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Review article

Chemical constituents and their biological activities from Taunggyi (Shan state) medicinal plants

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ABSTRACT

Medicinal plants are essential aspects of readily available primary healthcare remedies. Phytochemical constituents of medicinal plants cover a broad variety of chemical fields to explore medicines. This review highlights selected empirical data on traditional uses, phytochemistry, and pharmacological properties of Taunggyi medicinal plants, *Andrographis paniculata*, *Physalis peruviana*, and *Cassia fistula*. Historically, these plants have been used for many infections and diseases in Taunggyi. More than 361 chemical compounds have been isolated and identified from the selected plants. Some of the chemical constituents have substantial pharmacological properties. It is clear that these herbs have significant potential for useful natural supplements in many contemporary diseases. Thus, the aim of this review compiles an ethnobotanical survey and documentation of medicinal plants in Taunggyi (Myanmar). This review will also inspire Myanmar researcher's to further investigate the potential of these plants in their future work into new compound and new drugs.

1. Introduction

Throughout the history of human civilization, medicinal plants also played a significant part. Medicinal plants are used as a source of medication, and many modern drugs are made of these plants as a filled supply of traditional products [1, 2, 3, 4]. Natural ingredients derived from medicinal plants, which have their therapeutic potential, natural product-based medicines, and the application to the healthcare companies [5, 6, 7]. Such compounds have adjusted numerous physiological transforms in humans, and have furnished to the development of health. Natural products are an essential source in pharmaceutical enlargement, and are much more triumphant than artificially designed compounds [5, 8, 9, 10]. A lot of research attempted with advanced bioassays, and bioassay guided fractionation to find the biologically active compounds

of medicinal plants. Because of the researchers' enthusiastic efforts, many effective medicines have been produced from herbal plants [11].

Shan State is largely rural, with only three cities of significant size: Lashio, Kengtung, and the capital Taunggyi. It expands to China to the north, Laos to the east, and Thailand to the south, and five administrative divisions of Myanmar in the west. Taunggyi is 150.7 km north east of the nation's capital Naypyitaw. Taunggyi is the fifth largest city of Myanmar. Taunggyi has a humid subtropical climate. The climate usually comprises three seasons: the hot summer, the rainy monsoon, and the cold winter. There are 8 ethnic groups in Taunggyi, and almost every group has its own traditional medical knowledge and experiences. A lot of medicinal plants found in Taunggyi. Thus, this paper discusses the traditional uses and experimental studies of some plants, including *Andrographis paniculata*, *Physalis peruviana*, and *Cassia fistula*, used for natural remedies in Taunggyi.

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2. *Andrographis paniculata* (Burm.f.) Nees

47	Kingdom	Plantae
	Order	Lamiales
	Family	Acanthaceae
	Genus	<i>Andrographis</i>
	Species	<i>A. paniculata</i>
	English name	King of bitter
	Myanmar name	Say-khar

A. paniculata grows as an erect herb about 30–110 cm in height, with the dark green slender stem and the small flower. The flowers produce from September to December. The fruit is about 2 cm long and few millimeters broad. It is mainly found in America, south western Nigeria, Bangladesh, Pakistan, India, China, Hong Kong, Malaysia, Indonesia, Thailand, Brunei, Taunggyi (Myanmar), and the Philippines [12, 13]. In Taunggyi, dried powder of this plant used for diabetes, malaria, cough, and hypertension.

2.1. Chemical constituents

A total of 135 compounds, including 40 flavonoids, 82 terpenes (diterpene glucoside, diterpenoids, diterpenes dimer, and triterpenoid), 3 steroids, and 10 other compounds were isolated and identified from *A. paniculata* by chromatographic methods. Most have been studies for different biological activities [14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49]. The chemical structures of the isolated compounds from *A. paniculata* are shown in Figures 1, 2, and 3 and Figure S1. The list of compounds name and their biological activities are presented in Table S1, as well as their structure classification.

2.1.1. Flavonoids

Forty flavonoids (1–40) were identified from the roots, aerial parts, and the whole plant of *A. paniculata* (Figure 1) [14, 17, 18, 20, 21, 22, 26, 28, 29, 31, 32, 37, 41, 44, 45, 48]. Some isolated compounds were evaluated for their biological activities. For example, anti-HIV and cytotoxic activities of compounds 3 and 11 were reported by Reddy et al., 2005 [22]. In addition, compounds 3, 24, and 25 displayed antiplatelet aggregation activities [29]. Chao et al., 2010 [31], reported anti-inflammatory effects not only on NF- κ B-dependent luciferase activity but also on its downstream inflammatory mediators (TNF- α , IL-6, MIP-2, and NO). Compounds 3 and 11 showed the ability to inhibit NF- κ B transcriptional activity with IC₅₀ values of 6.1, and 6.7 μ g/mL. Chel et al., 2014 [41], evaluated antiproliferative activity of compounds 1, 3, 5, 7, 8, 11, 19, 24, and 28–32, using human leukemia HL-60 cell with adriamycin as a positive control. The result revealed that compound 30 displayed significant activity with IC₅₀ value of 3.5 μ M. Compounds 1, 3, 24, and 31 exhibited moderate activities with the IC₅₀ values in the range of 10–20 μ M. Moreover, compounds 1 (IC₅₀ 0.10 mM), 3 (IC₅₀ 0.05 mM), 11 (IC₅₀ 0.15 mM), and 16 (IC₅₀ 0.10 mM) demonstrated moderate cytotoxic activity against Jurkat cell line. Preferential cytotoxicity revealed that compound 17 (IC₅₀ 74.9 and 74.1 μ M) displayed weak activity on PANC-1 and PSN-1 (Human pancreatic cancer) cell lines [44].

2.1.2. Terpenes

Eighty-two terpenes (41–122), including diterpenes glycoside, terpenoids, diterpenes dimer, and triterpenoids have been isolated from the leaves, roots, aerial parts, and the whole plant of *A. paniculata* (Figure S1) [15, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 42, 43, 44, 45, 46, 47, 48, 49]. Some of these were evaluated for their biological activities. For example, Matsuda et al., 1994 [19], evaluated phagocytosis activity of compounds 41–50, and 52–58, using M1 (mouse myeloid leukemia) cells. According to the results, compounds 42, 44, and 45 have phagocytosis ratio of more than 30 % at the concentration of 5×10^{-6} M. The diterpene dimers (54–56) have more potent phagocytosis activity than that of diterpenes (42, and 44–50). Moreover,

diterpene glucosides (41, 43, and 52–54) have low activities of phagocytosis inducing and growth inhibition. Reddy et al., 2005 [22], evaluated anti-HIV and cytotoxic activity of compound 41, 51, and 60, using azidothymidine (AZT, as a positive control for anti-HIV, EC₅₀ = 0.02 5 μ g/mL) and etoposide (as a positive control for cytotoxicity, LD₅₀ = 5 μ g/mL). Compounds 41 and 51 have potential anti-HIV activity with EC₅₀ values of 49.0 and 56.8 μ g/mL, but compound 60 has no activity. However, compound 60 was very cytotoxic than the other compounds with LD₅₀ = 4.63 μ g/mL. Shen et al., 2006 [23], evaluated antibacterial activity of compounds 42, 43, 45–53, 56, 57, 61, 62, and 64–71 against *Bacillus subtilis*, *Staphylococcus aureus*, *Escherichia coli*, *Micrococcus luteus*, *Sarcina lutes*, *Candida albicans*, *Candida sake*, and *Aspergillus niger* using a disk diffusion assay. Compound 45, 50, 51, and 61 inhibited the activities with clear zones inhibition with a diameter of 7–8 mm at the minimal concentration (10 μ g/mL) used. Li et al., 2007 [26], evaluated cytotoxic activity of compounds 42, 45, 51, 53, and 72 against the oral epidermoid carcinoma KB cell lines. Compounds 42 and 45 displayed cytotoxic activities with ED₅₀ values of 6.5 and 5.1 μ g/mL. The others compounds have no significant cytotoxicity with both ED₅₀ values over 20 mg/mL. Chen et al., 2008 [27], evaluated antiproliferative activity of compounds 42, 43, 45, 46, 51, 53, 73–78, and 82–87, using human leukemia HL-60 cells with Adriamycin as a positive control. The most active compounds with GI₅₀ values of 9.33 and 6.30 μ M were 42 and 45, while compounds 83 (GI₅₀ 26.36 μ M), 84 (GI₅₀ 20.41 μ M), 85 (GI₅₀ 22.42 μ M), 86 (GI₅₀ 28.81 μ M), and 87 (GI₅₀ 24.95 μ M) displayed weak cytotoxic activities. Wu et al., 2008 [29], also reported antiplatelet aggregatory and vasorelaxing activities of compounds 41, 45, 47, 51 and 53. Geethangili et al., 2008 [28], evaluated the cytotoxicity of compounds 42, 45, 51, and 113, using MTT assay, with Jurkat (human lymphocytic cancer cell line), PC-3 (human prostate cancer cell line), HepG2 (human hepatoma cancer line), Colon 205 (human colonic cancer line), and normal cell PBMCs (peripheral blood mononuclear cells). The results revealed that compounds 113 (IC₅₀ 0.05, 0.07, and 0.05 mM) and 45 (IC₅₀ 0.10, 0.15, and 0.15 mM) displayed moderate cytotoxic activity on Jurkat, PC3 and Colon 205, while compound 51 (IC₅₀ 0.10 and 0.15 mM) showed moderate activity on Jurkat and Colon 205. Compound 42 (IC₅₀ 0.05 mM) possess only moderate activity on Colon 205 (IC₅₀ 0.05mM). Moreover, compound 113 inhibited exclusively cell cycle progression at G0/G1, while compounds 45 and 51 inhibited G2/M phase of the Jurkat cell line. Chao et al., 2010 [31], noted that compounds 113 and 114 displayed significant anti-inflammatory activities with IC₅₀ values of 2.0 and 4.4 μ g/mL. In another study, Xu et al., 2012 [39], reported that compounds 96–100 exhibited no significant antibacterial activity using microtitre plate both dilution method. Compounds 43, 46, 49, 51, and 53 have no significant cardiovascular effects [31]. Moreover, Wang et al., 2014 [43], documented that the weak antiviral activity of compounds 43 (IC₅₀ 1.5 μ g/mL) and 103 (IC₅₀ 30 μ g/mL), using respiratory syncytial virus (RSV) assay with ribavirin (IC₅₀ 1.5 μ g/mL) as a positive control. Additionally, Lee et al., 2015 [44], noted that compound 51 (IC₅₀ 10.0 and 9.27 μ M) exhibited potent preferential cytotoxic activity against PANC-1 and PSN-1 cells, whereas compound 61 (IC₅₀ 46.0 and 43.9 μ M) has weak activity. The mechanism of cell death induced by compound 51 in PANC-1 and PSN-1 cell using microscopical observation, EB/AO double staining, and flow cytometry were also studied in the same report. Compounds 108 and 109 displayed potential anti-inflammatory activities in vitro and in vivo [47]. Furthermore, Hanh et al., 2020 [48], documented that compound 63 (IC₅₀ 31.8, 43.5, 37.9, 45.9, and 42.1 μ M) showed not only the cytotoxic activities toward five human cancer cell lines (LNCaP, HepG2, KB, MCF7, and SK-Mel2), but also inhibited the overproduction of NO (nitric oxide) in lipopolysaccharide (LPS)-stimulated RAW264.7 macrophages (IC₅₀ 13.4 mM). Additionally, compounds 119 (IC₅₀ 40.4 and 58.6 μ M) has weak cytotoxic activity against PANC-1 and PSN-1 cell. Wen et al., 2020 [49], found that the anticomplement activity of compounds 1, 43, 46, 50–54, 67–68, 70–71, 80, 94, and 115–118 with the CH₅₀ and AP₅₀ values of 23.1–638.3 μ g/mL and 54.2–603.9 μ g/mL.

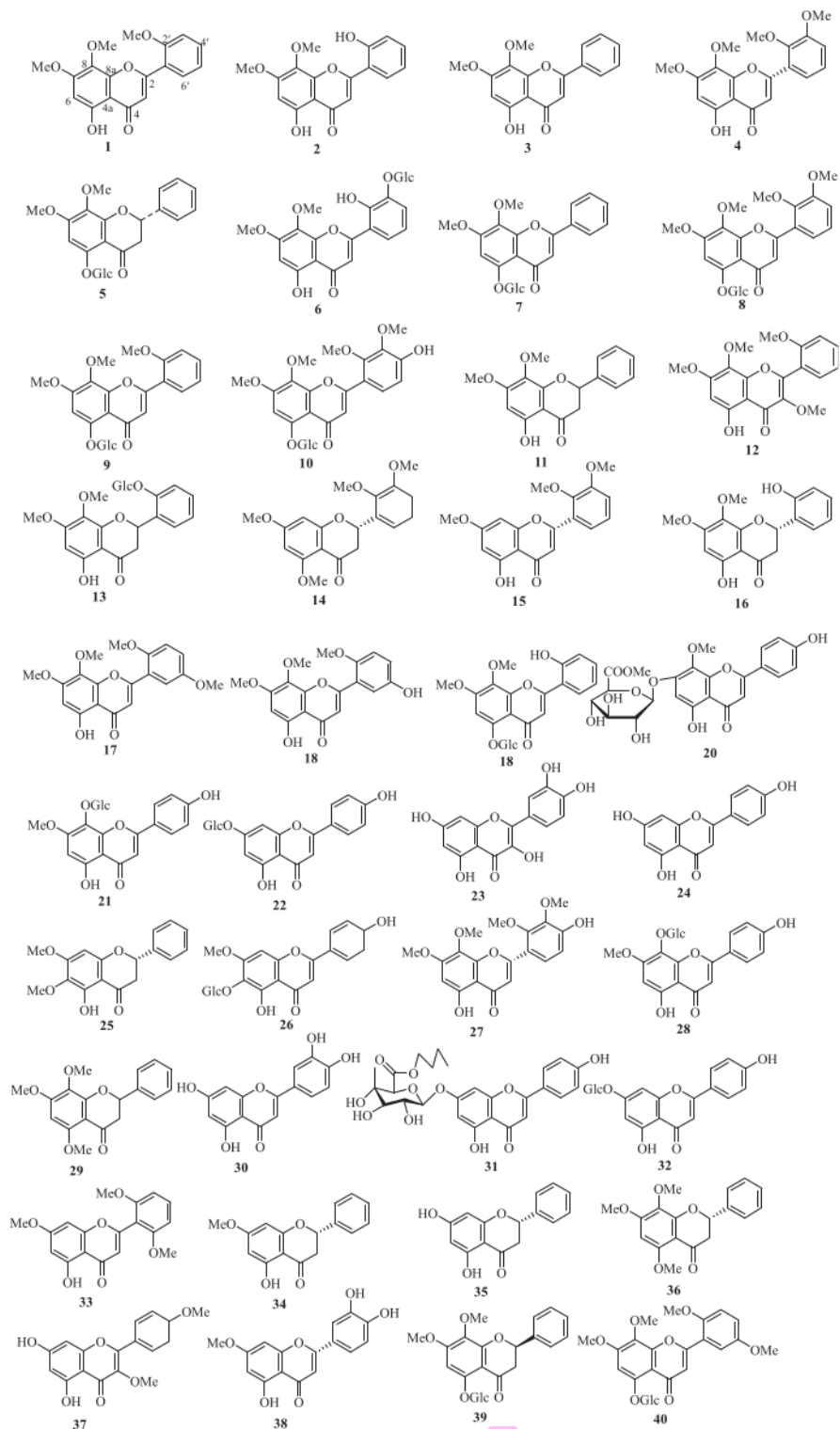


Figure 1. The structure of flavonoids (1–40) isolated from *A. paniculata*.

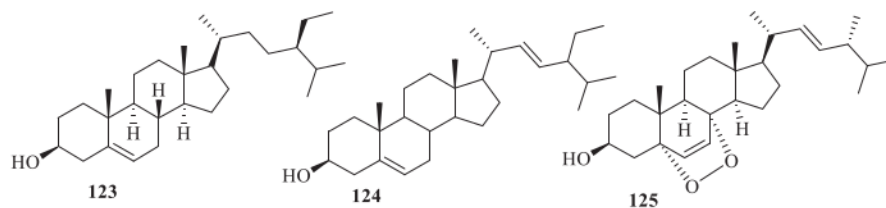


Figure 2. The structure of steroids (123–125) isolated from *A. paniculata*.

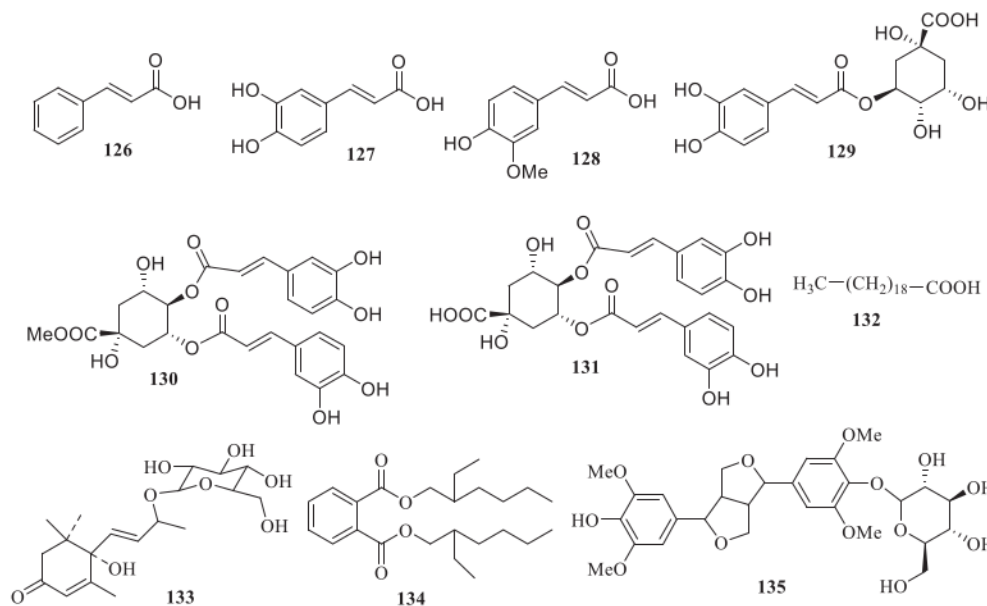


Figure 3. The structure of other compounds (126–135) isolated from *A. paniculata*.

2.1.3. Steroids

Three steroids (123–125) were isolated from the whole plant, aerial part, and leaves of *A. paniculata* (Figure 2). Compounds (123 + 124) and 125 displayed the significant activity to inhibit NF- κ B transcriptional activity with IC_{50} values of 5.2 and 4.7 μ g/mL. Compounds 125 (IC_{50} 60.5 and 79.2 μ M) has weak cytotoxic activity against PANC-1 and PSN1-cell [21, 31, 44].

2.1.4. Other compounds

Other compounds (126–135) were isolated from the leaves, aerial parts, and whole part of *A. paniculata* (Figure 3) [21,29,37–38,44–45].

3. *Physalis peruviana* (L.)

Kingdom Plantae
Order Solanales
Family Solanaceae
Genus *Physalis*
Species *P. peruviana*

English name Cape gooseberry, goldenberry, and physalis
Myanmar name Bout-tee

P. peruviana is a perennial evergreen plant that produces a group of branched stems. It can expand by 1.0–1.5 m without guidance, but it may reach 2.0 m high with trimmed and guided. Leaves are soft, simple, alternate, and heart-shaped with lengths between 5 and 15 cm and widths from 4 and 10 cm. Leaves turn yellow and collapse after the fruit

maturation. The fruit is a globose berry, yellowish in color, around 12.5–25.0 mm, with several yellowish seeds [50, 51, 52]. In Taunggyi, this plant is locally used for antidiabetic and antihypertension.

3.1. Chemical constituents

A total of 106 compounds, including 76 withanolides, 5 flavonoids, 2 alkaloids, 14 sucrose ester, and 9 other compounds were isolated and identified from *P. peruviana* by chromatographic methods. Most have been studied for different biological activities [53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83]. The chemical structures of the isolated compounds from *A. paniculata* are shown in Figures 4, 5, 6, and 7 and Figure S2. The list of compounds name and their biological activities are presented in Table S2, as well as their structure classification.

3.1.1. Withanolides

In the plant of *P. peruviana*, withanolides are prominent components. A total of 76 withanolides and a triterpene (136–211) have been isolated from the roots, leaves, calyces, whole plant, fruits, and aerial parts of *P. peruviana* (Figure S2) [54–61,63–73,78,80,83]. Some isolated compounds displayed significant biological activities. For example, compounds 142, 172, 174, 176, and 191 (IC_{50} 0.04, 2.1, 1.1, 2.1, and 0.06 μ M) displayed the NF- κ B activity with stably-transfected NF- κ B Luc-293 human embryonic kidney cells induced by TNF- α . Compounds 142, 154, and 191 also possessed NO inhibitory activity against lipopolysaccharide

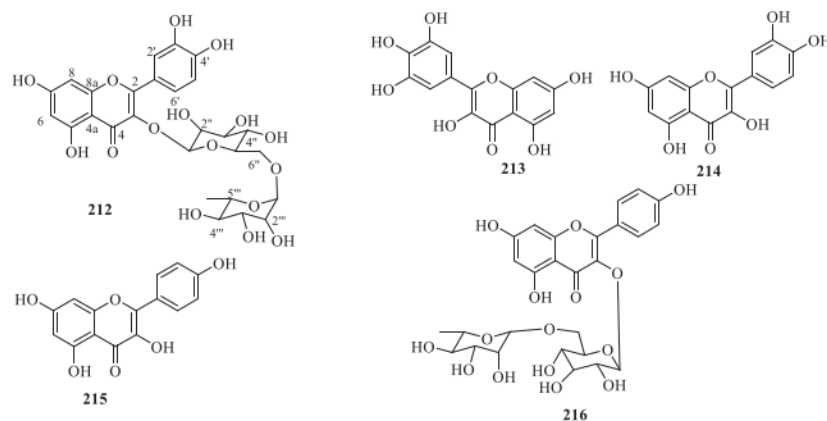


Figure 4. The structure of flavonoids (212–216) isolated from *P. peruviana*.



Figure 5. The structure of alkaloids (217–218) isolated from *P. peruviana*.

41 (LPS)-induced NO (nitric oxide) release with IC_{50} values of 0.32, 2.4, and 2.3 μ M. In addition, no significant cytotoxicity has been observed at the concentration of 50 μ M. Antiproliferative activity of compound 142 was also observed with the HT-29 human colorectal cancer cell line [78, 79]. Ergostanoid lactone, perulactone 3-*O*- β -*D*-glucopyranoside (205) reduces the growth of *Helicoverpa zea* larvae to 50% of control size at a dietary concentration of 150 mg/kg [61]. Moreover, compounds 141 and 142 were obviously cytotoxic at concentration $>10^{-5}$ M, but there were no specific agonistic or antagonistic effects of either compound [63]. Cirigliano et al., 2008 [69], studied the biological effects of *P. peruviana* extract and its major withanolides, 4 β -hydroxywithanolide E (140) and withanolide E (142) against *Ceratitis capitata* Wiedemann (Diptera: Tephritidae). According to the results, *P. peruviana* could not only provide edible fruits but could be a source of natural insecticides. Lan et al., 2009 [71], evaluated cytotoxic activity of fractions and compounds 139, 140, 142, 152, 156, 167–171, 191, 192, 198, 201, and 227 isolated from the aerial parts of *P. peruviana*, using MTT assay against lung (A549), breast (MEA-MB-231 and MCF7), and liver (hepG2 and 3B) cancer cell lines, with Doxorubicin as a positive control. The results revealed that the MeOH/water fraction displayed inhibitory activity against A549, MDA-MB-231, and HepG2 cells ($IC_{50} < 20$ mg/mL). Compounds 139, 140, 142, and 167 exhibited potent cytotoxic activity against lung (A549), breast (MEA-MB-231 and MCF7), and liver (HepG2 and Hep 3B) cancer cell lines. Xu et al., 2017 [80], studied the cytotoxic activity of compounds (140, 142–151, 162, 164, 167, 173, 175, 181–185, 192, 194, and 199–200) isolated from aerial parts of *P. peruviana* against a panel of tumor cell lines, androgen-sensitive human prostate adenocarcinoma (LNCaP), androgen-resistant human prostate adenocarcinoma (22Rv1), human renal adenocarcinoma (ACHN), human melanoma (M14), human melanoma (SK-MEL-28), and normal human foreskin fibroblast cells. According to the results, compounds 142–144, 146–147, 149, 162, 164, 167, and 199–200 demonstrated cytotoxicity against LNCaP and 22Rv1, whereas compounds 140 and 200 showed cytotoxicity against ACHN cell lines. The other compounds have no potential cytotoxicity at the concentration of 5 μ M. In another study, compounds 187–190 inhibited NO production with IC_{50} values below 8

μ M. Compounds 187–190 also showed strong interaction with iNOS protein [83].

3.1.2. Flavonoids

The fruits extract of *P. peruviana* reported to contain flavonoids, like rutin (212), myricetin (213), quercetin (214), and kaempferol (215) (Figure 4) [76–77]. Toro et al., 2014 [76], evaluated the antioxidant and anti-inflammatory activity of crude extracts, fractions, and compounds, rutin (212) and nicotiflorin (216) obtained from the bioassay guided isolation and identification of calyces from *P. peruviana*. Compound 212 showed not only potent superoxide anion scavenging activity (88.8%), comparable to positive control, *n*-propylgallate (92.9%), but also showed higher NO inhibition (66.7%) than the positive control, gallic acid (43.9%). In addition, compound 216 showed lower superoxide anion scavenging activity, but displayed an important NO scavenging effect (49.6%), comparable to that of gallic acid.

3.1.3. Alkaloid

The roots of extract of *P. peruviana* contain alkaloids, like (+)-physperuvine (217) and cuscohygrine (218) (Figure 5) [53,74].

3.1.4. Sucrose esters

A series of sucrose esters, peruvioses A–M (219–231), and nicandrose D (232) were isolated from the fruits and calyces of *P. peruviana* (Figure 6) [75,81,82]. Bernal et al., 2018 [81], studied the α -amylase inhibition activity of compounds 219–224 at the concentration of 640 μ g/mL. The study revealed that compound 222 displayed the highest activity, with an inhibition value of 84.8%. It was the first research to identify the ability of sucrose esters for alpha-amylase inhibitors and explain the hypoglycemic impact of gooseberry fruit. Moreover, a mixture of compounds (219 + 220) has potent anti-inflammatory activity [75].

3.1.5. Other compounds

Nine other compounds; such as hydroxyester disaccharides (233–235), glycosidically bound compounds (236–237), carbohydrate ester of cinamic acid (238), blumenol A (239), (+)-*S*-dehydrovomifolol (240), and loliolide (241) have been isolated from the roots, fruits, and aerial parts of *P. peruviana* (Figure 7) [62, 67, 68, 70, 71].

4. Plant description of *Cassia fistula* (Linn.)

Kingdom Plantae
Order Fabales
Family Fabaceae

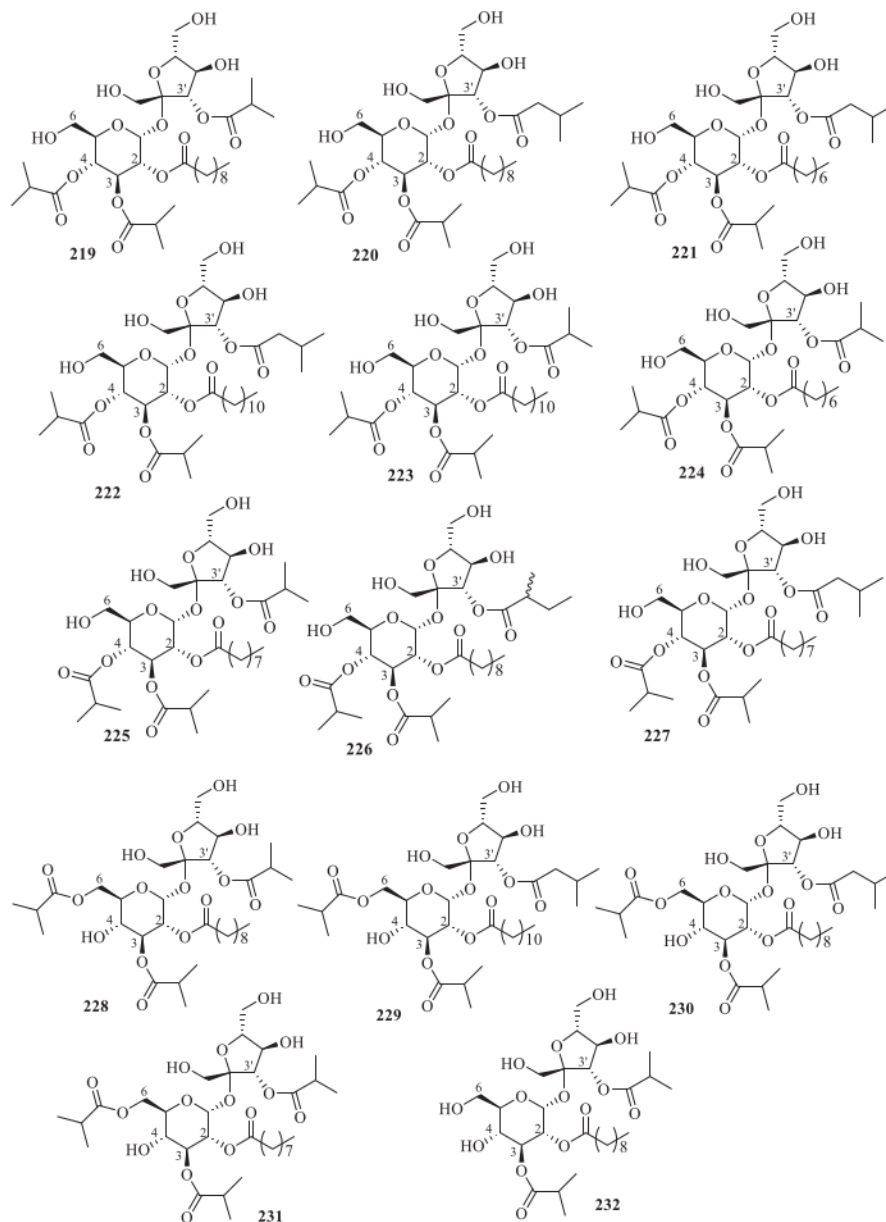


Figure 6. The structure of sucrose esters (219–232) isolated from *P. peruviana*.

Genus *Cassia*

Species *C. fistula*

English name Golden Shower

Myanmar name Ngu-wah

C. fistula is a medium-sized tree up to 24 m in height. It is a deciduous tree with greenish grey bark, composites with leaves; leaflets are each 5–12 cm long pairs. The fruit is a legume, 40–70 cm long with a pungent smell and containing many seeds. It grows throughout in Bangladesh, India, China, Philippines, Malaysia, Indonesia, Thailand, and Taunggyi (Myanmar) [84, 85]. In Taunggyi, the bark of this plant locally used in anti-hepatic C.

4.1. Chemical constituents

A total of 120 compounds, including 39 flavonoids, 19 anthraquinones, 22 chromones, 3 coumarins, 10 alkaloids, 11 phenolic and other compounds, 4 phytosterols and a triterpene, and 11 long-chain hydrocarbons were isolated and identified from *C. fistula* by chromatographic methods [86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112]. Most have been studied for different biological activities. The chemical structures of the isolated compounds from *C. fistula* are shown in Figures 8, 9, 10, 11, 12,

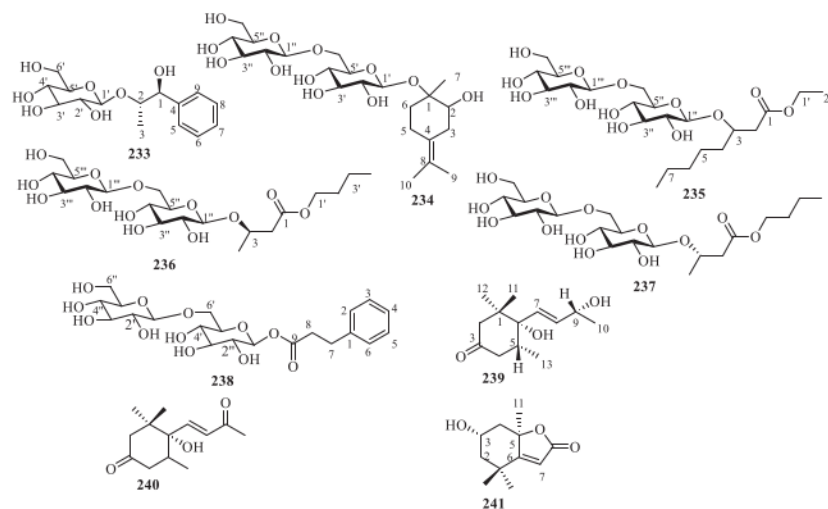


Figure 7. The structure of other compounds (233–241) isolated from *P. peruviana*.

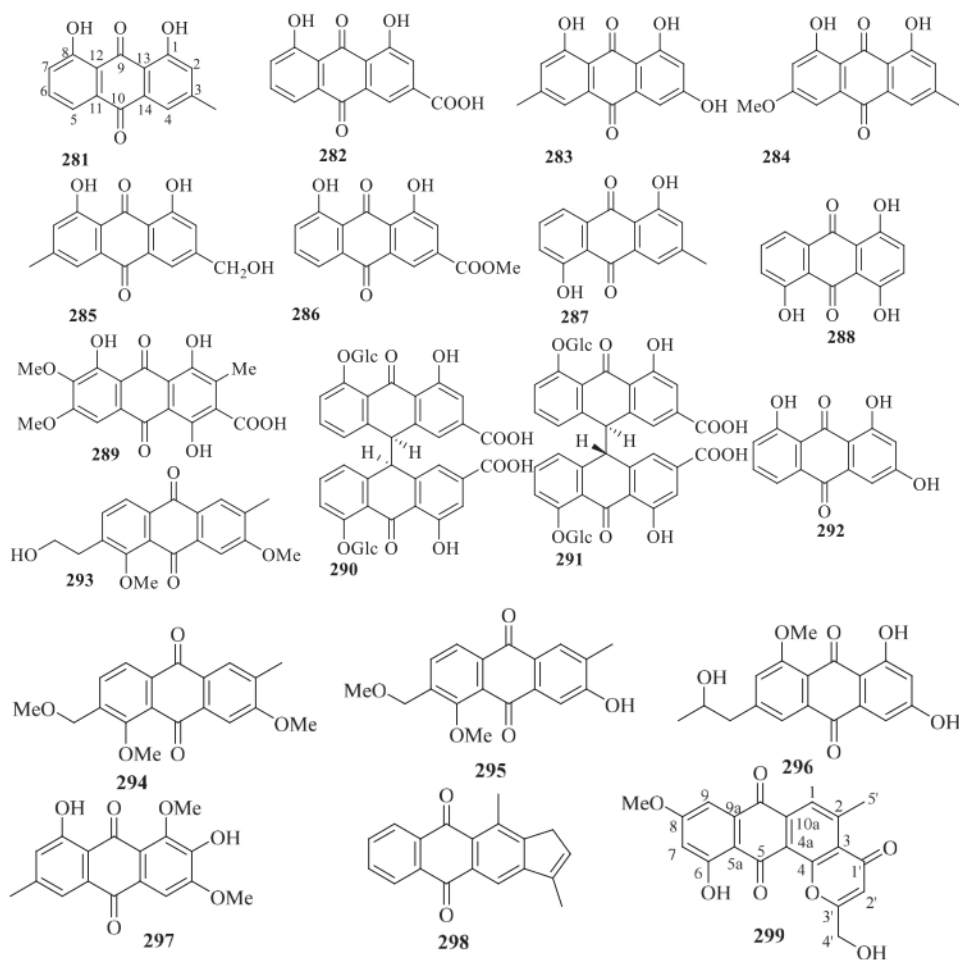


Figure 8. The structure of anthraquinones (281–299) isolated from *C. fistula*.

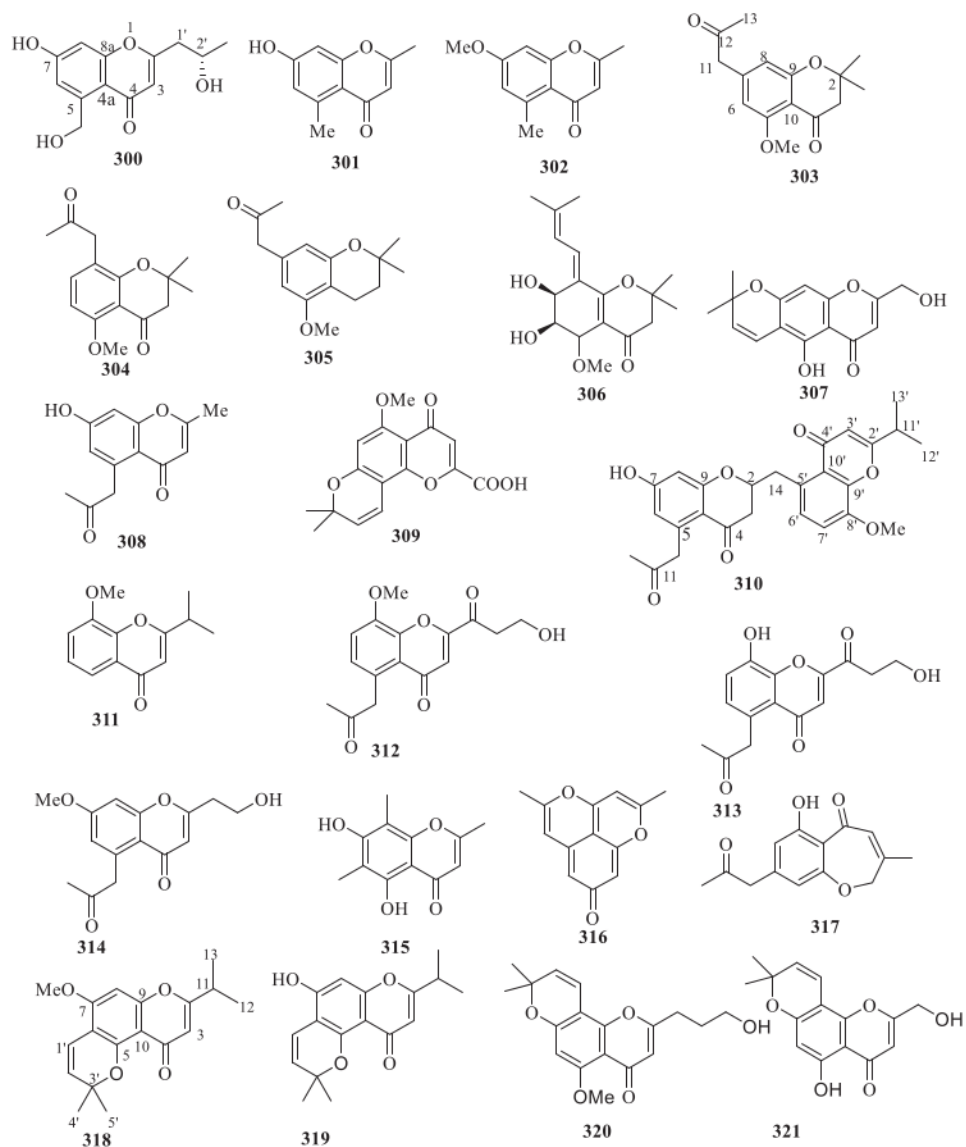


Figure 9. The structure of chromones (300–321) isolated from *C. fistula*.

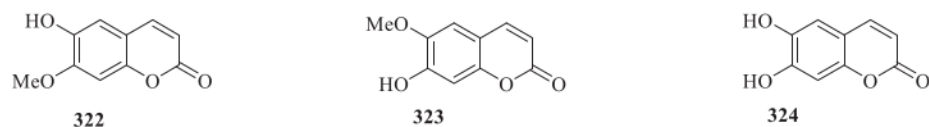


Figure 10. The structure of coumarins (322–324) isolated from *C. fistula*.

13, and 14 and S3. The list of compounds name and their biological activities are presented in Table S3, as well as their structure classification.

4.1.1. Flavonoids

A total of 39 flavonoids (242–280) have been isolated and identified from the fruits, stems, leaves, roots, and bark of *C. fistula* (Figure S3) [86, 87, 88, 91, 93, 97, 98, 99, 100, 105]. Some isolated flavonoids have

significant biological activities. For example, Sartorelli et al., 2009 [93], evaluated the antileishmanial, antitrypanosomal, cytotoxic, and hemolytic activity of compound 260 isolated from the fruits of *C. fistula*. Compound 260 (EC_{50} 18.32 $\mu\text{g}/\text{mL}$) showed the best activity (2.5-fold more effective) against the trypomastigotes form of *T. cruzi* as compared to the standard drug, benznidazole (EC_{50} 44.86 $\mu\text{g}/\text{mL}$), and cytotoxic (EC_{50} 42.85 $\mu\text{g}/\text{mL}$) against rhesus monkey kidney cell (LLC-MK2-ATCC)

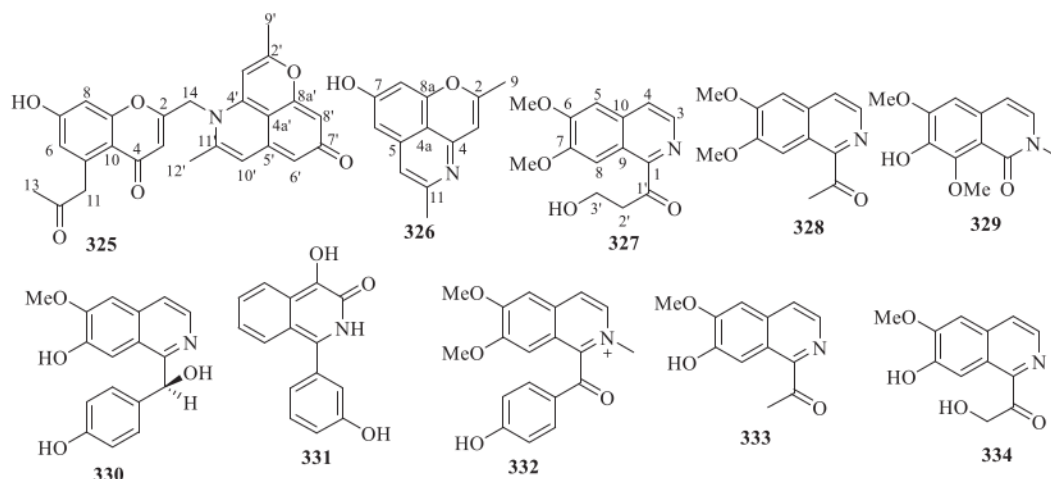


Figure 11. The structure of alkaloids (325–334) isolated from *C. fistula*.

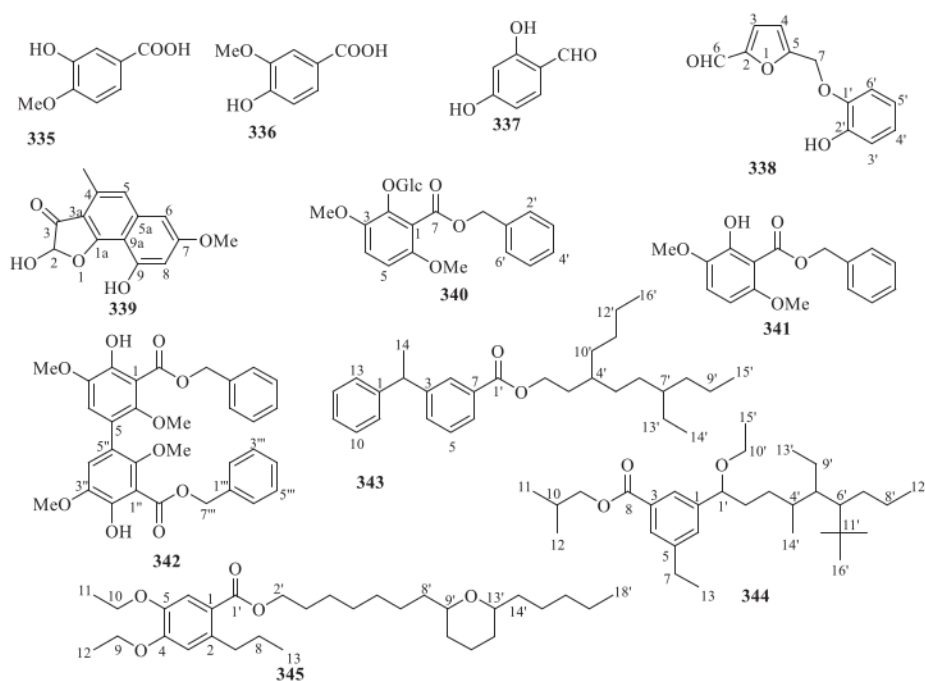


Figure 12. The structure of phenolic and other compounds (335–345) isolated from *C. fistula*.

after 48 h incubation. The findings of this analysis suggest that compound 260 could be a new therapeutic drug for Chagas' disease. Gao et al., 2013 [97], evaluated the cytotoxicity of compounds 272–279 against five human tumor cell lines (NB4, A549, SHSY5Y, PC3, and MCF7). The results revealed that compound 274 displayed significant activity against SHSY5Y and MCF7 cell lines with IC_{50} values of 2.7 and 2.6 $\mu\text{mol/L}$. Compounds 273, 276, 277, and 279 showed no activity against all selected cell lines ($IC_{50} > 10 \mu\text{mol/L}$), while compounds 272, 275, and 278 displayed moderate activity against some selected cell lines ($IC_{50} < 10 \mu\text{mol/L}$). Zeng et al., 2013 [99], evaluated the antitobacco mosaic virus activity (anti-TMV) of compound 261 isolated from the roots of *C. fistula*. Compound 261 displayed moderate activity with

inhibition rate of 18.2% at a concentration of 20 mM. In another study, Zhao et al., 2013 [100], also reported the anti-TMV activity of compounds 262–267 and 271 isolated from the bark and stems of *C. fistula*, using half-leaf method with Ningnanmycin (24.7%, a commercial product for plant disease in China) as a positive control. According to the results, compounds 262 and 263 demonstrated high activity with inhibition rate of 28.5% and 31.3% at a concentration of 20 μM . Compounds 265–267 and 271 exhibited moderate activity with inhibition rate of 18.5%, 22.7%, 16.4%, and 15.3% at the same concentration. Additionally, Srividhya et al., 2017 [105], evaluated antioxidant and cytotoxic activity of compound 280 isolated from the leaves of *C. fistula* using DPPH and MTT assays. Compound 280 was presumably dose-dependent

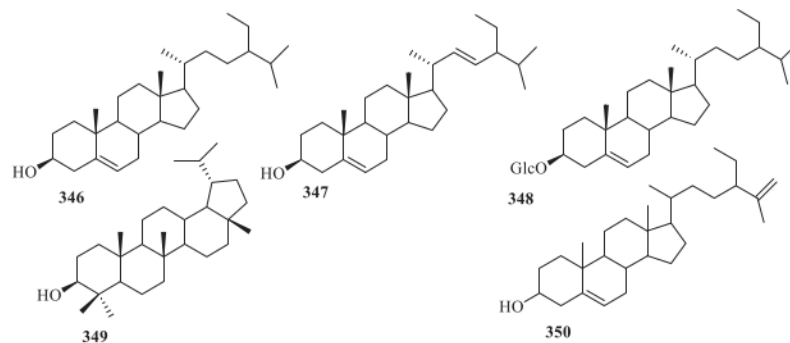


Figure 13. The structure of phyosterols and a triterpene (346–350) isolated from *C. fistula*.

antioxidant and cytotoxic activities with IC_{50} values of 29.7 and 25.3 $\mu\text{g}/\text{mL}$.

4.1.2. Anthraquinone

Nineteen anthraquinones (281–299) were reported from the arils, leaves, fruits, and flower of *C. fistula* (Figure 8) [87, 89, 91, 95, 98, 101, 108, 110]. A study by Duraipandiyar et al., 2012 [95], on compound 282 isolated from *C. fistula* flower exhibited cytotoxicity toward COLO 320 DM (human colon cancer cells) and it also induced apoptosis at 6.25 mg/mL . Compound 282 also has anti-inflammatory activity. Cytotoxicity of compound 300 isolated from the fruit of *C. fistula* was evaluated by using five human tumor cell lines (NB4, A549, SHSY5Y, PC3, and MCF7), and the results revealed that compound 299 displayed significant cytotoxicity against NB4 and PC3 cell lines with IC_{50} value of 6.3 and 5.8 μM . Zhou et al., 2017 [108], evaluated the anti-TMV activity of compounds 293–298 isolated from the twigs of *C. fistula* using half-leaf method with Ningnanmycin (28.8%, a commercial product for plant disease in China) as a positive control. The results showed that compound 295 displayed potential anti-TMV activity with inhibition rate of 35%. The other compounds displayed weak anti-TMV activity with inhibition rates in the ranges of 18.2–26.3%. Cytotoxicity of compounds 293–298 was also evaluated against NB4 (human leukemia), A549 (carcinomic human alveolar basal epithelial), SHSY5Y (human neuroblastoma), PC3 (human

prostate cancer), and MCF7 (human breast adenocarcinoma) cell lines, using MTT assay with taxol as a positive control. According to the analysis, all compounds displayed moderate cytotoxic activity for some selected human tumor cell lines with IC_{50} values in the ranges of 2.8–9.4 μM .

4.1.3. Chromones

Twenty-two chromones (300–321) were isolated from the arils, seeds, and stems of *C. fistula* (Figure 9) [89, 90, 94, 102, 103, 104, 109]. Chromones from *C. fistula* have reported for their insightful biological activity. For example, compound 300 has the highest antifungal activity against *Sacromycescerevisiae* and lowest activity against *Penicillium chrysogenum*. The MIC values of compound 300 against used fungal strains range from 18–27 $\mu\text{g}/\text{mL}$. Moreover, compound 300 also has the highest antibacterial activity against *Staphylococcus aureus* and lowest activity against *Klebsella pneumonia*. The MIC values of compound 300 against Gram-positive and Gram-negative ranged from 22–38 $\mu\text{g}/\text{mL}$ [94]. Anti-TMV activity of compounds 303–309 isolated from the stem of *C. fistula* was evaluated by using half-leaf method with Ningnanmycin (34.8%, a commercial product for plant disease in China) as a positive control. The results demonstrated that compound 307 exhibited high activity with inhibition rate of 30.8% at a concentration of 20 μM , and the other compounds 303–306, 308, and 309 also showed potential

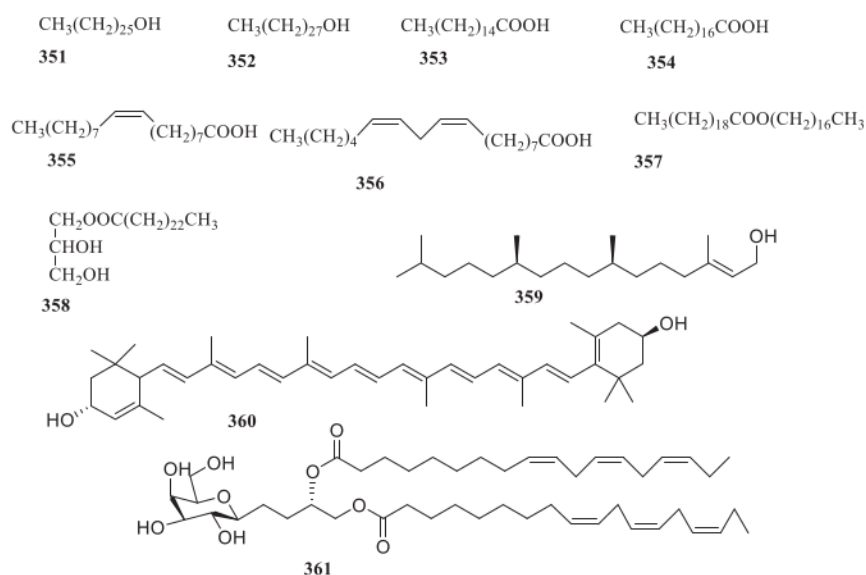


Figure 14. The structure of long-chain hydrocarbons (351–361) isolated from *C. fistula*.

activity with inhibition rates in the ranges of 15.6–22.1% at the same concentration [102]. In another study, compounds 310 and 311 isolated from the bark of *C. fistula* were evaluated for their biological activities, including antidiabetic, antimicrobial, anti-TMV, and cytotoxic activities. Compounds 310 and 311 showed no significant antidiabetic and antimicrobial activity, while weak activity on anti-TMV and cytotoxic activity was detected [103]. Moreover, Hu et al., 2015 [104], also documented the anti-TMV activity of compounds 312–314 isolated from the twigs of *C. fistula*, using half-leaf method with Ningnanmycin (30.8%, a commercial product for plant disease in China) as a positive control. The results showed that compounds 312–314 exhibited high activity with inhibition rates of 26.6, 28.2, and 29.7% at the concentration of 20 μM . Hu et al., 2017 [109], also evaluated anti-TMV activity of compounds 318 and 319 isolated from the twigs of *C. fistula*, using half-leaf method with Ningnanmycin (32.8%, a commercial product for plant disease in China) as a positive control, and the result showed that both compounds exhibited high activity with inhibition rates of 27.5 and 30.8% at the concentration of 20 μM .

4.1.4. Coumarins

Three coumarins, isoscopoletin (322), scopoletin (323), and esculetin (324), were isolate from the arils and leaves, of *C. fistula* (Figure 10) [89, 98].

4.1.5. Alkaloids

Ten alkaloids (325–334) were recorded on the bark and twigs of *C. fistula* (Figure 11) [103, 106, 107]. Alkaloids from *C. fistula* have an important biological activity. For example, compound 325 showed not only significant anti-TMV activity with an IC_{50} value of 43.8 μM as compared to the positive control Ningnanmycin (IC_{50} 52.4 μM), but also weak cytotoxic activity ($\text{IC}_{50} < 10 \mu\text{M}$) against NB4, A459, and MCF7 cell lines [103]. In another study, Wu et al, 2016 [106], reported the anti-TMV activity of compounds 327–332 isolated from the twigs of *C. fistula*, using half-leaf method with Ningnanmycin (30.8%, a commercial product for plant disease in China) as a positive control. The results showed that compounds 327–332 exhibited weak activity with inhibition rates in the range of 15.4–23.5% at the concentration of 20 μM . Similarly, Zhou et al, 2017 [107], noted that the anti-TMV activity of compounds 333 and 334 isolated from the bark of *C. fistula*, using half-leaf method with Ningnanmycin (30.8%, a commercial product for plant disease in China) as a positive control. Compounds 333 and 334 displayed weak activity with inhibition rates of 18.9 and 22.6%.

4.1.6. Phenolic and other compounds

Eleven phenolic and other compounds (335–345) were reported from the arils, seeds, and leaves of *C. fistula* (Figure 12) [89, 90, 94, 96, 98, 111]. The results of the analysis by Nagpal et al., 2011 [94], exhibited the highest antifungal activity against *Sacromyces cerevisiae* and lowest activity against *Aspergillus niger* by compound 340. The MIC values of compound 340 against used fungal strains ranged from 22 to 28 $\mu\text{g}/\text{mL}$. In addition, compound 340 also showed highest antibacterial activity against *Bacillus subtilis* and lowest activity against *Pseudomonas aeruginosa*. The MIC values of compound 341 against Gram-positive and Gram negative ranged from 41 to 50 $\mu\text{g}/\text{mL}$. Sartorellet al., 2012 [96], found that no antifungal activity on compounds 341 and 342 against *Cladosporium cladosporioides* and *Cladosporiums phaeospermum*. Aftab et al., 2019 [111], demonstrated the antioxidant properties of compounds 343–345 isolated from the EtOAc soluble fraction of *C. fistula*, using DPPH, ABTS, and super oxide anion radical scavenging assays with ascorbic acid and trolox as positive controls. The results showed that *C. Fistula* includes active antioxidant compounds that can help cure oxidative stress disorder and other diseases.

4.1.7. Phytosterols and a triterpene

Four phytosterol like β -sitosterol (346), stigmasterol (347), β -sitosterol-*D*-glucopyranoside (348), clerosterol (349) and a triterpene, lupeol (350), were isolated from the arils, fruits, and leaves of *C. fistula* (Figure 13) [89, 92, 98]. Compound 351 displayed significant anti-leishmanial activity against axenic promastigotes and intercellular amastigotes of *Leishmania* (L.) *chagai* in vitro. According to the mammalian cytotoxic activity, compound 351 has 3.6-fold less toxic than the standard drug pentamidine [92].

4.1.8. LONG-CHAIN hydrocarbons

Eleven long-chain hydrocarbons, including 1-hexacosanol (351), 1-octacosanol (352), palmitic acid (353), steric acid (354), oleic acid (355), linoleic acid (356), heptacosyleicosanate (357), glyceryl-1-tetraeicosanoate (358), E-phytol (359), lutein (360), and DLGG (361) were isolated and identified from the arils and leaves of *C. fistula* (Figure 14) [89, 98, 112]. Grace et al., 2012 [112] noted that compounds 359–361 displayed antiplasmodial activity with IC_{50} values of 18.9, 12.5, and 12.8 μM . Furthermore, compound 361 showed very low toxicity against Chinese Hamster Ovarian (CHO) cell lines, although compounds 359 and 360 were nontoxic, expect at the highest doses.

5. Conclusions

This review finds the description of the plants, different types of chemical constituents, and their biological activities from the selected Taunggyi medicinal plants. Over 361 chemical compounds were isolated and identified from three selected Taunggyi medicinal plants. Among then, flavonoids and terpenes are the main bioactive components in *Andrographis paniculata*, withanolides and sucrose ester are the principle bioactive constituents in *Physalis peruviana*, and the main bioactive constituents in *Cassia fistula* are flavonoids, chromones, anthraquinones, and alkaloids. A total of 140 compounds were evaluated for their biological activity. Some of the biological findings on the selected plants provide scientific data to support the traditional use of Taunggyi medicinal plants. However, the mechanism of action of the selected plants is weakly implicit and further analysis is required.

19 Declarations

Author contribution statement

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18 Declaration of interests statement

The authors declare no conflict of interest.

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