6 Simple Phenols, Phenolic Acids, and Related Esters from the Medicinal Plants of Africa

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6.1 Introduction

Plants synthesize a wide range of organic compounds referred to as secondary metabolites. Among these, phenolic compounds are ubiquitous constituents, generally involved in defense against ultraviolet radiation or aggression by pathogens. Commonly, phenolic compounds are found in a wide range of edible plant foods, such as fruits, vegetables, cereals, and legumes, and in beverages, such as wine, tea, and coffee. Phenolics embrace a wide range of plant substances, possessing in common an aromatic ring with at least one aromatic compound ring substituted by at least one hydroxyl group; they are located in the vacuole and tend to be water soluble as they occur in combined forms with sugars as heterosides [1,2]. Structurally, phenolic compounds can be grouped into two main classes: flavonoids and nonflavonoids, according to their basic structures, and into subclasses, according to specific substituent in basic structure (Figure 6.1) [3–5]. The nonflavonoid phenolics are classified, based on their carbon skeletons, into the following subgroups: simple phenols, phenolic acids and derivatives, phenones, phenylacetic acids and derivatives, hydrolyzable tannins, and stilbenes.

Simple phenols (**1**) are described as compounds having at least one hydroxyl group attached to an aromatic ring as a basic skeleton. Within the class of simple phenols are phenol (**6**), catechol (**7**), resorcinol (**8**), and phloroglucinol (**9**). These phenols are themselves uncommon plant constituents, but phloroglucinol, resorcinol, and catechol may be found in combination with cinnamic acids (**3**) to form various plant flavonoids. Phenolic acids and derivatives (**2**) are major classes of phenolic compounds widely occurring in the plant kingdom [6]. Phenolic acids have a carboxyl group attached to a benzene ring. Depending to their structures,

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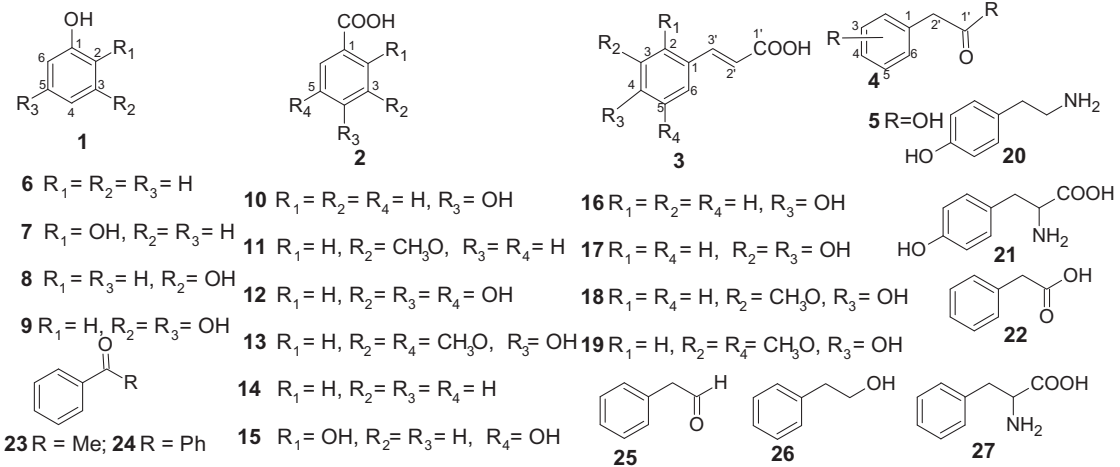


Figure 6.1 Basic structures of phenolic compounds and derivatives: simple phenols (**1**); phenolic acids (**2**); cinnamic acids (**3**); phenylcetone (**4**); phenylacetic acid (**5**); phenol (**6**); catechol (**7**); resorcinol (**8**); phloroglucinol (**9**); protocatechuic acid (**10**); vanillic acid (**11**); gallic acid (**12**); syringic acid (**13**); salicylic acid (**14**); gentisic acid (**15**); *p*-coumaric acid (**16**); caffeic acid (**17**); ferulic acid (**18**); sinapic acid (**19**); tyramine (**20**); tyrosine (**21**); phenylacetic acid (**22**); acetophenone (**23**); benzophenone (**24**); phenylacetaldehyde (**25**); phenylethanol (**26**); phenylamine (**27**).

two main classes of phenolic acids can be distinguished, namely, benzoic acid derivatives and cinnamic acid derivatives [7]. Benzoic acid derivatives with the basic structure C_6-C_1 consist of hydrobenzoic acids, occurring in grapes and wines, including protocatechuic acid (**10**), vanillic acid (**11**), gallic acid (**12**), syringic acid (**13**), salicylic acid (**14**), and gentisic acid (**15**) [8]. Hydroxybenzoic acids are found in common plants such as *Citrus paradisi*, *Olea europaea*, *Daucus carota*, *Fagara macrophylla*, *Mespilus germanica*, *Lonicera japonica*, and *Morus alba* [9–14]. Cinnamic acid derivatives such as hydrocinnamic acids (C_6-C_3) are generated from phenylpropanoids; the most common are *p*-coumaric acid (**16**), caffeic acid (**17**), ferulic acid (**18**), and sinapic acid (**19**) [15]. The phenylpropanoids (C_6-C_3) will be discussed in depth in Chapter 7. The phenolic acids are seldom found in a free state and more often in a combined form such as esters. Other phenolic acids are the alkaloids, namely, tyramine (**20**) and tyrosine (**21**) [16]. The hydroxycinnamic acids and their derivatives are present in various parts of forest trees, as they are direct precursors of the monolignols, which are implicated in lignin biosynthesis [17]. Another source of hydrocinnamic acids is dietary. Good sources of caffeic acid are coffee, blueberries, apples, and cider; *p*-coumaric acid is found in spinach, sugar beets, and cereal brans; sinapic acid is found in broccoli, kale and leafy brassicas, and citrus juices [18,19]. Phenylacetic acid (**22**) and its acetates, acetophenone (**23**), benzophenone (**24**), phenylacetaldehyde (**25**), and phenylethanol (**26**), contain a benzene ring with two side chains and are therefore referred to as the C_6-C_2 class of phenolic compounds, while benzophenone consists of a $C_6-C_1-C_6$ structure [20]. In plants, they are synthesized in response to environmental stresses such as salinity, cold, and heat shock, or as flavors and aromas in fruits, flowers, and tea [21–23]. The class of quinones includes the benzoquinones, napthaquinones, and anthraquinones (see Chapter 10). Ubiquinone, a benzoquinone, is found not only in the plant kingdom but also in the animal kingdom. It functions as an agent in the electron transport system. Betacyanins are often referred to as nitrogenous anthocyanidins, as they are nitrogen-containing phenols having an absorption spectrum resembling that of the anthocyanidins [24]. Phenolic compounds exhibit a wide range of physiological activities. There are a few reviews focusing on the activity of simple phenol, phenolic acids, and derivatives [15,25–27]. Many phenolic acid compounds have displayed antioxidant activity related to the acid moiety and the number and relative positions of hydroxyl groups on the aromatic ring structure [8]. Catechol and pyrogallol, both hydroxylated phenols, were found to be toxic to microorganisms, and their documented antimicrobial activity was due to the site(s) and number of hydroxyl groups on the phenol group. Increased hydroxylation results in increased toxicity [28]. Other activities include anticancer or anticarcinogenic, antimutagenic, antiatherosclerotic, antibacterial, antiviral, and anti-inflammatory activities to a greater or lesser extent; they also exhibit estrogenic, antihepatotoxic, antioxidant, free radical scavenger, chemopreventive and apoptotic, platelet aggregation inhibitor, neuroprotective, low-density lipoprotein (LDL) oxidation inhibitor, and antisickling activities [15,27,29–39].

6.2 Biosynthesis of Phenolic Compounds and Structural Diversity

Phenolic compounds are generally synthesized via two pathways: the shikimic acid pathway and the acetate malonate pathway.

6.2.1 Shikimic Acid Pathway

The shikimic acid pathway is related to the metabolism of carbohydrates and aromatic amino acids. The shikimate pathway consists of seven steps, starting with the condensation of phosphoenolpyruvate and erythrose-4-phosphate (Figure 6.2).

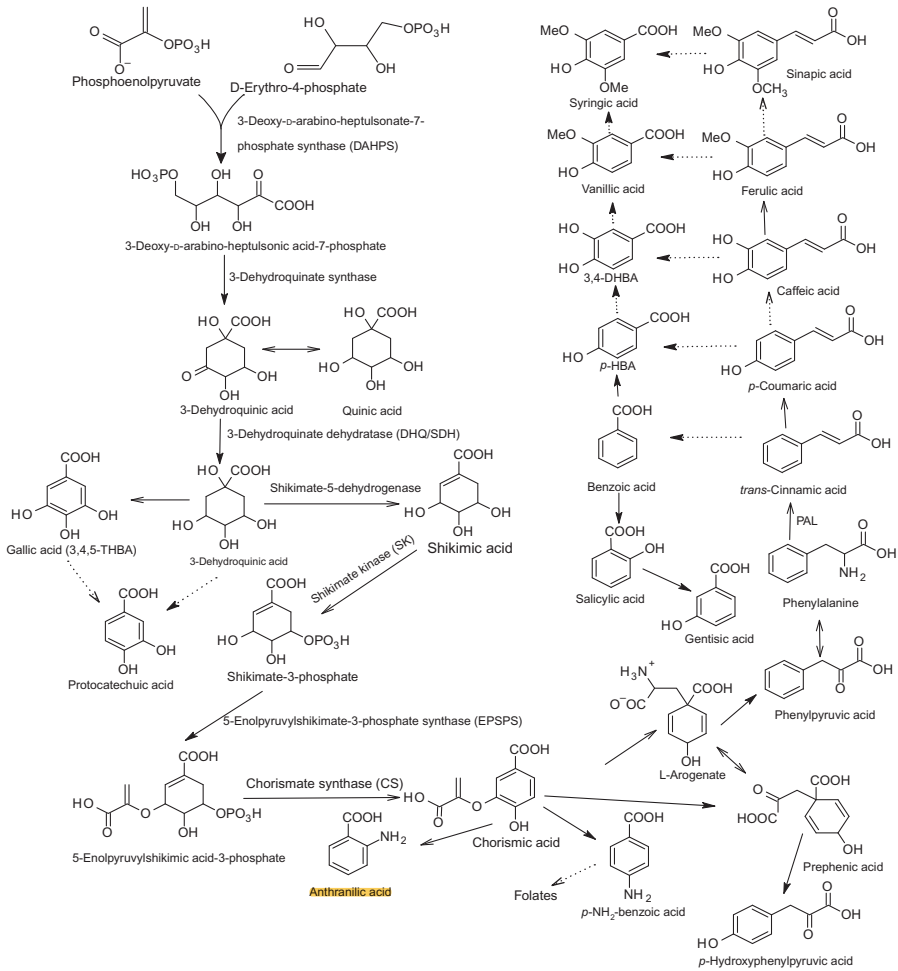


Figure 6.2 Biosynthetic pathways of some phenolic compounds.

Their condensation and cyclization lead to the formation of shikimic acid and end with the synthesis of chorismic acid (Figure 6.2). Active forms of these with coenzyme A (CoA) can access the main classes of phenolic compounds, quoting some transformations to acids of the benzoic acid series (gallic, protocatechuic, etc.) by β-oxidation. Gallic acid itself, in combination with simple sugars, leads to the hydrolyzable tannins (gallic and ellagic tannins), or, after the addition of a molecule of phosphoenolpyruvate and additional series of intermediate stages, followed by amination, gives rise to aromatic amino acids tyrosine (**21**) and phenylalanine (**27**), the starting point of the phenylpropanoid pathway [24,40].

6.2.2 The Phenylpropanoid Pathway

The phenylpropanoid pathway starts with the condensation of phenylalanine to cinnamate via the key enzyme phenylalanine ammonia lyase (PAL). The phenylpropanoid pathway is the precursor for several phenylpropanoids (C_6-C_3 compounds) such as cinnamic acid, caffeic acid, ferulic acid, sinapic acid, and esters of chlorogenic acid by esterification [24,41].

6.3 Simple Phenols, Phenolic Acids, and Related Ethers Isolated from African Medicinal Plants and Their Pharmacological Activities

6.3.1 Simple Phenols and Related Compounds

A survey of the literature and the PubMed, ScienceDirect, SciFinder, Scopus, and Web of Knowledge databases reveals the isolation of some new simple phenols and derivatives from different parts of some species of African plants. The root bark of *Lannea edulis* (Anacardiaceae), a plant used in the traditional medicine of Zimbabwe, was investigated, and the activity-guided isolation of the dichloromethane extract led to the purification of two new isoprenoid long-chain phenols (Figure 6.3), identified as cardonol 17 (**28**) and cardonol 13 (**29**). These two phenols were reported for their radical scavenging properties [42]. Phytochemical investigation of the methylene chloride extract of *Fagara zanthoxyloides* (Rutaceae) from Mali by Chaaib et al. [43] led to the isolation of 4′-(4″-hydroxy-3″-methylbutyloxy)-2-phenylethanol (**30**), a new phenylethanoid derivative, together with known simple phenols identified as dihydrocuspidiol (**31**) [44], cuspidiol (**32**) [43], *cis*-fagaramide (**33**), *trans*-fagaramide (**34**) [45], and 4″-(3″-methylbut-2″-enyloxy)-3-phenylpropanol (**35**) [46]. Dihydrocuspidiol (**31**), cuspidiol (**32**), and 4″-(3″-methylbut-2″-enyloxy)-3-phenylpropanol (**35**) showed potent antifungal activities against *Cladosporium cucumerinum*, with a minimum inhibitory quantity (MIQ) of 0.01, 0.1, and 0.1 μg, respectively, with miconazole used as the reference compound [43]. Cuspidiol (**32**) showed antifungal activity against *Candida albicans* and *Bacillus subtilis*, with an MIQ of 10 μg for both, with miconazole (0.1 μg) and chloramphenicol (1 μg), respectively, as reference compounds [42].

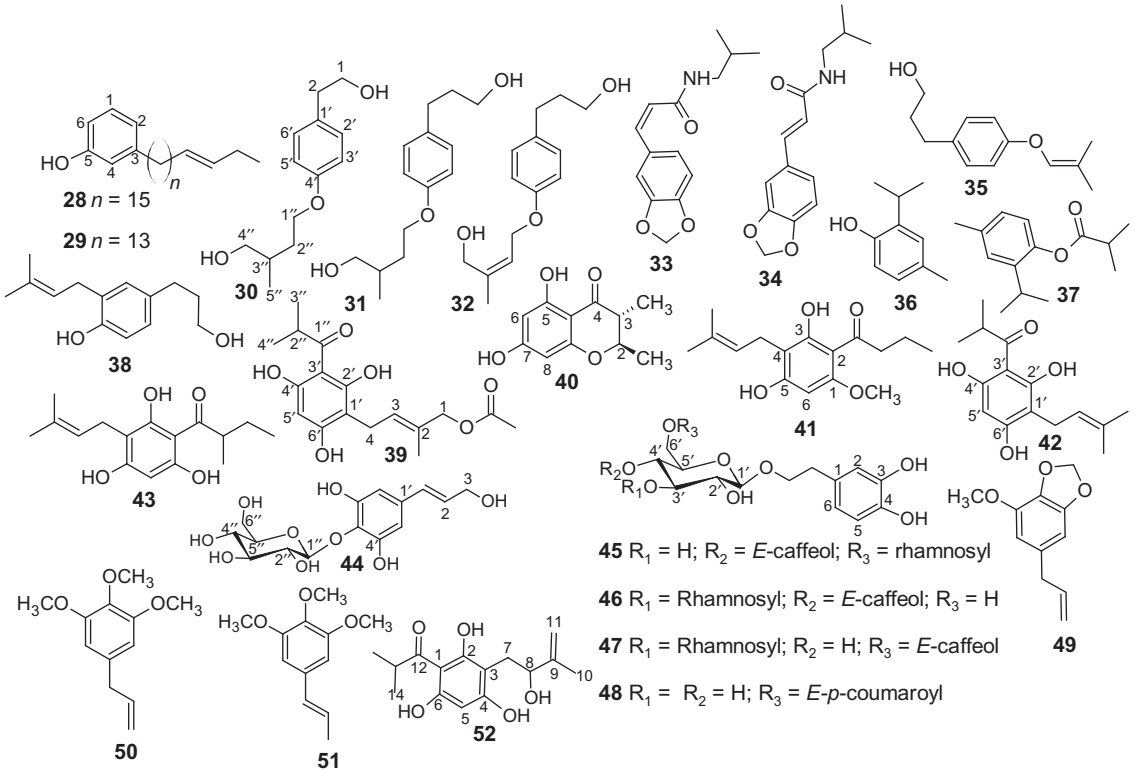


Figure 6.3 Simple phenols, phenolic acids, and related ethers from African medicinal plants: cardonol 17 (**28**); cardonol 13 (**29**); 4′-(4″-hydroxy-3″-methylbutyloxy)-2-phenylethanol (**30**); dihydrocuspidiol (**31**); cuspidiol (**32**); *cis*-fagaramide (**33**); *trans*-fagaramide (**34**); 4″-(3″-methylbut-2″-enyloxy)-3-phenylpropanol (**35**); 2-isopropyl-4-methylphenol (**36**); isobutyric acid 2-isopropyl-4-methylphenylester (**37**); zanthoxylol (**38**); 2-methyl-4-[2′,4′,6′-trihydroxy-3′-(2-methylpropanoyl)phenyl]but-2-enyl acetate (**39**); *trans*-(2*R*,3*R*)-5,7-dihydroxy-2,3-dimethyl-4-chromanone (**40**); 2-butanoyl-4-prenyl-1-methoxy phloroglucinol (**41**); 2-(2-methylpropanoyl)-4-prenylphloroglucinol (**42**); 2-(2-methyl-butanoyl)-4-prenylphloroglucinol (**43**); syringin (**44**); phenylethanoid P1(**45**); phenylethanoid P2 (**46**); phenylethanoid P3 (**47**); phenylethanoid P4 (**48**); myristicin (**49**); elemicin (**50**); isoelemicin (**51**); 2-methyl-1-[2,4,6-trihydroxy-3-(2-hydroxy-3-methyl-3-butenyl)phenyl]-1-propanone (**52**).

cis-Fagaramide (**33**) and *trans*-fagaramide (**34**) showed 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity [43]. One study reported the isolation and identification of essential oil from *Pulicaria odora* (Asteraceae), a Moroccan medicinal plant, and of two major phenol compounds, namely, 2-isopropyl-4-methylphenol (**36**) and isobutyric acid 2-isopropyl-4-methylphenylester (**37**), for the first time; these were examined *in vitro* for their antibacterial and antifungal activities. 2-Isopropyl-4-methylphenol demonstrated the most interesting inhibitory activity, with MIC ranging from 1 to 2 μg/mL (v/v) [47]. The phenol zanthoxylol (**38**), along with hydroxybenzoic acids, was isolated from extracts of *Zanthoxylum zanthoxyloides* (Rutaceae), a well-known local medicinal plant of Nigeria and Cameroon. Zanthoxylol demonstrated *in vitro* antisickling activity [48]. Many phloroglucinols were found from the aerial parts of *Helichrysum* spp. (Asteraceae) [49]. Intensive investigation of compounds in *Helichrysum caespititium* yielded caespitin, which showed interesting antimicrobial activities. An investigation of 27 other South African *Helichrysum* species yielded, in addition to known compounds, 21 new acylphloroglucinol derivatives [50–52]. A new acylated phloroglucinol, 2-methyl-4-[2′,4′,6′-trihydroxy-3′-(2-methylpropanoyl)phenyl]but-2-enyl acetate (**39**), with significant antimicrobial properties, was isolated from the shoots of the South African *H. caespititium* (Asteraceae) [53]. It shows growth inhibition against *Bacillus cereus*, *Bacillus pumilus*, *B. subtilis*, and *Micrococcus kristinae* at the very low concentration of 0.5 μg/mL, and against *Staphylococcus aureus* at 5.0 μg/mL [53]. Six other fungi tested, *Aspergillus flavus*, *A. niger*, *Cladosporium cladosporioides*, *C. cucumerinum*, *Cladosporium sphaerospermum*, and *Phytophthora capsici*, were similarly inhibited at low MICs of 1.0, 1.0, 1.0, 5.0, 0.5, and 1.0 μg/mL, respectively [53]. The investigation of *Helichrysum paronychioides* (Asteraceae), collected in southeastern Botswana, afforded four phloroglucinol derivatives, two of which were novel natural products, *trans*-(2*R*,3*R*)-5,7-dihydroxy-2,3-dimethyl-4-chromanone (**40**) and 2-butanoyl-4-prenyl-1-methoxy phloroglucinol (**41**), and two were known compounds, 2-(2-methylpropanoyl)-4-prenylphloroglucinol (**42**) and 2-(2-methyl-butanoyl)-4-prenylphloroglucinol (**43**) [54]. The four phloroglucinols were screened for antioxidant activity against Cu-induced LDL oxidation, of which 2-(2-methyl-butanoyl)-4-prenylphloroglucinol was found to be the most active at inhibiting LDL oxidation at all concentrations (0.5–10 μM), while the other three showed moderate to no activity [54]. Assay-guided fractionation of the Moroccan *Globularia alypum* (Globulariaceae) by Es-Safi et al. [55] led to the isolation of syringin (**44**) and four phenylethanoid derivatives (**45**–**48**) as the main constituents of the extract, and their antioxidant activity was determined, along with those of flavonoids and six iridoids. The results showed that activity toward the DPPH free radical was mainly due to the phenylethanoid constituents, which were more active than iridoids. Among the tested compounds, all phenylethanoid glycosides showed DPPH radical scavenging properties with an IC_{50} of 11.8, 12.1, 12.2, and 15.5 μmol/L, respectively, values better than butylated hydroxytoluene (BHT) (30.0 μmol/L) [55]. Phytochemical investigation of dichlomethane extract from the leaves of *Diplolophium buchanani* (Umbelliferae), growing in Malawi, yielded three new phenylpropanoids, namely, myristicin (**49**), elemicin (**50**), and isoelemicin (**51**), by means of centrifugal partition chromatography. Myristicin and a mixture of elemicin and isoelemicin showed antifungal activity against

C. cucumerinum, with MIC values of 20 and 8 μg, respectively, in thin-layer chromatography (TLC) bioassay [56]. From the dichloromethane extract of the flowers of *Helichrysum gymnocomum* (Asteraceae), one new acylphloroglucinol and a known acylphloroglucinol (**42**) were isolated for the first time [57]. The new acylphloroglucinol was characterized as 2-methyl-1-[2,4,6-trihydroxy-3-(2-hydroxy-3-methyl-3-butenyl) phenyl]-1-propanone (**52**). This new and the known acylphloroglucinols have shown antimicrobial activity, with MIC values below 64 μg/mL, against a selection of pathogens including *S. aureus*, with the known acylphloroglucinol having the highest sensitivity (6.3−45 μg/mL) for 8 of the 10 pathogens tested, including *S. aureus* (6.3 μg/mL) and the methicillin- and gentamycin-resistant strain of *S. aureus* (7.8 μg/mL) [57].

6.3.2 Phenolic Acids, Phenylacetic Acids, and Phenolic Aldehydes

The study of stem bark from *Terminalia superba* (Combretaceae), used in Cameroon folk medicine for the treatment of gastroenteritis, diabetes, female infertility, and abdominal pain, yielded two new ellagic acid derivatives (Figure 6.4): 3,4-*O*-methylellagic acid, 3′-*O*-β-D-xylopyranoside (**53**), and 4′-*O*-galloy-3,3′-di-*O*-methylellagic acid 4-*O*-β-D-xylopyranoside (**54**), which showed significant α-glucosidase inhibition activity, with IC_{50} of 7.95 and 21.21 μM, respectively [58]. These compounds also showed inhibitory activity using mononuclear cells (50.2% and 86.6%, respectively) at the lower concentration of 3.1 μM/mL tested [58]. An investigation of *Tylosema esculentum* (Fabaceae), collected in Botswana, yielded protocatechuic acid (**10**) and gallic acid (**12**). Both were assayed for DPPH radical scavenging activity and showed activities comparable to the standard (ascorbic acid). Gallic acid showed EC_{50} of 1.85 μg/mL after 30 min of reaction, compared to EC_{50} of 41.08 μg/mL for ascorbic acid, used as the reference compound [59]. Protocatechuic acid (**10**) was also isolated from *Ficus ovata* Vahl (Moraceae), collected in Cameroon, and when tested for antimicrobial activity, it prevented the growth of 80% of organisms tested [60]. An MIC value of 10 μg/mL was observed for protocatechuic acid (**10**) on *Microsporum audouinii* [60]. The phenolic acid derivative 3-hydroxy-4-methoxybenzoic acid (**55**) (isovanillic acid) was isolated from an extract of *Treculia obovoidea* (Moraceae) and tested for antimicrobial activity [61]. Vanillic acid (**11**), isolated from another Cameroonian medicinal plant, *Trilepisium madagascariense*, showed antimicrobial and antioxidant activity [62]. Vanillin and protocatechuic acid (**10**) were isolated from the roots of *Hydnora johannis* (Hydnoraceae), a Sudanese medicinal plant traditionally used for the treatment of dysentery, diarrhea, cholera, and swelling tonsillitis. These compounds showed low cytotoxicity against a selected human mouth epidermoid carcinoma cell line (KB) and the noncancer human fetal lung cell line (MRC-5) [63]. Other new phenolics, *N-p*-coumaroyl tyramine (**56**), 4-nerolidylcatechol (**57**), *N-trans*-feruloyltyramine (**58**), were isolated from *Piper umbellatum* (Piperaceae) collected in Cameroon [64]. *N-p*-Coumaroyl tyramine exhibited potent radical scavenging effects, with an IC_{50} value of 13.7 μM, while 4-nerolidylcatechol showed potent antifungal

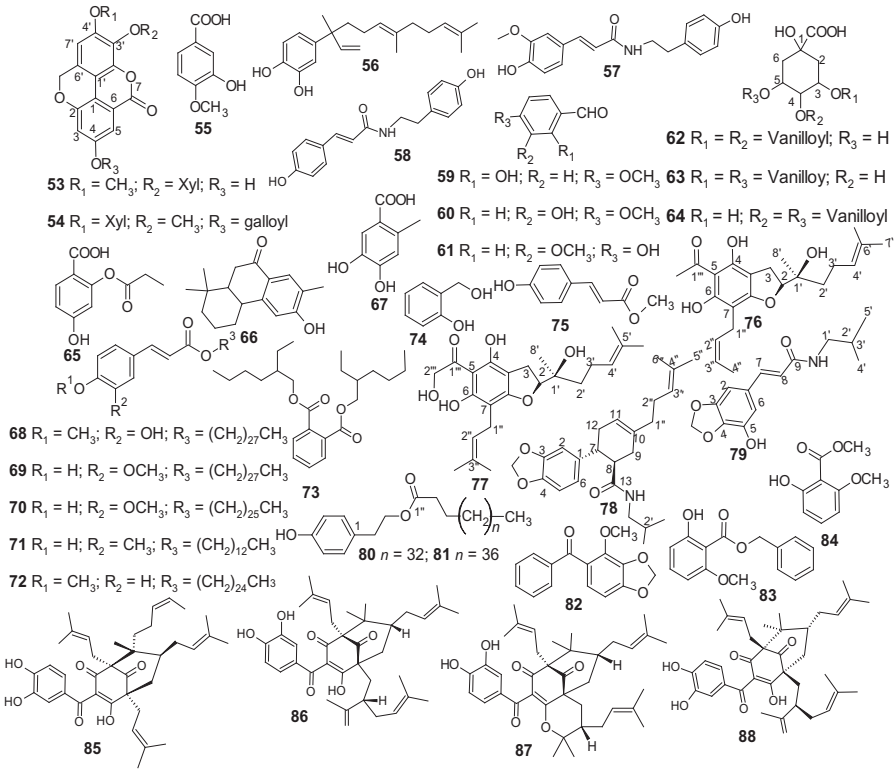


Figure 6.4 Acetophenones and benzophenones and derivatives from African medicinal plants: 3,4-*O*-methylellagic acid 3′-*O*-β-D-xylopyranoside (**53**); 4′-*O*-galloy-3,3′-di-*O*-methylellagic acid 4-*O*-β-D-xylopyranoside (**54**); 3-hydroxy-4-methoxybenzoic acid (**55**); *N*-*p*-coumaroyltyramine (**56**); 4-nerolidylcatechol (**57**); *N*-*trans*-feruloyltyramine (**58**); 2-hydroxy-4-methoxybenzaldehyde (**59**); 3-hydroxy-4-methoxybenzaldehyde (**60**); 4-hydroxy-3-methoxybenzaldehyde (**61**); 3,4-*O*-divanilloylquinic acid (**62**); 3,5-*O*-divanilloylquinic acid (**63**); 4,5-*O*-divanilloylquinic acid (**64**); 2-propionoxy-β-resorcylic acid (**65**); nimbiol (**66**); 2-methylprotocatechuic acid (**67**); erythrinasinate (**68**); erythrinasinate B (**69**); hexacosanyl (*E*)-ferulate (**70**); erythrinasinate C (**71**); erythrinasinate D (**72**); 1,2-benzenedicarboxylic acid bis-(2-ethylhexyl) ester (**73**); saligenin (**74**); 3-(4-hydroxyphenyl)methylpropenoate (**75**); 5-(ethan-1‴-one)-4,6-dihydroxy-7-(3″,3″-dimethylallyl)-2*S*-(1′*S*-hydroxy-1′,5′-dimethylhex-4′-enyl)-2,3-dihydrobenzofuran (**76**); 5-(2‴-hydroxyethan-1‴-one)-4,6-dihydroxy-7-(3″,3″-dimethylallyl)-2*S*-(1′*S*-hydroxy-1′,5′-dimethylhex-4′-enyl)-2,3-dihydrobenzofuran (**77**); heitziamide A (**78**); heitziamide B (**79**); heitziethanoid A (**80**); heitziethanoid B (**81**); (4-methoxy-benzo-[1,3]-dioxol-5-yl)-phenylmethanone (**82**); benzyl-2-hydroxy-6-methoxybenzoate (**83**); methyl-2-hydroxy-6-methoxybenzoate (**84**); guttiferone A (**85**); garcinol (**86**); cambogin (**87**); guttiferone F (**88**).

activity [64]. A bioassay-guided fractionation using mushroom tyrosinase (EC 1.14.18.1) yielded 2-hydroxy-4-methoxybenzaldehyde (**59**) and 3-hydroxy-4-methoxybenzaldehyde (**60**) from *Mondia whitei* Skeels (Asclepiadaceae) [65]. 2-Hydroxy-4-methoxybenzaldehyde was characterized as the principal tyrosinase inhibitor from three East African medicinal plants, the root of *M. whitei* (Hook) Skeels (Asclepiadaceae), the root of *Rhus vulgaris* Meikle (Anacardiaceae), and the bark of *Sclerocarya caffra* Sond (Anacardiaceae). It inhibited the oxidation of L-3,4-dihydroxyphenylalanine (L-DOPA) by mushroom tyrosinase (IC_{50} of 0.03 mM) [65]. 4-Hydroxy-3-methoxybenzaldehyde (**61**) and 4-methoxyphenol, isolated from the twigs of *Dorstenia turbinata* (Moraceae), showed moderate antibacterial activity, their effect being noted against Gram-positive and Gram-negative bacteria species [66]. In another study, 2-hydroxy-4-methoxybenzaldehyde (**59**) showed taste modifying properties [67]. Phytochemical analysis of *F. zanthoxyloides* (Rutaceae), collected in Burkina Faso, yielded three new isomeric divanilloylquinic acid derivatives: 3,4-*O*-divanilloylquinic acid (**62**), 3,5-*O*-divanilloylquinic acid (**63**), and 4,5-*O*-divanilloylquinic acid (**64**), named burkinabins A−C. These compounds play a useful role in sickle cell disease [68]. Phenolic acids, including the new compounds 2-propionoxy-β-resorcylic acid (**65**) and nimbiol (**66**) have been isolated from the Nigerian plant *Trichilia heudelotii* (Meliaceae) leaves, together with known compounds protocatechuic acid (**10**), 4-hydroxybenzoic acid, and 2-methylprotocatechuic acid (**67**). These compounds showed antimicrobial activity [69]. Cinnamate esters are also a class of simple phenolics reported in some African plants. Cinnamate esters have been reported in several African *Erythrina* (Fabaceae) genera. In 1986, a series of ester of cinnamates was isolated from Cameroonian *Erythrina senegalensis*, *Erythrina glauca*, and *Erythrina mildbaedii* [70]. Erythrinasinate (**68**) and erythrinasinate B (**69**) were isolated from *E. senegalensis*, and hexacosanyl (*E*)-ferulate (**70**) was reported from *Erythrina excelsa* [71]. One study reported the isolation of two new esters of ferulic and isoferulic acid, erythrinasinates C (**71**) and D (**72**), from the stem and root bark of *Erythrina sigmoidea* and *Erythrina eriotricha* [72], showing *in vitro* antimicrobial activities. These compounds exhibited central nervous system (CNS), cardiovascular, and metabolic activities [72]. Erythrinasinate B (**69**) showed antiarrhythmic effects (cardiovascular agent) as well as aquaretic properties [72]. Hexacosanyl (*E*)-ferulate (**70**) exhibited reflex depression, behavioral depression, muscle relaxation, cholinergic activation, antiarrhythmic, and aquaretic properties [72]. Erythrinasinate showed reflex depression, behavioral depression, muscle relaxant, cholinergic activation, anti-electric shock, antiarrhythmic, and aquaretic properties [70−72]. A bioguided study of the bark and leaves of *Salix subserrata* (Salicaceae) resulted in the isolation and characterization of 1,2-benzenedicarboxylic acid bis-(2-ethylhexyl) ester (**73**), saligenin (**74**), and catechol. 1,2-Benzenedicarboxylic acid bis-(2-ethylhexyl) ester and saligenin neither showed good activity against the alga *Chlorella fusca* nor antibacterial activity against the Gram-positive bacterium *Bacillus megaterium* or the Gram-negative bacterium *Escherichia coli* [73]. The methanol extract of the fresh Nigerian

plant *Gomphrena celosioides* (Amaranthaceae), commonly used in southern Nigeria for treatment of skin infections and as an abortifacient, yielded 3-(4-hydroxyphenyl) methylpropenoate (**75**), which showed antimicrobial activity against *Salmonella typhi*, *E. coli*, *Pseudomonas aeruginosa*, *B. subtilis*, and *S. aureus*, with inhibition diameter zones varying from 9 to 11 mm at 25 μg/mL [74].

6.3.3 Acetophenones, Benzophenones and their Derivatives

Two new prenylated acetophenones (Figure 6.5), harronin I [5-(ethan-1‴-one)-4,6-dihydroxy-7-(3″,3″-dimethylallyl)-2*S*-(1′*S*-hydroxy-1′,5′-dimethylhex-4′-enyl)-2,3-dihydrobenzofuran] (**76**) and harronin II [5-(2‴-hydroxyethan-1‴-one)-4,6-dihydroxy-7-(3″,3″-dimethylallyl)-2*S*-(1′*S*-hydroxy-1′,5′-dimethylhex-4′-enyl)-2,3-dihydrobenzofuran] (**77**), were isolated from the ripe berries of *Harrisonia abyssinica* (Simaroubaceae) [75]. Harronin I (**76**) showed an MIC of 5 μg/mL against *C. albicans* and 6 μg/mL against *B. cereus*, while harronin II (**77**) was not active (MIC > 100 μg/mL) [75]. Two novel phenylamides, heitziamide A (**78**) and heitziamide B (**79**), and two new phenylethanoids, heitziethanoid A (**80**) and heitziethanoid B (**81**), were isolated from the stem of *Fagara heitzii* (Rutaceae), a Cameroonian rainforest medicinal plant [76]. Heitziamides A (**78**) and B (**79**) were screened for their immunomodulatory potential. Both showed significant effects on the oxidative burst of whole blood, with an IC_{50} of 2.6 and 2.0 μM, respectively, compared to ibuprofen (IC_{50} of 12.1 μM), used as the control [76]. An investigation of the dichloromethane extract of Tanzanian *Securidaca longepedunculata* Fresen (Polygalaceae) yielded (4-methoxy-benzo-[1,3]-dioxol-5-yl)-phenylmethanone (**82**), together with other known compounds, benzyl-2-hydroxy-6-methoxybenzoate (**83**) and methyl-2-hydroxy-6-methoxybenzoate (**84**). (4-Methoxy-benzo-[1,3]-dioxol-5-yl)-phenylmethanone (**82**) exhibited antibacterial activity against *P. aeruginosa*, while benzyl-2-hydroxy-6-methoxybenzoate and methyl 2-hydroxy-6-methoxybenzoate were inactive against all tested bacteria and fungi [77]. Bioguided phytochemical investigation of Cameroonian medicinal plants *Allanblackia monticola* and *Symphonia globulifera* (Clusiaceae) led to the isolation of four known benzophenones: guttiferone A (**85**) from *S. globulifera* leaves, garcinol (**86**), cambogin (**87**), and guttiferone F (**88**) from *A. monticola* fruits (benzophenones are discussed in depth in Chapter 10). Guttiferones A (**84**) and F (**88**) showed particularly strong *in vitro* leishmanicidal activity, with IC_{50} values of 0.2 and 0.16 μM, respectively, comparable to that of the reference compound, miltefosine (0.46 μM) [78]. The four benzophenones showed potent anticholinesterase properties toward acetylcholinesterase (AChE) and butylcholinesterase (BChE). For AChE, the IC_{50} value (0.66 μM) of garcinol was almost equal to that of the reference compound galanthamine (0.50 μM) (Table 6.1). Furthermore, guttiferone A and guttiferone F, with IC_{50} values of 2.77 and 3.50 μM, respectively, were more active than galanthamine (IC_{50} of 8.5 μM) against BChE [78].

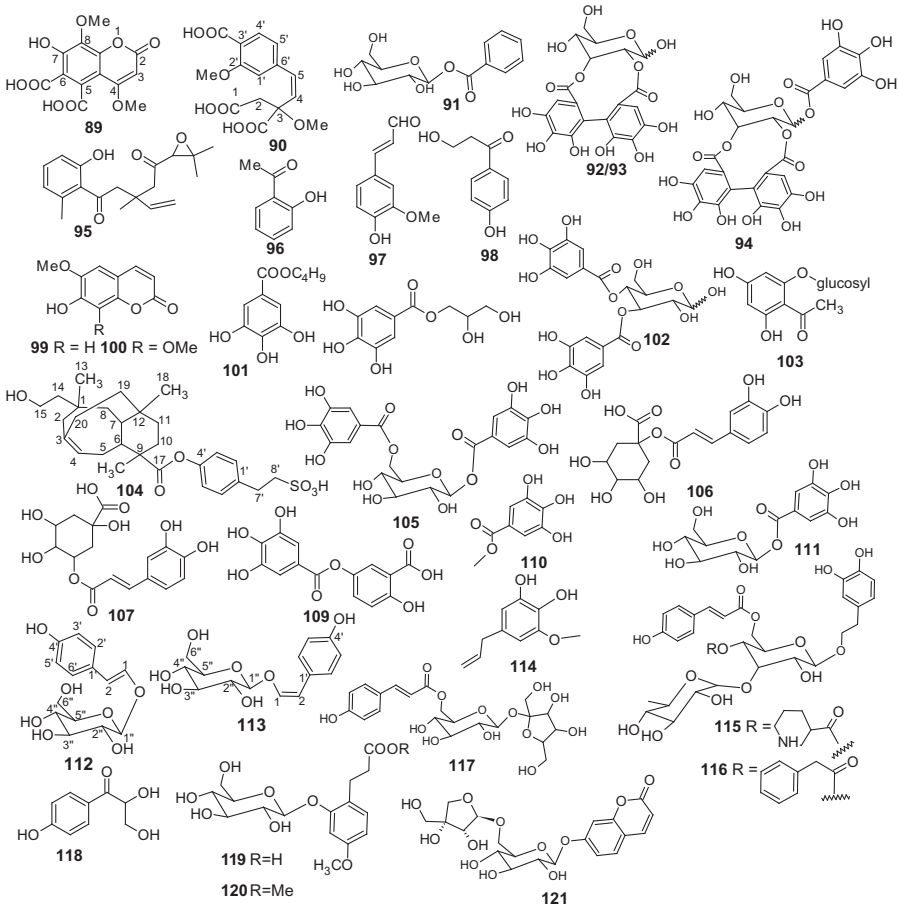


Figure 6.5 New simple phenols, phenolic acids, and related ethers isolated in African medicinal plants: 4,8-dimethoxy-7-hydroxy-2-oxo-2*H*-1-benzopyran-5,6-dicarboxylic acid (**89**); 2-(4-carboxy-3-methoxystyryl)-2-methoxysuccinic acid (**90**); β-glucogallin (**91**); 2,3-hexahydroxydiphenoyl-(α/β)-glucose (**92/93**); 1-galloyl-2,3-hexahydroxydiphenoyl-α-glucose (**94**); ethuliaconyzophenone (**95**); 2-hydroxyacetophenone (**96**); coniferaldehyde (**97**); 4-hydroxy-(3-hydroxypropionyl)-benzene (**98**); scopoletin (**99**); isofraxidin (**100**); gallic acid *n*-butyl ester (**101**); (α,β)-3,4-di-*O*-galloyl-glucopyranoside (**102**); 4,6-dihydroxy-2β-glucopyranosyloxyacetophenone (**103**); 1-*O*-galloylglycerol (**104**); reformin (**105**); 6′-*O*-galloylsalidroside (**106**); 1-caffeoylquinic acid (**107**); 5-caffeoylquinic acid (**109**); 2-hydroxy 5-[(3,4,5-trihydroxyphenyl)carbonyloxy] benzoic acid (**109**); methylgallate (**110**); 1-*O*-galloyl-β-D-glucose (**111**); *trans*-vaginoside (**112**); *cis*-vaginoside (**113**); 2-hydroxy-3-methoxy-5-(2-propenyl)phenol (**114**); 2-(3′,4′-dihydroxyphenyl) ethyl-3-*O*-α-L-rhamnopyranosyl-4-*O*-*p*-hydroxyphenylacetyl-6-*O*-caffeoyl-β-D-glucopyranoside (**115**); 2-(3′,4′-dihydroxyphenyl) ethyl-3-*O*-α-L-rhamnopyranosyl-4-*O*-piperidine-3-carboxylic acid-6-*O*-caffeoyl-β-D-glucopyranoside (**116**); 6-*p*-coumaroyl-sucrose (**117**); schweinfurthinol (**118**); 2-*O*-β-D-glucosyloxy-4-methoxybenzenepropanoic acid (**119/120**); adicardin (**121**).

Table 6.1 Biologically Active Simple Phenols and Related Compounds from African Medicinal Plants

Compounds	Class	Plants (Family)	Pharmacological Activities
Cardonol 17 (**28**); cardonol 13 (**29**)	Simple phenol	*L. edulis* (Anacardiaceae)	Radical scavenging [42]
4′-(4″-Hydroxy-3″-methylbutyloxy)-2-phenylethanol (**30**)	Phenylethanoid	*F. zanthoxyloides* (Rutaceae)	Antifungal; DPPH radical scavenging [43]
Dihydrocuspidiol (**31**); cuspidiol (**32**); *cis*-fagaramide (**33**); *trans*-fagaramide (**34**); 4″-(3″-methylbut-2″-enyloxy)-3-phenylpropanol (**35**)	Simple phenol		
2-Isopropyl-4-methylphenol (**36**); isobutyric acid 2-isopropyl-4-methylphenylester (**37**)	Simple phenol	*P. odora* (Asteraceae)	Antibacterial; antifungal [47]
Zanthoxylol (**38**)	Simple phenol	*Z. zanthoxyloides* (Rutaceae)	*In vitro* antisickling [48]
2-Methyl-4-[2′,4′,6′-trihydroxy-3′-(2-methylpropanoyl) phenyl]but-2-enyl acetate (**39**)	Phloroglucinol	*H. caespititium* (Asteraceae)	Antimicrobial [53]
trans-(2*R*,3*R*)-5,7-Dihydroxy-2,3-dimethyl-4-chromanone (**40**); 2-butanoyl-4-prenyl-1-methoxy phloroglucinol (**41**); 2-(2-methylpropanoyl)-4-prenylphloroglucinol (**42**); 2-(2-methyl-butanoyl)-4-prenylphloroglucinol (**43**)		*H. paronychioides* (Asteraceae)	Antioxidant [54]
Syringin (**44**); phenylethanoid P1 (**45**); phenylethanoid P2 (**46**); phenylethanoid P3 (**47**); phenylethanoid P4 (**48**)	Phenylethanoid	*G. alypum* (Globulariaceae)	DPPH radical scavenging [55]
Myristicin (**49**); elemicin (**50**); isoelemicin (**51**)	Phenylpropanoid	*D. buchanani* (Umbelliferae)	Antifungal [56]
2-Methyl-1-[2,4,6-trihydroxy-3-(2-hydroxy-3-methyl-3-butenyl)phenyl]-1-propanone (**52**)	Phloroglucinol	*H. gymnocomum* (Asteraceae)	Antimicrobial [57]
3,4-*O*-Methylellagic acid 3′-*O*-β-D-xylopyranoside (**53**); 4′-*O*-galloy-3,3′-di-*O*-methylellagic acid 4-*O*-β-D-xylopyranoside (**54**)	Phenolic acid	*T. superba* (Combretaceae)	α-Glucosidase inhibition [58]
Protocatechuic acid (**10**); gallic acid (**12**)	Phenolic acid	*T. esculentum* (Fabaceae); *F. ovata* (Moraceae)	DPPH radical scavenging [59]; antimicrobial [60]
3-Hydroxy-4-methoxybenzoic acid (**55**)	Phenolic acid	*T. obovoidea* (Moraceae)	Antimicrobial [61]
Vanillic acid (**11**); protocatechuic acid (**10**)	Phenolic acid	*T. madagascariense*; *H. johannis* (Hydnoraceae)	Antimicrobial, antioxidant [62]; cytotoxicity [63]

(*Continued*)

Table 6.1 (Continued)

Compounds	Class	Plants (Family)	Pharmacological Activities
N-p-Coumaroyl tyramine (**53**); 4-nerolidylcatechol (**57**); *N-trans*-feruloyltyramine (**58**)	Phenolamine	*P. umbellatum* (Piperaceae)	Radical scavenging; antifungal [64]
2-Hydroxy-4-methoxybenzaldehyde (**59**); 3-hydroxy-4-methoxybenzaldehyde (**60**)	Phenylaldehyde	*M. whitei* (Asclepiadaceae)	Tyrosinase inhibitor [65]
4-Hydroxy-3-methoxybenzaldehyde (**61**)	Phenylaldehyde	*D. turbinata* (Moraceae)	Antibacterial [66]; taste modifying [67]
Burkinabin A (**62**); burkinabin B (**63**); burkinabin C (**64**)	Phenolic acid	*F. zanthoxyloides* (Rutaceae)	Antisickling [68]
2-Propionoxy-β-resorcylic acid (**65**); nimbiol (**66**); protocatechuic acid (**10**); 4-hydroxybenzoic acid; 2-methylprotocatechuic acid (**67**)	Phenolic acid	*T. heudelotii* (Meliaceae)	Antimicrobial [69]
Erythrinasinate (**68**); erythrinasinate B (**69**) Hexacosanyl (*E*)-ferulate (**70**) Erythrinasinate C (**71**);erythrinasinate D (**72**)	Cinnamate	*E. senegalensis*; *E. excelsa*; *E. sigmoidea*; *E. eriotricha* (Fabaceae)	CNS, cardiovascular, muscle relaxation, cholinergic activation, antiarrhythmic, aquaretic properties; metabolic activities [70–72]
1,2-Enzenedicarboxylic acid bis-(2-ethylhexyl) ester (**73**); saligenin (**74**)	Phenolic acid	*S. subserrata* (Salicaceae)	Antifungal; antibacterial [73]
3-(4-Hydroxyphenyl)methylpropenoate (**75**)	Phenylacetate	*G. celosioides* (Amaranthaceae)	Antimicrobial [74]
Harronin I (**76**); harronin II (**77**)	Acetophenone	*H. abyssinica* (Simaroubaceae)	Antimicrobial [75]
Heitziamide A (**78**); heitziamide B (**79**)	Phenylamide	*F. heitzii* (Rutaceae)	Immunomodulatory [76]
Heitziethanoid A (**80**); heitziethanoid B (**81**)	Phenylethanoid		
(4-Methoxy-benzo-[1,3]-dioxol-5-yl)-phenylmethanone (**82**)	Phenylcetone	*S. longepedunculata* (Polygalaceae)	Antibacterial [77]
Garcinol (**86**); cambogin (**87**); guttiferone F (**88**) Guttiferone A (**85**)	Benzophenone	*A. monticola* (Clusiaceae) *S. globulifera* (Clusiaceae)	AChE, BChE inhibition; leishmanicidal [78]

AChE, antiacetylcholinesterase; BChE, antibutylcholinesterase; CNS, central nervous system.

6.4 New Simple Phenols, Phenolic Acids, and Related Ethers Isolated in African Medicinal Plants

Two new phenolic acids, 4,8-dimethoxy-7-hydroxy-2-oxo-2*H*-1-benzopyran-5,6-dicarboxylic acid (**89**) and 2-(4-carboxy-3-methoxystyryl)-2-methoxysuccinic acid (**90**), were isolated from the Egyptian *Sanguisorba minor* (Rosaceae) plant, together with known phenolics gallic acid, ellagic acid, β-glucogallin (**91**), 2,3-hexahydroxydiphenoyl-(α/β)-glucose (**92**, **93**), and 1-galloyl-2,3-hexahydroxydiphenoyl-α-glucose (**94**) with its β-isomer, were also characterized [79]. Reinvestigation of the aerial parts of the Egyptian *Ethulia conyzoides* (Asteraceae) yielded a new monoterpene acetophenone derivative named ethuliaconyzophenone (**95**) [80]. Chromatography of the extract of *Carissa edulis* (Apocynaceae), collected in Ghana, yielded aromatic compounds including 2-hydroxyacetophenone (**96**), vanillin, coniferaldehyde (**97**), 4-hydroxy-(3-hydroxypropionyl)-benzene (**98**), scopoletin (**99**), and isofraxidin (**100**) [81]. Investigation of *Pelargonium reniforme* (Geraniaceae), mainly distributed in coastal regions of Southern Africa, yielded the new gallic acid *n*-butyl ester (**101**), known compounds (α,β)-3,4-di-*O*-galloyl-glucopyranoside (**102**), 4,6-dihydroxy-2β-glucopyranosyloxyacetophenone (**103**), and 1-*O*-galloylglycerol (**104**), a new phenolic compound named reformin (**105**), and 6′-*O*-galloylsalidroside (**106**) [82]. Caffeic acid, 1-caffeoylquinic acid (**107**) and 5-caffeoylquinic acid (**108**) were identified from the leaves of a Tunisian *Morus* species by high-performance liquid chromatography with diode array detector (HPLC-DAD) and HPLC-mass spectrometry (HPLC-MS) [83]. Study of *Uapaca kirkiana* collected in Zimbabwe by Muchuweti et al. [84] yielded *p*-hydroxybenzoic acid in the peel and pulp fruit. The *p*-hydroxybenzoic acid was absent in the seed coat as well as in the embryo. However, the other six phenolic acids were not detected in the peel on the pulp. The seed coat contains ferulic acid, *p*-coumaric acid, and vanillic acid. The phenolic acids detected in embryo were caffeic acid, ferulic acid, *p*-coumaric acid, vanillic acid, and protocatechuic acid [84]. A new phenolic acid was identified and characterized as 2-hydroxyl-5-[(3,4,5-trihydroxyphenyl)carbonyloxy] benzoic acid (**109**) by HPLC-DAD and by HPLC-MS-MS from water extracts of *Delonix regia* (Caesalpiniaceae), together with gallic acid and protocatechuic acid [85]. Activity-guided fractionation of the methanolic extract of Egyptian *Acacia nilotica* pods resulted in the separation of eight phenolic compounds, including methyl gallate (**110**), gallic acid, 1-*O*-galloyl-β-D-glucose (**111**), 1,6-di-*O*-galloyl-β-D-glucose (**105**), digallic acid (**109**), and tannin compound derivatives [86]. Butanol extracts of the flowers of the Egyptian plant *Ononis vaginalis* Vahl. Symb (Fabaceae) yielded two new norphenylpropanoid glucosides, characterized as 1-β-D-glucopyranosyl-2-(4′-hydroxyphenyl) (*E*)-ethene (*trans*-vaginoside) (**112**) and 1-β-D-glucopyranosyl-2-(4′-hydroxyphenyl) (*Z*)-ethene (*cis*-vaginoside) (**113**) [87]. Studies performed on roots and aerial parts of *Bulbine capitata* (Asphodelaceae), an important medicinal plant widely used in Botswana, yielded a novel allyl-substituted pyrogallol derivative, 2-hydroxy-3-methoxy-5-(2-propenyl)phenol (**114**), along with other natural compounds [88]. Two other new natural compounds, characterized as

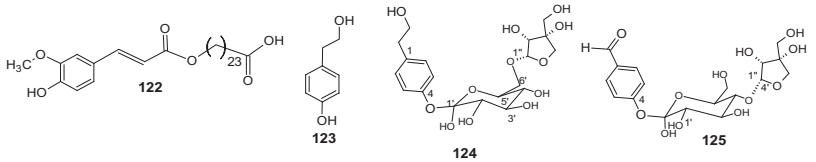
Table 6.2 New Phenolic Acids, Phenylacetic Acids, and Phenolic Aldehydes Isolated from African Plants

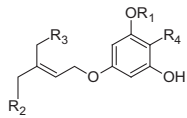
Compounds	Class	Plants	Area of Plant Collection	Plant Part	Physical Properties
4,8-Dimethoxy-7-hydroxy-2-oxo-2*H*-1-benzopyran-5,6-dicarboxylic acid (**89**); 2-(4-carboxy-3-methoxystyryl)-2-methoxysuccinic acid (**90**)	Phenolic acid	*S. minor* (Rosaceae)	Egypt [79]	Whole	–
Ethuliaconyzophenone (**95**)	Acetophenone	*E. conyzoides* (Asteraceae)	Egypt [80]	Aerial parts	$[\alpha]_D$ +32° (*c* 0.125, $CHC1_3$)
2-Hydroxyacetophenone (**96**)	Acetophenone	*C. edulis* (Apocynaceae)	Ghana [81]	Root bark	$[\alpha]_D$ +32° (*c* 0.125, $CHCl_3$)
Reformin (**105**); gallic acid *n*-butyl ester (**101**)	Phenyl ester	*P. reniforme* (Geraniaceae)	South Africa [82]	Aerial parts	$[\alpha]_D$ +33° (*c* 0.03, MeOH)
2-Hydroxy 5-[(3,4,5-trihydroxyphenyl) carbonyloxy] benzoic acid (**109**)	Phenolic acid	*D. regia* (Caesalpiniaceae)	Ivory Coast [85]	Petals	–
trans-Vaginoside (**112**); *cis*-vaginoside (**112**)	Phenylpropanoid	*O. vaginalis* (Fabaceae)	Egypt [87]	Flowers	–
2-Hydroxy-3-methoxy-5-(2-propenyl) phenol (**114**)	Pyrogallol	*B. capitata* (Asphodelaceae)	Botswana [88]	Roots and aerial parts	–
2-(3′,4′-Dihydroxyphenyl) ethyl-3-*O*-α-L-rhamnopyranosyl-4-*O*-*p*-hydroxyphenylacetyl-6-*O*-caffeoyl-β-D-glucopyranoside (**115**); 2-(3′,4′-dihydroxyphenyl) ethyl-3-*O*-α-L-rhamnopyranosyl-4-*O*-piperidine-3-carboxylic acid-6-*O*-caffeoyl-β-D-glucopyranoside (**116**)	Phenylpropanoid	*J. mimosifolia* (Bignoniaceae)	Egypt [89]	Stem bark	–
6-*p*-Coumaroyl-sucrose (**117**)	Phenylpropanoid	*K. pinnata* (Bignoniaceae)	Egypt [90]	Fruits	–
Schweinfurthinol (**118**)	Phenylpropanoid	*C. schweinfurthii* (Burseraceae)	Cameroon [91]	Seeds	mp 210−212°C$[\alpha]_D$ −56,7° (*c* 0.11, MeOH)
2-*O*-β-D-Glucosyloxy-4 methoxybenzenepropanoic acid (**119**)	Phenylpropanoid	*G. polycephala* (Thymelaeaceae)	Botswana [92]	Stem	–

2-(3′,4′-dihydroxyphenyl) ethyl-3-*O*-α-L-rhamnopyranosyl-4-*O*-*p*-hydroxyphenylacetyl-6-*O*-caffeoyl-β-D-glucopyranoside (**115**) and 2-(3′,4′-dihydroxyphenyl) ethyl-3-*O*-α-L-rhamnopyranosyl-4-*O*-piperidine-3-carboxylic acid-6-*O*-caffeoyl-β-D-glucopyranoside (**116**), were isolated from the stem bark of *Jacaranda mimosifolia* (Bignoniaceae) [89]. Further phytochemical investigation of the fruit of *Kigelia pinnata* (Bignoniaceae) yielded a new phenylpropanoid derivative, identified as 6-*p*-coumaroyl-sucrose (**117**), along with 10 known phenylpropanoid and phenylethanoid derivatives. The structures of the isolated compounds were elucidated using various techniques of NMR and mass spectral analysis [90]. The seeds of *Canarium schweinfurthii* (Burseraceae) yielded a new phenylpropanoid, schweinfurthinol (**118**), characterized as 1-(4-hydroxyphenyl)-2,3-dihydroxypropan-1-one [91], and two other new phenylpropanoid glucosides, 2-*O*-β-D-glucosyloxy-4-methoxybenzenepropanoic acid (**119**) and its methyl ester (**120**), together with syringin (**44**) and adicardin (**121**), were isolated from the stem of *Gnidia polycephala* (Thymeleaeceae) and characterized by physical and spectroscopic data (Table 6.2) [92].

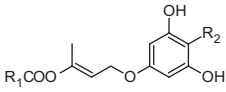
6.5 Other Simple Phenols, Phenolic Acids, and Related Ethers in African Medicinal Plants

Another chemical investigation of the Cameroonian plant *Autranella congolensis* led to the isolation (Figure 6.6) of 24-feruloytetracosanoic acid (**122**) [93]. Continued investigations into the phenolic content of the leaves and stems of *Cyclopia intermedia* yielded tyrosol (**123**), a methoxy analog, 2-[4-[*O*-α-apiofuranosyl-(1″→6′)-β-D-glucopyranosyloxy]phenyl]ethanol (**124**), and 4-[*O*-α-apiofuranosyl-(1″→2′)-β-D-glucopyranosyloxy]benzaldehyde (**125**) [94]. *p*-Hydroxybenzoic acid and phenylethanol esters were isolated from the stem bark of *Spathodea campanulata* [95]. A study of aqueous acetone extract of leaves from 10 Ethiopian browse plant species by HPLC and TLC by Mueller-Harvey et al. [96] allowed the characterization of gallic, ellagic, and chlorogenic acids. In the same study, *trans*- and *cis*-*p*-coumaric and *trans*-ferulic acid were identified after hydrolysis of browse leaves [97]. The large tribe *Inuleae* yielded acylphloroglucinols derivatives. The investigation of several South African species belonging to tribe *Inuleae*, including 27 *Helichrysum* species, namely, *Helichrysum asperum*, *Helichrysum monticola*, *Helichrysum gymnocomum*, *Helichrysum natalitium*, *Helichrysum bellum*, and *Leontonyx-arten*, using high-field NMR-yielded acylphloroglucinol derivatives (**126**–**157**) [98–101]. The hexane-soluble fraction of the methanolic extract of stem bark of *Harungana madagascariensis* (Hypericaceae) yielded methyl-3-formyl-2,4-dihydroxy-6-methylbenzoate (**158**), together with new anthranoids [102]. Phytochemical study of the leaves and twigs of *Dorstenia picta* and the stem bark of *Newbouldia laevis*, two Cameroonian medicinal plants, afforded naringeninic acid (**159**) and 4-(4-hydroxyphenyl)ethyl tricontanoate (**160**), respectively [103]. Further phytochemical investigation of the fruits of *K. pinnata* (Bignoniaceae) yielded 10 known phenylpropanoid and phenylethanoid derivatives (**161**–**170**).

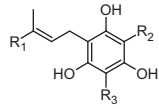




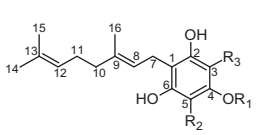
	126	127	128	129	130	131	132	133	134	135	136	137	138
R_1	H	H	H	H	H	H	H	H	H	H	H	H	H
R_2	H	OH	H	OH	OAc	OH	H	Prenyl	OH	OAc	H	OH	OAc
R_3	H	H	H	H	H	OH	H	H	H	H	H	H	H
R_4	PhCO	PhCO	*n*Bu	*n*Bu	*n*Bu	*n*Bu	*i*Bu	*i*Bu	*i*Bu	*i*Bu	MeBu	MeBu	MeBu

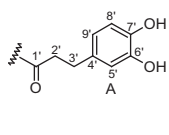


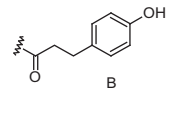
	139	140	141	142	143
R_1	H	H	H	**Me**	**Me**
R_2	*n*Bu	*i*Bu	PhCO	COPh	*i*Bu



	144	145	146	147	148	149	150	151
R_1	Me	Me	Me	Me	Me	CH_2OAc	CH_2OAc	Me
R_2	*n*Bu	*i*Bu	MeBu	PhCO	Ac	*n*Bu	*i*Bu	PhCO
R_3	H	H	H	H	H	H	H	Prenyl







	152	153	154	155	156	157
R_1	H	H	H	**Me**	H	**Me**
R_2	H	H	H	H	OH	H

Figure 6.6 Other simple phenols, phenolic acids, and related ethers in African medicinal plants: 24-feruloytetracosanoic acid (**122**); tyrosol (**123**); 2-[4-[*O*-α-apiofuranosyl-(1″→6′)-β-D-glucopyranosyloxy]phenyl]ethanol (**124**); 4-[*O*-α-apiofuranosyl-(1″→2′)-β-D-glucopyranosyloxy]benzaldehyde (**125**); methyl-3-formyl-2,4-dihydroxy-6-methylbenzoate (**158**); naringeninic acid (**159**); 4-(4-hydroxyphenyl)ethyl tricontanoate (**160**); darendoside A (**161**); 6-*O*-caffeol-β-D-fructofuranoside-(2→1)-α-D-glucopyranoside (**162**); 2-(3-hydroxy-4-methoxyphenol)ethyl *O*-α-L-rhamnopyranosyl-(1→3)-[β-D-glucopyranosyl-(1→6)]-(4-*O*-feruloyl)-β-D-glucopyranoside (**163**); decaffeoylacteoside (**164**); acteoside (**165**); isoacteoside (**166**); jionoside (**167**); echinacoside (**168**); 6-caffeoylglucose (**169**); 6-feruloylsucrose (**170**).

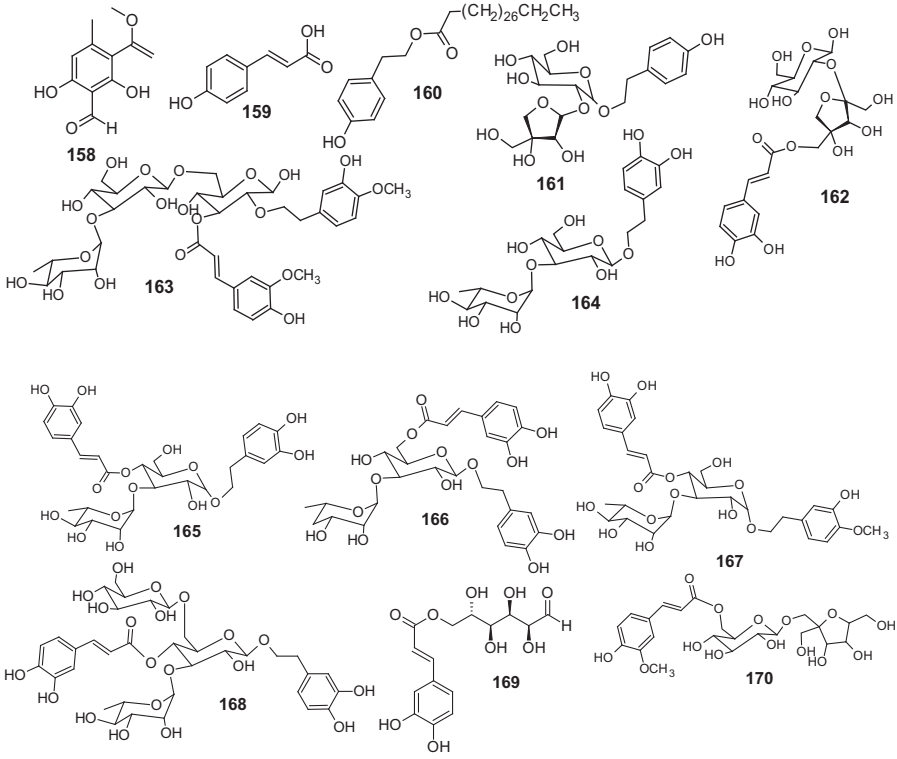


Figure 6.6 (Continued)

The structures of the isolated compounds were elucidated using various techniques of NMR and mass spectral analysis [90].

6.6 Conclusions

The present chapter presents an overview of simple phenols isolated from African plants. When necessary, an overview of phenylpropanoids, phenylethanoids, quinines, and anthranoids was provided. The present chapter shows the richness of African plants as sources of simple phenolic compounds with potent bioactivity.

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