 763–766

23 Shen YH, Yao CS, Xu YL. New diterpenoids from Coleus forskohlii. Chin 

24 Han YP, Wang XB, Kong LY. Forskolin G. Acta Crystallography Sect E 
et/issue/2006/06/00/hk2036/index.html

25 Shen YH, Xu YL. Two new diterpenoids from Coleus forskohlii. J Asian 

26 Yang WM, Jin QD, Xu YL. Spectral characteristics of forskolins (4). Nat 

27 Jauhari PK, Katti SB, Tandon JS, Dhar MM. Coleosol – a new diterpene 
from Coleus forskohlii. Indian J Chem Sect B Org Chem Incl Med Chem 
1978; 16B: 1055–1057

28 Singh S, Painuly R, Jauhari P, Tandon JS. Diterpenequinones from Coleus 
forskohlii: stereochemistry of the carbonyl chromophore. Indian J Chem 
Sect B Org Chem Incl Med Chem 1984; 23B: 952–955

29 Katti SB, Jauhari PK, Tandon JS. New diterpenes from Coleus forskohlii: 
structures of the diterpenes, coleon-D, coleol and coleonedol. Indian 

30 Tandon JS, Jauhari PK, Singh RS, Dhar MM. Structures of three new 
diterpenes, coleon B, coleol C and deoxycoleonol isolated from 
Coleus forskohlii. Indian J Chem Sect B Org Chem Incl Med Chem 
1978; 16B: 341–345

31 Shan YP, Kong LY. Isolation and identification of terpenes from 

32 Tandon JS, Roy R, Balachandran S, Vishwakarma RA. Epi-deoxycoleonol, 
a new antihypertensive labdane diterpenoid from Coleus forskohlii. Bioorg 

33 Sashidhara KV, Rosiaah JK, Kumar A, Bid HK, Konwar R, Chattopadhyay 
N. Cell growth inhibitory action of an unusual labdane diterpene, 13-
epi-sclareol in breast and uterine cancers in vitro. Phytother Res 
2007; 21: 1105–1108

Coleus forskohlii (WILLD.) BRIQ. (Labiateae). Chem Pharm Bull 2008; 
56: 52–56

35 Liu Y, Wang XM, Wu H. Main components of Coleus forskohlii extract 
and relevant extraction method. Chinese Patent CN 1944384 A; 2007

36 Shan Y, Wang X, Zhou X, Kong L, Niwa M. Two minor diterpene glyco-
sides and an eudesman sesquiterpene from Coleus forskohlii. Chem 
Pharm Bull 2007; 55: 376–381

37 Kelecom A, de Albuquerque RL, Machado MLI, Matos FJ, Craveiro AA. 
Essential oils from leaves, stems and roots of Plectranthus barbatus 

38 Mancini B, Rubinolo CL, Pozzati GL, Mancini MAD. Chromatographic study 
of essential oils from plants of Ariaragua region. 1. Thin-layer and 
vaso-phase chromatographic analysis of essential oil from leaves of Co-
leus barbatus Labiatae. Rev Fac Farm Odontol Araraquara 1972; 6: 41–46
71 Shah VC, D’Souza AS, de Souza NJ. Chomemorphine, stigmasterol, and ecdysterone: steroids isolated through bioassay-directed plant screening programs. Steroids 1989; 53: 559–565
74 Matu EN, van Staden J. Antibacterial and anti-inflammatory activities of some plants used for medicinal purposes in Kenya. J Ethnopharmacol 2003; 87: 35–41

Alasbahi RH, Melzig MF. Plectranthus barbatus: A Review... Planta Med 2010; 76: 653–661