FLAVONOIDS IN THE SPECIES OF THE FAMILY ARACEAE: A REVIEW

Sebuah tinjauan: Senyawa-senyawa flavonoid pada suku Araceae

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Abstrak

Flavonoid merupakan salah satu metabolit sekunder dan terdiri dari dua cincin fenil (cincin A dan B) yang dihubungkan oleh jembatan tiga karbon. Lebih dari 8000 jenis flavonoid dilaporkan dari tumbuhan berpembuluh dan Bryophyta. Makalah ini mengulas karakter flavonoid dari suku Araceae s.l. (termasuk Lemnaceae). Sebagian besar flavonoid utama dari suku Araceae adalah C-glikosilflavon dengan pengecualian untuk anak suku Gymnostachyoideae dan Orontioideae. Jenis flavonoid lainnya, yaitu anthocyanin, flavon, flavonol, flavan, dan proanthocyanidins dilaporkan terdapat pada semua anak suku Araceae. Flavanon dan C-glikosil flavanon diisolasi masing-masing dari *Spirodela polyrhiza* dan *Anthurium binotii*. Namun demikian, dihydroflavonol, chalcone, dihydrochalcone, aurone, dan isoflavonoid tidak dilaporkan terdapat pada jenis-jenis dari suku Araceae yang telah diteliti. Meskipun Araceae s.l. merupakan suku tumbuhan besar yang terdiri atas sekitar 3645 jenis dan 144 marga, baru 146 jenis dari 48 marga yang diketahui kandungan flavonoidnya.

Kata kunci: Araceae, C-glycosylflavone, distribusi, flavonoid, Lemnaceae

Abstract

Flavonoids is one of the secondary metabolites and consists of two phenyl rings (A- and B-rings) connected by a three carbon bridge. Over 8000 kinds of flavonoids were reported from vascular plants and Bryophytes. This paper reviewed the flavonoid characters of the Araceae s.l. (including the Lemnaceae). Major flavonoids of the family were C-glycosylflavones with the exception for subfamilies Gymnostachyoideae and Orontioideae. Other flavonoid classes, i.e. anthocyanins, flavones, flavonols, flavan and proanthocyanidins, were reported in all subfamilies. Flavanone and C-glycosylflavanone were isolated from *Spirodela polyrhiza* and *Anthurium binotii*, respectively. However, dihydroflavonol, chalcone, dihydrochalcone, aurone, and isoflavonoids were not reported in the Araceae. Although Araceae s.l. is a large family consisting of ca. 3645 species and ca. 144 genera, flavonoids were surveyed only in 146 species of 48 genera, as far as known.

Keywords: Araceae, C-glycosylflavones, distribution, flavonoids, Lemnaceae

INTRODUCTION

Flavonoids is the general term for the compounds which have a fifteen carbon skeleton. At the simplest level, the skeleton consists of two phenyl rings (A- and B-rings) connected by a three carbon bridge (C-ring). In general, vascular plants and Bryophytes alone possess the biosynthetic ability of the flavonoids except for a few algae and

fungi (List & Freud 1968, Zeng *et al.* 2001, Liu *et al.* 2009). Flavonoids can be divided into several classes, e.g. anthocyanins, aurones, biflavones, chalcones, dihydrochalcones, dihydroflavonols, flavan and proanthocyanidins, flavanones, flavones, flavonols, isoflavonoids, and so on. Anthocyanins are based on the flavilium salt structure (Figure 1). The common anthocyanidins are pelargonidin, cyanidin, peonidin, delphinidin, petunidin, and

malvidin. Flavones have substitutions on the A- and B-rings but lack oxygenation at the 3-position of the C-ring (Figure 2). Although flavones are generally present in vacuoles of cells as *O*- and/or *C*-glycosides (*C*-glycosylflavones), some compounds particularly the simple and polymethoxylated flavones, occur in heart woods and as farinose exudates, bud wax, and so on. Flavonols are flavones that are attached to a hydroxyl group at 3-position (Figure 3).

Figure 1. Anthocyanin

Figure 2. Flavone

Figure 3. Flavonol

Chalcones and dihydrochalcones lack a central heterocyclic ring (C-ring). Positions on these compounds are identified using a numbering system unique to these groups. Chalcones were apparently recognized as being structurally related to acetophenones whose ring carbons were identified by primed numbers. Hence, chalcones and dihydrochalcones A-ring carbons are also identified with primed numbers and the B-ring carbon is identified with unprimed numbers. Chalcones are double bonding between the α - and β -positions, but not in dihydrochalcones. So that the color of many chalcones turns yellow (Figure 4). Aurones are based on the 2-benzylidene-coumaranone or 2-benzylidene-3(2H)-benzofuranone system, and characterized by the presence of a five-membered heterocyclic ring. Aurone glycosides act as water-soluble yellow pigments on the flowers (Figure 5). Two structural features, i.e. the absence of the double bond between the 2- and 3-positions, and the presence of a chiral center at the 2-position, characterize flavanone. Dihydroflavonols, i.e. 3-hydroxyflavones are requisite intermediates on the pathway to flavonols by one route and to

anthocyanins via flavan 3,4-diols by another (Figure 6).

Figure 4. Chalcone (upper) and Dihydrochalcone (lower)

Figure 5. Aurone

Figure 6. Flavanone (upper) and Dihydroflavonol (lower)

Figure 7. Basic chemical structures of isoflavonoids

Isoflavonoids differ from other flavonoid classes in having as a basic structural feature that B-ring attaches to C-3 but not C-2, and subdivided into several classes, e.g. isoflavones, coumestans, coumaronochromones, pterocarpanes, rotenoids, and so on (Figure 7). Flavan and proanthocyanidins which lack a 4-carbonyl group are noteworthy for their activities on human health. Moreover, numerous sorts of flavonoids occur in plants with additional hydroxyl, methoxyl, methyl and/or glycosyl substitution patterns. Additionally, aromatic and aliphatic acids, sulfate, prenyl and/or methylenedioxy groups also attach to flavonoids and their glycosides. Thus, more than 8000 kinds of flavonoids have been reported as naturally occurring compounds. The isolation and identification, structures, distribution and biosynthesis of flavonoids in plants have been reviewed by many authors e.g. Harborne *et al.* (1975), Harborne & Mabry (1982), Harborne (1988, 1994), Iwashina (2000), Andersen & Markham (2006).

The flavonoids as medicinal resources were also reviewed by several researchers such as Cody *et al.* (1986, 1988), Rice-Evans & Packer (1998). Anthocyanins in particular were recently noticed as antioxidants, antitumor, astringents as well as other medicinal properties (Ohba *et al.* 2000). However, secondary metabolites such as flavonoids were considered to be a waste products of plant metabolism in early days of the 20th century. One of the most important functions of flavonoids may be to serve as an ultraviolet filter in land plants. It was shown by the survey of some plant species that the flavonoids act as UV shield.

The occurrence of anthocyanins as pollinator attractants is well-known as a function of flavonoids in plants. Additionally, it is known that flavones and flavonols, which can hardly be seen by human eyes, also act as pollinator attractants in addition to visible anthocyanins. Moreover, other functions, e.g. oviposition stimulants, feeding attractants, feeding deterrents, allelopathy and phytoalexins of naturally occurring flavonoids, were reported by many authors e.g. Iwashina (2003).

The Araceae is a large family of mostly herbaceous species, with great diverse in appearance. They are herbaceous with aerial stems or underground tubers or rhizomes, but there are a few woody species. The family included several

climbers and epiphytes as well as a floating water plant, and consists of ca. 3645 species of ca. 144 genera (Boyce & Croat 2011 onwards). APG III (2009) excluded the genus *Acorus* from Araceae, erected it in its own family, Acoraceae, and included Lemnaceae (genera *Landoltia*, *Lemna*, *Spirodela*, *Wolffia*, *Wolffiella*) into the Araceae. Araceae is divided into eight subfamilies, i.e. Aroideae, Gymnostachydoideae, Lasioideae, Lemnoideae, Monsteroideae, Orontioideae, Pothoideae, and Zamioculcadoideae. Of the araceous species, flavonoids were reported from 146 taxa of 48 genera. However, flavonoids were not reported from three genera of the Zamioculcadoideae growing in Africa. This review paper presents and describes the characters and distribution of flavonoids in the Araceae. The abbreviations used in Tables 1 – 8 are as follows: ap = aerial part, cr = corm, ep = epidermis, fl = flower, fr = fruit, if = inflorescence, lf = leaf, pt = petiole, rz = rhizome, sp = spathe, st = stem, sx = spadix, tb = tuber, wp = whole plant.

FLAVONOIDS IN THE SUBFAMILY GYMNSTACHYDOIDEAE

Gymnostachys anceps alone belongs to this subfamily and was surveyed for flavonoids (Table 1). A flavonol glycoside, kaempferol 3-sophoroside-7-rhamnoside (Figure 8) was isolated from the leaves of this species (Williams *et al.* 1971). Other flavonoids were not reported. Williams *et al.* (1971) surveyed the C-glycosylflavones which were common flavonoids in the Araceae including Lemnaceae, however they were not present in this species.

Figure 8. Kaempferol 3-sophoroside-7-rhamnoside

Table 1. Reports on the flavonoids from the species of subfamily Gymnostachydoideae

Gymnostachys anceps R.Br.

Flavonol: kaempferol 3-sophoroside-7-rhamnoside (lf) (Williams *et al.* 1971)

Figure 9. Quercetin 3-arabinosyl-(1→6)-galactoside

Figure 10. Isorhamnetin 3-arabinosyl-(1→6)-galactoside

Figure 11. Cyanidin 3-glucoside

Figure 12. Cyanidin 3-rutinoside

Figure 13. Peonidin 3-rutinoside

FLAVONOIDS IN THE SUBFAMILY ORONTIOIDEAE

Four species of subfamily Orontioideae, i.e. *Lysichiton camtschatcensis*, *Orontium aquaticum*, *Symplocarpus foetidus*, and *S. renifolius*, were surveyed for flavonoids (Table 2). Williams *et al.* (1981) and Whang & Lee (1999) reported that major flavonoids of this subfamily were flavonols, namely, kaempferol 3-arabinosyl-(1→6)-galactoside, 3-xylosylgalactoside and 3-sophoroside-7-glucoside, quercetin 3-arabinosyl-(1→6)-galactoside (Figure 9), 3-galactoside, 3-sophoroside and 3-sophoroside-7-glucoside, and isorhamnetin 3-arabinosyl-(1→6)-galactoside (Figure 10).

A quercetin glycoside which was acylated with caffeic acid, quercetin 3-sophoroside-7-(6''-*E*-caffeoylglucoside), was isolated from the leaves of *Symplocarpus renifolius* (Whang & Lee 1999). Three anthocyanins, namely cyanidin 3-glucoside (Figure 11), 3-rutinoside (Figure 12) and peonidin 3-rutinoside (Figure 13), were detected in the flowers of *Symplocarpus foetidus* (Chang *et al.* 1970).

Table 2. Reports on the flavonoids from the species of subfamily Orontioideae

Lysichiton camtschatcensis (L.) Schott

Flavonol: isorhamnetin 3-arabinosyl-(1→6)-galactoside, kaempferol 3-arabinosyl-(1→6)-galactoside, kaempferol 3-xylosylgalactoside, quercetin 3-arabinosyl-(1→6)-galactoside (lf) (Williams *et al.* 1981)

Orontium aquaticum L.

Flavonol: isorhamnetin 3-galactoside, isorhamnetin 3-rhamnosylgalactoside, kaempferol 3-galactosylglucoside, quercetin 3-galactoside (lf) (Williams *et al.* 1981)

Symplocarpus foetidus (L.) Salisb. ex W.P.C.Barton

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside, peonidin 3-rutinoside (fl) (Chang *et al.* 1970),

Flavonol: kaempferol 3-diglucoside, kaempferol galactosylglucoside, quercetin galactosylglucoside (lf) (Williams *et al.* 1981)

Symplocarpus renifolius Schott ex Tzvelev

Flavonol: isorhamnetin 3-sophoroside-7-glucoside, kaempferol 3-sophoroside-7-glucoside, quercetin 3-sophoroside, quercetin 3-sophoroside-7-(6''-*E*-caffeoylglucoside), quercetin 3-sophoroside-7-glucoside (lf) (Whang & Lee 1999)

Figure 14. Vitexin

Figure 15. Isovitexin

Figure 16. Orientin

Figure 17. Isoorientin

Figure 18. Vicenin-2

Figure 19. Apigenin 7-glucoside

Figure 20. Luteolin 7-glucoside

Figure 21. Naringenin 6,8-di-C-glucoside

FLAVONOIDS IN THE SUBFAMILY LEMNOIDEAE

Nineteen species of four genera of the Lemnoideae were surveyed for flavonoids (Table 3). The major flavonoid class of the subfamily is C-glycosylflavone. C-glycosylflavones such as vitexin (Figure 14), isovitexin (Figure 15), orientin (Figure 16), isoorientin (Figure 17), vicenin-2 (Figure 18) and their O-glycosides were found in all species surveyed, except for two *Wolffia* and three *Wolffiella* species. Major flavonoids in *Wolffia microscopica* and *W. brasiliensis* were flavonols, and kaempferol, quercetin and their 3-glycosides and 3,7-diglycoside were characterized (McClure & Alston 1966). Major flavonoids in other *Wolffia* species, *W. arrhiza*, *W. columbiana*, *W. globosa* were flavones and C-glycosylflavones such as apigenin 7-glucoside (Figure 19), luteolin 7-glucoside (Figure 20) (flavones), and vitexin, isovitexin, orientin, isoorientin (C-glycosylflavones) (McClure & Alston 1966, Wang *et al.* 2014b).

Quercetin 3- and 3,7-diglycosides were found in three *Wolffiella* species (McClure & Alston 1966). Various C-glycosylflavones, e.g. isovitexin,

vitexin, orientin, isoorientin, vicenin-2, and their O-glycosides and acylated glycosides, were isolated from *Lemna* species, together with anthocyanin (cyanidin 3-glucoside) and flavones (McClure & Alston 1966, Wallace & Alston 1966, Veen 1975, Akhtar *et al.* 2010).

C-glycosylflavones frequently occurred in *Spirodela* species with minor anthocyanins and flavonols. Another anthocyanin, petunidin 3,5-diglucoside, was found in *S. oligorrhiza* (McClure & Alston 1966). Rare C-glycosylflavanone, naringenin 6,8-di-C-glucoside (Figure 21), and C-glycosylflavone, 5,7-dihydroxy-3',4'-methylenedioxyflavone 8-C-glucoside, were isolated from *S. polyrrhiza*, together with two acylated C-glycosylflavones, apigenin 8-C-(2''-feruloylglucoside) and luteolin 8-C-(2''-feruloylglucoside) (Quiao *et al.* 2011). Two rare flavans, 3,5,4'-trihydroxy-7,3'-dimethoxyflavan 5-glucoside and 3,5,4'-trihydroxy-4,7,3'-trimethoxyflavan 5-glucoside, were isolated from *S. punctata* (as *Landoltia punctata*), together with some common flavones and C-glycosylflavones (Wang *et al.* 2014a).

Table 3. Reports on the flavonoids from the species of subfamily Lemnoideae

Lemna aequinoctialis Welw. (as *Lemna trinervis* (Austin) Small) (McClure & Alston 1966)

Flavone: luteolin, luteolin 7-glycoside (wp),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, apigenin 6,8-di-C-glycoside (acylated), luteolin 6,8-di-C-glycoside (wp) (McClure & Alston 1966)

Lemna gibba L.

Anthocyanin: cyanidin 3-glucoside (wp) (McClure & Alston 1966),

Flavone: luteolin malonylglucosyl-malylglucoside (wp) (Akhtar *et al.* 2010),

C-Glycosylflavone: isoorientin, isoorientin 7-glucoside, isovitexin, isovitexin 4'-glucoside, apigenin 6-C-(malonylglucoside)-glucosyl-malylglucoside, luteolin 6-C-(malonylglucoside)-glucosyl-malylglucoside, orientin, vitexin (wp) (McClure & Alston 1966, Veen 1975, Akhtar *et al.* 2010)

Lemna japonica Landolt

Flavone: chrysoeriol, luteolin 7-glucoside (wp),

C-Glycosylflavone: isoorientin, isoorientin 2''-(*E*-caffeoyl-malate), isoorientin 2''-(*E-p*-coumaroyl-malate), isoscoparin, isovitexin, isovitexin 2''-(*E*-caffeoyl-malate), lucenin-2, vicenin-2 (wp) (Bai *et al.* 2018)

Lemna minor L.

Flavone: apigenin 7-glycoside, chrysoeriol glucoside, isoscoparin, luteolin 7-glucoside (wp) (Wallace & Alston 1966, Wallace *et al.* 1969, Vladimirova & Georgiyants 2013),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, isoorientin, isoorientin 7-glucoside, isovitexin, isovitexin 4'-glucoside, luteolin 6,8-di-C-glycoside, orientin, vitexin (wp) (McClure & Alston 1966, Wallace & Alston 1966, Veen 1975)

Lemna minor (as *Lemna minima* Thuill. ex P.Beauv.) (McClure & Alston 1966)

Flavone: apigenin 7-diglycoside, apigenin 7-glycoside (wp),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, isoorientin, orientin (wp) (McClure & Alston 1966)

Lemna obscura (Austin) Daubs

Anthocyanin: cyanidin 3-glucoside (wp),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, apigenin 6,8-di-C-glycoside (acylated), isoorientin, luteolin 6,8-di-C-glycoside (acylated) (wp) (McClure & Alston 1966)

Lemna perpusilla Torr.

Flavone: apigenin 7-glycoside (wp),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, apigenin 6,8-di-C-glycoside (acylated) (wp) (McClure & Alston 1966)

Lemna trisulca L.

Anthocyanin: cyanidin 3-glucoside (wp),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, apigenin 6,8-di-C-glycoside (acylated), isoorientin, luteolin 6,8-di-C-glycoside, luteolin 6,8-di-C-glycoside (acylated), orientin, vitexin (wp) (McClure & Alston 1966)

Lemna valdiviana Phil.

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, apigenin 6,8-di-C-glycoside (acylated), luteolin 6,8-di-C-glycoside, luteolin 6,8-di-C-glycoside (acylated) (wp) (McClure & Alston 1966)

Spirodela oligorrhiza (Kurz) Hegelm.

Anthocyanin: petunidin 3,5-diglucoside (wp),

Flavone: luteolin, luteolin 7-diglycoside (wp),

Flavonol: quercetin, quercetin 3,7-diglycoside (wp) (McClure & Alston 1966),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, isoorientin, isoorientin 7-glucoside, isovitexin, isovitexin (acylated), isovitexin 7-glucoside, isovitexin 4'-glucoside, luteolin 6,8-di-C-glycoside, orientin (wp) (Jurd *et al.* 1957, McClure & Alston 1966)

Spirodela polyrrhiza (L.) Schleid.

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-malonylglucoside (wp) (McClure & Alston 1966, Reznik & Menschick 1969, Krause & Strack 1979),

Flavanone: eriodictyol 7-glucoside, hesperetin 7-glucoside (wp) (Quiao *et al.* 2011),

Flavone: apigenin, apigenin 7-glucoside, chrysoeriol, luteolin, luteolin diglucoside, luteolin 7-glucoside (wp) (McClure & Alston 1966, Wallace & Alston 1966, Reznik & Menschick 1969, Wallace *et al.* 1969, Wallace 1975, Kim *et al.* 2010, Quiao *et al.* 2011),

Flavonol: quercetin diglucoside, quercetin diglucosylxyloside (wp),

C-Glycosylflavanone: naringenin 6,8-di-C-glucoside (wp) (Quiao *et al.* 2011),

C-Glycosylflavone: apigenin 8-C-(2''-feruloylglucoside), 5,7-Dihydroxy-3',4'-methylene-dioxyflavone 8-C-glucoside, isoorientin, isoorientin 7-glucoside, isovitexin, luteolin 8-C-(2''-feruloylglucoside), orientin, vitexin, vitexin 7-glucoside (wp) (McClure & Alston 1966, Wallace & Alston 1966, Reznik & Menschick 1969, Wallace *et al.* 1969, Saunders & McClure 1976,

Wallace 1975, Kim *et al.* 2010, Quiao *et al.* 2011)

Spirodela punctata (G.Mey.) C.H.Thomps. (as *Landoltia punctata* (G.Mey) Les & D.J.Crawford) (Wang *et al.* 2014a)

Flavan and Proanthocyanidin: 3,5,4'-trihydroxy-7,3'-dimethoxyflavan 5-glucoside, 3,5,4'-trihydroxy-4,7,3'-trimethoxyflavan 5-glucoside (wp),

Flavone: apigenin, apigenin 7-glucoside, luteolin, luteolin 7-glucoside (wp),

C-Glycosylflavone: apigenin 6-C-glucoside-8-C-galactoside, isoorientin, isovitexin, orientin, vicenin-2, vitexin (wp) (Wang *et al.* 2014a)

Spirodela punctata (G.Mey.) C.H.Thomps. (as *Spirodela biperforata* W.Koch) (McClure & Alston 1966)

Flavone: apigenin 7-glycoside, luteolin, luteolin 7-glycoside (wp),

C-Glycosylflavone: isoorientin, isoorientin 7-glucoside, orientin, vitexin (wp) (McClure & Alston 1966)

Spirodela punctata (as *Spirodela intermedia* W.Koch) (McClure & Alston 1966, McClure 1968, Saunders & McClure 1976)

Anthocyanin: cyanidin 3-glucoside (wp),

Flavonol: kaempferol, kaempferol 3-glycoside, quercetin, quercetin 3-glycoside (wp) (McClure & Alston 1966, McClure 1968),

C-Glycosylflavone: isovitexin 4'-glucoside, orientin, vitexin (wp) (McClure & Alston 1966, McClure 1968, Saunders & McClure 1976)

Wolffia arrhiza (L.) Horkel ex Wimm.

Flavone: luteolin, luteolin 7-diglycoside (wp),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, Isoorientin, Isovitexin, orientin (wp) (McClure & Alston 1966)

Wolffia brasiliensis Wedd. (as *Wolffia papulifera* C.H.Thomps.) (McClure & Alston 1966)

Flavonol: kaempferol, kaempferol 3,7-diglycoside, kaempferol 3-glycoside, quercetin, quercetin 3,7-diglycoside, quercetin 3-glycoside, quercetin 3,7-triglycoside (wp) (McClure & Alston 1966)

Wolffia brasiliensis (*Wolffia punctata* Griseb.) (McClure & Alston 1966)

Flavonol: kaempferol, kaempferol 3,7-diglycoside, kaempferol 3-glycoside, kaempferol 3,7-triglycoside, quercetin, quercetin 3-diglycoside, quercetin 3-glycoside, quercetin 3,7-triglycoside (wp) (McClure & Alston 1966)

Wolffia columbiana H.Karst.

Flavone: luteolin, luteolin 7-diglycoside (wp),

C-Glycosylflavone: apigenin 6,8-di-C-glycoside, isoorientin, isovitexin, orientin, vitexin (wp) (McClure & Alston 1966)

Wolffia globosea (Roxb.) Hartog & Plas

Flavone: apigenin 7-glucoside, luteolin 7-glucoside (wp),

C-Glycosylflavone: isoorientin, isoorientin 6''-glucoside, isovitexin, orientin, vicenin-2, vitexin (wp) (Wang *et al.* 2014b)

Wolffia microscopica (Griff.) Kurz

Flavonol: kaempferol, kaempferol 3,7-diglycoside, kaempferol 3-glycoside, quercetin, quercetin 3,7-diglycoside, quercetin 3-glycoside, quercetin 3,7-triglycoside (wp) (McClure & Alston 1966)

Wolffiella gladiata (Hegelm.) Hegelm.

Flavonol: quercetin 3-glycoside, quercetin 3,7-triglycoside (wp) (McClure & Alston 1966)

Wolffiella gladiata (*Wolffiella floridana* (J.D.Sm.) C.H.Thomps.) (McClure & Alston 1966)

Flavonol: quercetin 3,7-triglycoside (wp) (McClure & Alston 1966)

Wolffiella lingulata (Hegelm.) Hegelm.

Flavonol: quercetin 3,7-diglycoside, quercetin 3-glycoside, quercetin 3,7-triglycoside (wp) (McClure & Alston 1966)

Wolffiella oblonga (Phil.) Hegelm.

Flavonol: quercetin 3,7-diglycoside, quercetin 3-glycoside, quercetin 3,7-triglycoside (wp) (McClure & Alston 1966)

FLAVONOIDS IN THE SUBFAMILY POTHODEAE

The subfamily Pothoideae consists of ca. 900 species of four genera. Twenty two species of two genera and *Anthurium* cultivars were surveyed for flavonoids (Table 4). Anthocyanins were found in the fruits, spathe and spadix of many *Anthurium* species and identified as cyanidin 3-glucoside, 3-rutinoside, pelargonidin 3-rutinoside (Figure 22) and peonidin 3-rutinoside. Proanthocyanidins, procyanidins were also detected in some *Anthurium* species (Williams *et al.* 1981).

C-glycosylflavones flavones were isolated from three *Anthurium* species. They were relatively rare compounds, except for vitexin in *A. versicolor*, i.e. three embigenin (Figure 23) O-glycosides, 2''-

rhamnoside, 2''-(4'''-3,4-dimethoxycinnamoyl-rhamnoside) and 2''-(4'''-feruloylrhamnoside) from *A. andraeanum* (Clark *et al.* 2012), isoschaftoside (Figure 24) and schaftoside (Figure 25) from *A. bellum* (Williams *et al.* 1981), and cytoside (Figure 26) 3''-rhamnoside, and isocytoside (Figure 27) 3''-apiofuranoside, 3''-rhamnoside and 6''-xyloside from *A. versicolor* (Aquino *et al.* 2001). Crude extract of *A. versicolor* including their flavonoids was shown to have radical-scavenging activity (Aquino *et al.* 2001). Common flavonols, kaempferol and/or quercetin, were reported from four *Anthurium* species (Williams *et al.* 1981) and cultivars (Li *et al.* 2013).

Acacetin (Figure 28) was obtained from *A. polyschistum* (Williams *et al.* 1981), and rare methylated eucalyptin (Figure 29) and sideroxylin (Figure 30) glycosides were obtained from *Anthurium* cultivars (Li *et al.* 2013). A flavanone, hesperetin 7-rutinoside (Figure 31), was isolated from the epidermis of *A. binotii* (Brunswik 1921). From another Pothodeae species, *Pothos chinensis*, flavone glycoside, chrysoeriol (Figure 32) 7-rhamnosylglucoside, and seven C-glycosylflavones, vitexin, vitexin 7-glucoside, isoschaftoside, schaftoside, isovitexin 7-glucoside, isoscoparin 7-glucoside (Figure 33) and scoparin 7-glucoside (Figure 34), were isolated (Iwashina *et al.* 2010).

Figure 22. Pelargonidin 3-rutinoside

Figure 23. Embigenin

Figure 24. Isoschaftoside

Figure 25. Schaftoside

Figure 26. Cytoside

Figure 27. Isocytoside

Figure 28. Acacetin

Figure 29. Eucalyptin

Figure 30. Sideroxylin

Figure 31. Hesperetin 7-rutinoside

Figure 32. Chrysoeriol

Figure 33. Isoscoparin 7-glucoside

Figure 34. Scoparin 7-glucoside

Table 4. Reports on the flavonoids from the species of subfamily Pothoideae*Anthurium affine* Schott

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (fr) (Williams *et al.* 1981)

Anthurium andraeanum Linden ex André

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (sp) (Iwata *et al.* 1979),

C-Glycosylflavone: embigenin 2''-rhamnoside, embigenin 2''-(4'''-3,4- dimethoxycinnamoyl-rhamnoside), embigenin 2''-(4'''-feruloyl-rhamnoside) (lf) (Clark *et al.* 2012)

Anthurium bakeri Hook.f.

Anthocyanin: cyanidin 3-rutinoside (fr) (Williams *et al.* 1981)

Anthurium bellum Schott

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (sx),

Flavan and Proanthocyanidin: procyanidin (lf),

C-Glycosylflavone: isoschaftoside, schaftoside (lf) (Williams *et al.* 1981)

Anthurium binotii Linden

Flavanone: hesperetin 7-rutinoside (ep) (Brunswik 1921)

Anthurium cultivars

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside, peonidin 3-rutinoside (sp),

Flavone: apigenin glucoside, chrysoeriol arabinosylglucoside, eucalyptin benzoylglucoside, luteolin glucoside, methylapigenin rhamnosylglucoside, methyleucalyptin benzoylglucoside, sideroxylin benzoylglucoside (sp),

Flavonol: kaempferol acetylmalonylglucoside, kaempferol 3-rhamnoside-7-(acetyl-arabinoside), kaempferol rhamnosylglucoside, quercetin rhamnoside (sp) (Li *et al.* 2013)

Anthurium erskinei Mayo

Anthocyanin: cyanidin 3-rutinoside (sp, sx) (Williams *et al.* 1981)

Anthurium galeottii K.Koch

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside, pelargonidin 3-rutinoside (sp) (Williams *et al.* 1981)

Anthurium gladiifolium Schott

Anthocyanin: cyanidin 3-rutinoside (sx),

Flavan and Proanthocyanidin: procyanidin (lf),

Flavonol: kaempferol, quercetin (lf) (Williams *et al.* 1981)

Anthurium gracile (Rudge) Lindl.

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (fr),

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Anthurium hookeri Kunth

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Anthurium inconspicuum N.E.Br.

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (sp, sx) (Williams *et al.* 1981)

Anthurium jilekii Schott

Anthocyanin: cyanidin 3-rutinoside (sx) (Williams *et al.* 1981)

Anthurium lindmanianum Engl.

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Anthurium longifolium (Hoffm.) G.Don

Anthocyanin: cyanidin 3-rutinoside (sp, sx) (Williams *et al.* 1981)

Anthurium parasiticum (Vell.) Stellfeld (as

Anthurium miquelianum K.Koch & Augustin) (Williams *et al.* 1981)

Anthocyanin: cyanidin 3-rutinoside (pt, sx) (Williams *et al.* 1981)

Anthurium pentaphyllum (Aubl.) G.Don

Flavan and Proanthocyanidin: procyanidin (lf),

Flavonol: kaempferol, quercetin (lf) (Williams *et al.* 1981)

Anthurium polyschistum R.E.Schult. & Idrobo

Flavone: acacetin (lf) (Williams *et al.* 1981)

Anthurium radicans K.Koch & Haage

Anthocyanin: cyanidin 3-rutinoside (pt),

Flavan and Proanthocyanidin: procyanidin (lf),

Flavonol: kaempferol, quercetin (lf) (Williams *et al.* 1981)

Anthurium regale Linden

Anthocyanin: cyanidin 3-rutinoside (sx),

Flavan and Proanthocyanidin: procyanidin (lf),

Flavonol: quercetin (lf) (Williams *et al.* 1981)

Anthurium schlechtendalii Kunth

Anthocyanin: cyanidin 3-rutinoside (fr) (Williams *et al.* 1981)

Anthurium versicolor Sodiro

C-Glycosylflavone: cytisoside 3''-rhamnoside, isocytisoside 3''-apiofuranoside, isocytisoside 3''-rhamnoside, isocytisoside 6''-xyloside, vitexin (lf) (Aquino *et al.* 2001)

Pothos chinensis (Raf.) Merr.

Flavone: chrysoeriol 7-rhamnosylglucoside (ap),
C-Glycosylflavone: isoschaftoside, isoscoparin 7-glucoside, isovitexin 7-glucoside, schaftoside, scoparin 7-glucoside, vitexin, vitexin 7-glucoside (ap) (Iwashina *et al.* 2010)

FLAVONOIDS IN THE SUBFAMILY MONSTEROIDEAE

The Monsteroideae consists of ca. 360 species and 12 genera. Only one species, *Scindapsus pictus*, was surveyed for its flavonoids. Flavone (chrysoeriol) and flavonol (quercetin) were detected (Table 5) (Williams *et al.* 1981).

Table 5. Reports on the flavonoids from the species of subfamily Monsteroideae

Scindapsus pictus Hassk.

Flavone: chrysoeriol (lf),

Flavonol: quercetin (lf) (Williams *et al.* 1981)

FLAVONOIDS IN THE SUBFAMILY LASIOIDEAE

About 60 species of 10 genera belong to the Lasioideae. Two species, *Dracontium asperum* and *Lasia spinosa*, were surveyed for flavonoids (Table 6). Common anthocyanins, cyanidin and

pelargonidin 3-rutinosides, were found in *Dracontium asperum* (Williams *et al.* 1981). C-Glycosylflavones were detected in *D. asperum* and *L. spinosa*, and characterized as isovitexin xyloside and vitexin glucoside (*D. asperum*) (Williams *et al.* 1981), and vitexin and its 2''-glucoside (*L. spinosa*) (Hong Van *et al.* 2006).

Table 6. Reports on the flavonoids from the species of subfamily Lasioideae

Dracontium asperum K.Koch

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (pt),

C-Glycosylflavone: isovitexin xyloside, vitexin glucoside (lf) (Williams *et al.* 1981)

Dracontium asperum (as *Dracontium foecundum* Hook.f.) (Williams *et al.* 1981)

Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (sp, sx) (Williams *et al.* 1981)

Lasia spinosa (L.) Thwaites

Flavonol: quercetin 3-rutinoside (wp),

C-Glycosylflavone: vitexin, vitexin 2''-glucoside (wp) (Hong Van *et al.* 2006)

FLAVONOIDS IN THE SUBFAMILY AROIDEAE

The Aroideae is the largest subfamily of Araceae and consists of 70 genera. Flavonoids from 94 species of 35 genera were surveyed (Table 7). Of seven surveyed *Alocasia* species, anthocyanin, cyanidin 3-rutinoside was found in five species. Procyanidins and common flavonols, kaempferol and/or quercetin, were accompanied by anthocyanin in almost species (Williams *et al.* 1981). An acylated anthocyanin was isolated from the tubers of *A. cucullata* and identified as cyanidin 3-(6''-*E-p*-coumaroylglucoside)-5-(6''-malonylglucoside) (Figure 35) (Lei *et al.* 2014).

Figure 35. Cyanidin 3-(6''-*E-p*-coumaroylglucoside)-5-(6''-malonylglucoside)

Five *Amorphophallus* species were surveyed for their flavonoids. Of these species, *A. titanum* is the most well-known as the plant having the largest inflorescence among the plant kingdom, and the flavonoids of its spathe, and spadix and leaves were analyzed. The major flavonoids were anthocyanins and C-glycosylflavones, and identified as cyanidin 3-glucoside and 3-rutinoside, pelargonidin 3-coumaroylglucoside and 3-rhamnosylglucoside and peonidin 3-coumaroylglucoside, 3-glucoside and 3-rutinoside as anthocyanins, and isoorientin, orientin, schaftoside, isoschaftoside, vicenin-2, lucenin-2, vitexin and its 2''-glucoside, and isovitexin and its 2''-glucoside and X''-rhamnoside (Gallori *et al.* 2004, Iwashina *et al.* 2015, 2020). Two flavones and five flavonols were accompanied by C-glycosylflavones and identified as chrysoeriol 7-glucoside and luteolin 7-glucoside, and kaempferol 3-robinobioside (Figure 36), 3-rhamnosylarabinoside and 3-rutinoside, and quercetin 3-robinobioside and 3-rutinoside (Iwashina *et al.* 2015, 2020). Although similar anthocyanins, C-glycosylflavones and flavonols were obtained from the other two *Amorphophallus* species, i.e. *A. paeoniifolius* and *A. konjac* (Iwashina *et al.* 2015), a rare flavonol, 3,5-diacetyltambulin (7,8,4'-trimethoxy-3,5-diacetylflavone) was found in the former species (Khan *et al.* 2008). This flavonoid showed significant antibacterial activities against four Gram-positive bacteria (e.g. *Bacillus subtilis* and *Staphylococcus aureus*) and six Gram-negative bacteria (e.g. *Escheichia coli*, *Shigella sonnei*, *Pseudomonas aeruginosa*, and *Salmonella typhi*) (Khan *et al.* 2008).

Figure 36. Kaempferol 3-robinobioside

Three C-glycosylflavones, apigenin 6,8-di-C-galactoside (Figure 37), isocorymboside (Figure 38) and neocorymboside (Figure 39), were isolated from the rhizomes and tubers of *Arisaema erubescens*, together with isoschaftoside,

schaftoside and vicenin-2 (Du *et al.* 2005, 2011). Of their compounds, isoschaftoside and schaftoside showed the strong nematocidal activity against the root-knot nematode (*Meloidogyne incognita*) (Du *et al.* 2011).

Seven *Arum* taxa were surveyed for flavonoids. Although common C-glycosylflavones such as isovitexin, vitexin, isoorientin, orientin and rarely their O-glucosides were major flavonoids in *Arum* species, flavones e.g. apigenin, luteolin and chrysoeriol, flavonols e.g. quercetin and its 3-glycosides, and anthocyanins, cyanidin 3-glucoside and 3-rutinoside were scattered present (Phouphas 1956, Williams *et al.* 1981, Koleva 1982, 1984, Afifi *et al.* 2016). Polymethoxylated flavonol, quercetin 7,3',4'-trimethyl ether (Figure 40), was isolated from the aerial parts of *Arum palaestinum* (Farid *et al.* 2015). Of the flavonoids from *A. palaestinum*, each two of flavones and C-glycosylflavones, i.e. luteolin and chrysoeriol, and isoorientin and isovitexin, showed a significant high antiproliferative activity (Farid *et al.* 2015).

Figure 37. Apigenin 6,8-di-C-galactoside

Figure 38. Isocorymboside

Figure 39. Neocorymboside

Figure 40. Quercetin 7,3',4'-trimethyl ether

Six rare C-glycosylflavones were isolated from the leaves of *Asterostigma riedelianum*. They were characterized as apigenin 7,4'-dimethyl ether 6-C-arabinoside (Figure 41), 6,8-di-C-arabinoside (Figure 42), 6-C-arabinoside-2''-glucoside (Figure 43) and 6-C-arabinoside-2''-caffeoylglucoside, and isomolludistin 2''-glucoside (Figure 44) and 2''-caffeoylglucoside (Markham & Williams 1980).

Colocasia esculenta is widely cultivated in the world especially in tropical zone for its tubers (known as "taro"). The species was fully analyzed for flavonoids. Major flavonoids are C-glycosylflavones together with minor flavones, and many compounds were isolated, e.g. isoschaftoside, schaftoside, vicenin-2, isoorientin, orientin and its 7-glucoside, isovitexin and its 4'-glucoside, and apigenin, chrysoeriol, diosmetin, luteolin O-glycosides and so on (Iwashina *et al.* 1999, Leong *et al.* 2010, Ferreres *et al.* 2012, Li *et al.* 2014). Of their C-glycosylflavones, orientin and isoorientin significantly inhibited rat lens aldose reductase (Li *et al.* 2014). Anthocyanins, cyanidin 3-glucoside and 3-rhamnoside, and pelargonidin 3-glucoside, flavones, chrysoeriol and luteolin 7-glycosides, procyanidins and flavonol, quercetin, were accompanied by C-glycosylflavones, were also found in this species (Chan Jr. & Kao-Jao 1977, Williams *et al.* 1981, Iwashina *et al.* 1999).

Figure 41. Apigenin 7,4'-dimethyl ether 6-C-arabinoside

Figure 42. Apigenin 7,4'-dimethyl ether 6,8-di-C-arabinoside

Figure 43. Apigenin 7,4'-dimethyl ether 6-C-arabinoside-2''-glucoside

Figure 44. Isomolludistin 2''-glucoside

Nine *Cryptocoryne* species were surveyed for flavonoids. Vitexin 2''-glucoside (Figure 45) and sometimes 2''-glucoside-6''-E-sinapate were isolated from all species, except for *C. wendtii* (Franke *et al.* 2006). A rare sulfated C-glycosylflavone was isolated from *Culcasia saxatilis* and identified as vitexin 7-sulfate (Figure 46) (Williams *et al.* 1981). Two sulfated C-glycosylflavones were also isolated from *Philodendron ornatum* and identified as vitexin 7-sulfate and isovitexin 7-sulfate (Williams *et al.* 1981). Although 26 *Philodendron* species were surveyed for flavonoids and anthocyanins such as cyanidin 3-glycosides and rarely delphinidin, flavonols such as kaempferol, quercetin and isorhamnetin and procyanidins were found. They were roughly analyzed, except for *P. undulatum* containing four C-glycosylflavones (isorientin, orientin, isoschaftoside and schaftosife) and *P. saxicola* containing four flavonols (isorhamnetin 3-glucoside, isorhamnetin 3-rutinoside, quercetin 3-glucoside and quercetin 3-rutinoside), and apigenin and luteolin C-glycosides (Williams *et al.* 1981).

Figure 45. Vitexin 2''-glucoside

Figure 46. Vitexin 7-sulfate

Aquatic weed, *Pistia stratiotes*, contained flavones, chrysoeriol 4'-glucoside (Figure 47), luteolin and its 7-glycoside, and C-glycosylflavones, vitexin, orientin, and apigenin, luteolin 6,8-di-C-glycosides, and anthocyanin, cyanidin 3-glucoside (Zennie & McClure 1977, Liu *et al.* 2008, Tripathi *et al.* 2016). Six C-glycosylflavones, vitexin, vicenin-2, apigenin 6-C-glucoside-8-C-apiofuranoside, and isovitexin and its 6''-glucoside and 4'-rhamnoside, were isolated from the leaves of *Xanthosoma sagittifolium*, together with anthocyanin, cyanidin 3-rutinoside (Williams *et al.* 1981, Picerno *et al.* 2003). The fraction containing their C-glycosylflavones showed a significant antioxidant/free-radical scavenging activity (Picerno *et al.* 2003). Six C-glycosylflavones were isolated from *Zantedeschia aethiopica*, together with other flavonoids, apigenin, luteolin, kaempferol and quercetin, and identified as isoorientin, isovitexin, orientin, swertiajaponin (Figure 48), swertisin (Figure 49) and vitexin (Martens *et al.* 2003, Luzzatto *et al.* 2007, Nakayama *et al.* 2015). Of their C-glycosylflavones, isoorientin and swertiajaponin responded to low temperature-induced yellow pigmentation of the bracts of this species (Nakayama *et al.* 2015). Moreover, swertisin and isovitexin showed the antimicrobial activity against *Pectobacterium carotovorum* (Luzzatto *et al.* 2007).

Figure 47. Chrysoeriol 4'-glucoside

Figure 48. Swertiajaponin

Figure 49. Swertisin

Williams *et al.* (1981) analyzed the flavonoids of many Aroideae species, e.g. *Aglaonema modestum*, *Alocasia* spp., *Anchomanes* spp., *Anubias varteri* var. *glabra*, *Apoballis acuminatissima*, *Arophyton crassifolium*, *Caladium bicolor*, *Calla palustris*, *Carlephyton* spp., *Cercestis* spp., *Dracunculus* spp., *Eminium* spp., *Helicodiceros muscivorus*, *Homalomena* spp., *Peltandra virginica*, *Pinellia tripartita*, *Stylochaeton* spp., *Synandropadix vermitoxicus*, *Syngonium* spp., *Typhonium flagelliforme*, and *Typhonodorum lindleyanum*. Although anthocyanins, flavones, flavonols and proanthocyanidins were reported, they were insufficiently identified.

Table 7. Reports on the flavonoids from the species of subfamily Aroideae

<i>Aglaonema modestum</i> Schott ex Engl.
Flavan and Proanthocyanidin: procyanidin (lf) (Williams <i>et al.</i> 1981)
<i>Alocasia cucullata</i> (Lour.) G. Don
Anthocyanin: cyanidin 3-(6''-E-p-coumaroyl-glucoside)-5-(6''-malonylglucoside) (tb) (Lei <i>et al.</i> 2014)
<i>Alocasia cuprea</i> K. Koch
Anthocyanin: cyanidin 3-rutinoside (lf),
Flavonol: kaempferol, quercetin (lf) (Williams <i>et al.</i> 1981)

Alocasia lauterbachiana (Engl.) A.Hay (as *Xenophya lauterbachiana* (Engl.) Nicolson) (Williams *et al.* 1981)

Anthocyanin: cyanidin 3-rutinoside (lf),
Flavonol: quercetin (lf) (Williams *et al.* 1981)

Alocasia longiloba Miq. (as *Alocasia thibantiana* Mast.) (Williams *et al.* 1981)

Anthocyanin: cyanidin 3-rutinoside (lf),
Flavonol: kaempferol, quercetin (lf) (Williams *et al.* 1981)

Alocasia macrorrhizos (L.) G.Don (as *Alocasia macrorrhizos* var. *rubra* (Hassk.) Furtado) (Williams *et al.* 1981)

Anthocyanin: cyanidin 3-rutinoside (pt),
Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: quercetin (lf) (Williams *et al.* 1981)

Alocasia macrorrhizos (as *Alocasia macrorrhizos* var. *variegata* (K.Koch & C.D.Bouché) Furtado) (Williams *et al.* 1981)

Anthocyanin: cyanidin 3-rutinoside (pt),
Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: kaempferol, quercetin (lf) (Williams *et al.* 1981)

Alocasia macrorrhizos (as *Colocasia indica* (Lour.) Kunth) (Williams *et al.* 1981)

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Alocasia odora (Lindl.) K.Koch

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Alocasia portei Schott

Anthocyanin: cyanidin 3-rutinoside (pt) (Williams *et al.* 1981)

Amorphophallus abyssinicus (A.Rich.) N.E.Br.

Anthocyanin: cyanidin 3-rutinoside (sp) (Williams *et al.* 1981)

Amorphophallus konjac K.Koch

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside, peonidin 3-glucoside, peonidin 3-rutinoside, pelargonidin 3-rhamnosylglucoside (if),
Flavonol: quercetin 3-glucoside (if),
C-Glycosylflavone: isoorientin, isovitexin, orientin, vitexin 2''-xyloside (if) (Iwashina *et al.* 2015)

Amorphophallus paeoniifolius (Dennst.) Nicolson (*Amorphophallus campanulatus* Decne)

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-diglucoside, pelargonidin 3-glucoside (if) (Iwashina *et al.* 2015),
Flavonol: 3,5-diacetyltambulin, kaempferol 3-glucoside, quercetin, quercetin 3-glucoside (cr, if, tb) (Khan *et al.* 2008, Sharstry *et al.* 2010, Iwashina *et al.* 2015),
C-Glycosylflavone: isovitexin, orientin, schaftoside, vicenin-2, vitexin (if) (Iwashina *et al.* 2015)

Amorphophallus stuhlmannii (Engl.) Engl. & Gehrm.

Anthocyanin: cyanidin 3-rutinoside (sp) (Williams *et al.* 1981)

Amorphophallus titanum (Becc.) Becc.

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside, pelargonidin 3-coumaroylglucoside, pelargonidin 3-rhamnosylglucoside, peonidin 3-coumaroylglucoside, peonidin 3-glucoside, peonidin 3-rutinoside (sp, sx) (Gallori *et al.* 2004, Iwashina *et al.* 2015),
Flavone: chrysoeriol 7-glucoside (sp, sx) (Iwashina *et al.* 2015), luteolin 7-glucoside (lf) (Iwashina *et al.* 2020),
Flavonol: kaempferol 3-robinobioside, kaempferol 3-rhamnosylarabinoside, kaempferol 3-rutinoside, quercetin 3-robinobioside, quercetin 3-rutinoside (lf) (Iwashina *et al.* 2020),
C-Glycosylflavone: isoscoparin X''-glucoside, isovitexin 2''-glucoside, isovitexin X''-rhamnoside, vitexin 2''-glucoside (sp, sx) (Iwashina *et al.* 2015), isoorientin, isoschaftoside, isovitexin, lucenin-2, orientin, schaftoside, vicenin-2, vitexin (sp, sx, lf) (Iwashina *et al.* 2015, 2020)

Anchomanes abbreviatus Engl.

Anthocyanin: cyanidin 3-gentiobioside, pelargonidin 3-gentiobioside, pelargonidin 3-glucoside (fr) (Williams *et al.* 1981)

Anchomanes difformis (Blume) Engl.

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Anubias barteri Schott var. *glabra* N.E.Br. (*Anubias lanceolata* N.E.Br.) (Williams *et al.* 1981)

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Apoballis acuminatissima (Schott) S.Y.Wong & P.C.Boyce (as *Schismatoglottis concinna* Schott var. *immaculata* N.E.Br.) (Williams *et al.* 1981)

Anthocyanin: delphinidin 3-rutinoside (lf, pt),
Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: isorhamnetin, quercetin (lf) (Williams *et al.* 1981)

Arisaema erubescens (Wall.) Schott

C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neocorymboside, schaftoside, vicienin-2 (rz, tb) (Du *et al.* 2005, 2011)

Arisaema serratum (Thunb.) Schott

Anthocyanin: cyanidin 3,5-diglycoside (sp) (Ueno *et al.* 1969)

Arisarum vulgare O.Targ.Tozz.

C-Glycosylflavone: orientin, vitexin (lf) (Pagani 1982)

Arophyton crassifolium (Buchet) Bogner

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Arum dioscoridis Sm.

Flavone: apigenin, luteolin (fl, lf),
Flavonol: quercetin, quercetin 3-glucoside (fl, lf),
C-Glycosylflavone: isoorientin, vitexin (fl, lf) (Afifi *et al.* 2016)

Arum italicum Mill. subsp. *italicum*

Flavone: chrysoeriol, luteolin (lf) (Williams *et al.* 1981),
C-Glycosylflavone: isovitexin 7-glucoside (rz) (Phouphas 1956)

Arum italicum subsp. *neglectum* (F.Towns.) Prime

Flavone: chrysoeriol (lf) (Williams *et al.* 1981)

Arum maculatum L.

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside (sp, sx),
Flavone: chrysoeriol 7-glucoside, luteolin 7-glucoside (lf),
C-Glycosylflavone: apigenin di-C-glycoside, isoorientin, isovitexin, luteolin di-C-glycoside, orientin (lf) (Williams *et al.* 1981)

Arum orientale M.Bieb.

Flavone: apigenin (lf),
Flavonol: quercetin, quercetin 3-rhamnoside, quercetin 3-rutinoside (lf) (Koleva 1984),
C-Glycosylflavone: isoorientin, isovitexin, isovitexin 7-glucoside, orientin, vitexin (lf) (Koleva 1982, 1984)

Arum palaestinum Boiss.

Flavone: apigenin, chrysoeriol, luteolin (ap, fl, lf),
Flavonol: quercetin, quercetin 7,3',4'-trimethyl ether (ap, fl, lf) (Farid *et al.* 2015, Afifi *et al.* 2016),
C-Glycosylflavone: isoorientin, isovitexin, vitexin (ap, fl, lf) (Afifi *et al.* 1999, 2016, Farid *et al.* 2015)

Asterostigma riedelianum (Schott) Kuntze

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside (st) (Williams *et al.* 1981),
C-Glycosylflavone: apigenin 7,4'-dimethyl ether 6-c-arabinoside, apigenin 7,4'-dimethyl ether 6,8-di-C-arabinoside, apigenin 7,4'-dimethyl ether 6-C-arabinoside-2''-glucoside, apigenin 7,4'-dimethyl ether 6-C-arabinoside-2''-(caffeoylglucoside), isomolludistin 2''-(caffeoylglucoside), isomolludistin 2''-glucoside (lf) (Markham & Williams 1980, Williams *et al.* 1981)

Biarum tenuifolium (L.) Schott

Flavone: chrysoeriol, luteolin (lf) (Williams *et al.* 1981),
C-Glycosylflavone: isovitexin 7-glucoside (rz) (Phouphas 1956)

Caladium bicolor (Aiton) Vent.

Anthocyanin: cyanidin 3-rutinoside (lf),
Flavonol: quercetin (lf) (Williams *et al.* 1981)

Calla palustris L.

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Carlephyton glaucophyllum Bogner

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Carlephyton madagascariense Jum.

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Cercestis afzelii Schott

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Cercestis congoensis Engl.

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Cercestis mirabilis (N.E.Br.) Bogner (as

Rhektophyllum mirabile N.E.Br.) (Williams *et al.* 1981)

Anthocyanin: cyanidin 3-gentiobioside (pt),
Flavan and Proanthocyanidin: propelargonidin (lf) (Williams *et al.* 1981)

Colocasia esculenta (L.) Schott

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rhamnoside, pelargonidin 3-glucoside (cr) (Chan Jr. & Kao-Jao 1977),

Flavone: chrysoeriol 7-hexoside, chrysoeriol 7-rhamnosyl-(1→6)-hexoside, luteolin 7-glucoside, luteolin 7-rutinoside, luteolin 7-sophoroside (lf, st) (Iwashina *et al.* 1999, Leong *et al.* 2010, Ferreres *et al.* 2012, Li *et al.* 2014),

Flavan and Proanthocyanidin: procyanidin (lf),

Flavonol: quercetin (lf) (Williams *et al.* 1981),

C-Glycosylflavone: apigenin 6-C-hexoside-6''-hexoside, apigenin 8-C-pentoside-2''-hexoside, apigenin 6-C-hexoside-2''-hexoside-8-C-pentoside, apigenin 6-C-pentoside-8-C-hexoside-7-hexoside, apigenin 6-C-pentoside-8-C-hexoside-2''-hexoside, chrysoeriol 6-C-hexoside, chrysoeriol 8-C-hexoside, chrysoeriol 6-C-hexoside-8-C-pentoside, diosmetin 6-C-hexoside-8-C-pentoside, isoschaftoside, isovitexin, isovitexin 4'-glucoside, isoorientin, luteolin 6-C-hexoside-6''-hexoside, luteolin 6-C-hexoside-3''-hexoside-8-C-pentoside, luteolin 6,8-di-C-hexoside, luteolin 6-C-hexoside-2''-pentoside, luteolin 6-C-hexoside-8-C-pentoside, luteolin 6-C-pentoside-8-C-hexoside, orientin, orientin 7-glucoside, schaftoside, vicianin-2, vitexin, vitexin X''-glucoside (lf, st) (Iwashina *et al.* 1999, Leong *et al.* 2010, Ferreres *et al.* 2012, Li *et al.* 2014)

Cryptocoryne albida R.Parker

C-Glycosylflavone: vitexin 2''-glucoside-6''-E-sinapate, vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Cryptocoryne crispatula Engl.

C-Glycosylflavone: vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Cryptocoryne pontederiifolia Schott

C-Glycosylflavone: vitexin 2''-glucoside-6''-E-sinapate, vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Cryptocoryne retrospiralis (Roxb.) Kunth

C-Glycosylflavone: vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Cryptocoryne spiralis (Retz.) Fisch. ex Wydler

C-Glycosylflavone: vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Cryptocoryne usteriana Engl.

C-Glycosylflavone: vitexin 2''-glucoside-6''-E-sinapate, vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Cryptocoryne vietnamensis I.hertel & H.Mühlberg

C-Glycosylflavone: vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Cryptocoryne wendtii de Wit

Flavone: chrysoeriol, luteolin (lf) (Williams *et al.* 1981)

Cryptocoryne xwillisii Reitz

C-Glycosylflavone: vitexin 2''-glucoside (lf) (Franke *et al.* 2006)

Culcasia scandens P.Beauv. (as *Culcasia saxatilis*

A.Chev.) (Williams *et al.* 1981)

C-Glycosylflavone: vitexin 7-sulfate (lf) (Williams *et al.* 1981)

Dracunculus canariensis Kunth

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside (sp),

Flavone: chrysoeriol, luteolin (lf) (Williams *et al.* 1981)

Dracunculus vulgaris Schott (as *Arum dracunculus* L.) (Proliac *et al.* 1992)

C-Glycosylflavone: isoorientin, orientin, vitexin (lf) (Proliac *et al.* 1992)

Eminium regelii Vved.

Flavone: luteolin (lf),

Flavonol: quercetin (lf) (Silybayeva *et al.* 2014)

Eminium spiculatum (Blume) Schott

Flavone: chrysoeriol 7-glucoside, luteolin, luteolin 7-glucoside (lf),

C-Glycosylflavone: isoorientin, vitexin (lf) (Afifi & Abu-Dahab 2012)

Helicodicerus muscivorus (L.f.) Engl.

Anthocyanin: cyanidin 3-rutinoside (sp) (Williams *et al.* 1981)

Homalomena pendulata (Blume) Bakh.f. (as

Homalomena coerulescens Jungh. ex Miq.)

(Williams *et al.* 1981)

Flavan and Proanthocyanidin: procyanidin (lf) (Williams *et al.* 1981)

Homalomena rubescens (Roxb.) Kunth

Anthocyanin: cyanidin 3-glucoside (lf, pt),

Flavonol: quercetin (lf) (Williams *et al.* 1981)

Peltandra virginica (L.) Schott

Flavan and Proanthocyanidin: procyanidin (lf),

Flavonol: quercetin (lf) (Williams *et al.* 1981)

Philodendron auriculatum Standl. & L.O.Williams

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron crassinervium Lindl.

Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: isorhamnetin, kaempferol, quercetin
(lf) (Williams *et al.* 1981)

Philodendron erubescens K.Koch & Augustin

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-
rutinoside (pt, sp, sx),
Flavonol: quercetin (lf) (Williams *et al.* 1981)

Philodendron fendleri K.Krause

Anthocyanin: cyanidin, delphinidin (sp) (Forsyth
& Simmonds 1954)

Philodendron giganteum Schott

Anthocyanin: cyanidin (sp) (Forsyth & Simmonds
1954)

Philodendron goeldii G.M.Barroso

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron hastatum K.Koch & Sello

Anthocyanin: cyanidin 3-glucoside, cyanidin 3-
rutinoside (sp),
Flavonol: quercetin 3-glucoside (sp) (Alfa *et al.*
1987)

Philodendron hederaceum (Jacq.) Schott (as

Philodendron scandens K.Koch & F.Sello subsp.
prieurianum (Schott) G.S.Bunting) (Williams *et al.*
1981)

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron hederaceum as *Philodendron*
scandens subsp. *scandens* in Williams *et al.* (1981)

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron imbe Schott & Kunth

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron insigne Schott

Anthocyanin: cyanidin 3-rutinoside (lf),
Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: kaempferol, quercetin (lf) (Williams *et al.*
1981)

Philodendron latifolium K.Koch

Anthocyanin: cyanidin, delphinidin (sp) (Forsyth
& Simmonds 1954)

Philodendron leal-costae Mayo & G.M.Barroso

Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: kaempferol, quercetin (lf) (Williams *et al.*
1981)

Philodendron linnaei Kunth

Anthocyanin: cyanidin 3-rutinoside (lf),
Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: kaempferol, quercetin (lf) (Williams *et al.*
1981)

Philodendron longilaminatum Schott

Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: kaempferol, quercetin (lf) (Williams *et al.*
1981)

Philodendron melanochrysum Linden & André

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron melinonii Brongn. & Regel

Anthocyanin: cyanidin 3-glucoside (lf),
Flavonol: isorhamnetin, quercetin (lf) (Williams
et al. 1981)

Philodendron ornatum Schott

Anthocyanin: cyanidin 3-glucoside (lf),
C-Glycosylflavone: isovitexin 7-sulfate, vitexin 7-
sulfate (lf) (Williams *et al.* 1981)

Philodendron pachyphyllum K.Krause

Flavonol: quercetin (lf) (Williams *et al.* 1981)

Philodendron pedatum (Hook.) Kunth

Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: quercetin (lf) (Williams *et al.* 1981)

Philodendron radiatum Schott

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron saxicola K.Krause

Flavan and Proanthocyanidin: procyanidin (lf),
Flavonol: isorhamnetin 3-glucoside,
isorhamnetin 3-rutinoside, quercetin 3-glucoside,
quercetin 3-rutinoside (lf),
C-Glycosylflavone: apigenin di-C-glycoside,
luteolin di-C-glycoside, luteolin C-glycoside (lf)
(Williams *et al.* 1981)

Philodendron simsii (Hook.) Sweet ex Kunth

Flavan and Proanthocyanidin: procyanidin (lf)
(Williams *et al.* 1981)

Philodendron smithii Engl.

Flavan and Proanthocyanidin: procyanidin (lf),

<p>C-Glycosylflavone: isoschaftoside, schaftoside (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Philodendron squamiferum</i> Poepp.</p> <p>Anthocyanin: cyanidin 3-rutinoside (pt) (Williams <i>et al.</i> 1981)</p> <p><i>Philodendron undulatum</i> Engl. (as <i>Philodendron eichleri</i> Engl.) (Williams <i>et al.</i> 1981)</p> <p>Flavan and Proanthocyanidin: procyanidin (lf), C-Glycosylflavone: isoorientin, isoschaftoside, orientin, schaftoside (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Philodendron verrucosum</i> L.Mathieu ex Schott</p> <p>Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside (lf, pt) (Williams <i>et al.</i> 1981)</p> <p><i>Pinellia tripartita</i> (Blume) Schott</p> <p>Anthocyanin: cyanidin 3-rutinoside (st) (Williams <i>et al.</i> 1981)</p> <p><i>Pistia stratiotes</i> L.</p> <p>Anthocyanin: cyanidin 3-glucoside (wp) (Zennie & McClure 1977, Tripathi <i>et al.</i> 2016), Flavone: chrysoeriol 4'-glucoside, luteolin, luteolin 7-glycoside (wp) (Zennie & McClure 1977, Liu <i>et al.</i> 2008, Tripathi <i>et al.</i> 2016), C-Glycosylflavone: apigenin 6,8-di-C-glycoside, luteolin 6,8-di-C-glycoside, orientin, vitexin (wp) (Zennie & McClure 1977, Tripathi <i>et al.</i> 2016)</p> <p><i>Sauromatum giganteum</i> (Engl.) Cusimano & Hett. (as <i>Typhonium giraldui</i> (Baroni) Engl.) (Williams <i>et al.</i> 1981)</p> <p>Anthocyanin: cyanidin 3-rutinoside (st), Flavone: chrysoeriol, luteolin (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Stylochaeton borumensis</i> N.E.Br.</p> <p>Flavonol: quercetin (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Stylochaeton lancifolius</i> Kotschy & Peyr.</p> <p>Anthocyanin: cyanidin 3-rutinoside (st), Flavan and Proanthocyanidin: procyanidin (lf), Flavonol: kaempferol, quercetin (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Synandropadix vermitoxicus</i> (Griseb.) Engl.</p> <p>C-Glycosylflavone: isoorientin, isovitexin, isovitexin 7-glucoside, orientin, vitexin (lf) (Sosa <i>et al.</i> 1978)</p> <p><i>Syngonium auritum</i> (L.) Schott</p> <p>Flavan and Proanthocyanidin: procyanidin (lf) (Williams <i>et al.</i> 1981)</p>	<p><i>Syngonium podophyllum</i> Schott</p> <p>C-Glycosylflavone: isoschaftoside (lf) (Gomes <i>et al.</i> 2014)</p> <p><i>Typhonium flagelliforme</i> (Lodd.) Blume</p> <p>C-Glycosylflavone: isovitexin (lf) (Farida <i>et al.</i> 2012)</p> <p><i>Typhonodorum lindleyanum</i> Schott</p> <p>Anthocyanin: cyanidin 3-glucoside, cyanidin 3-rutinoside (lf), Flavan and Proanthocyanidin: procyanidin (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Xanthosoma brasiliense</i> (Desf.) Engl.</p> <p>Flavonol: quercetin (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Xanthosoma helleborifolium</i> (Jacq.) Schott</p> <p>Anthocyanin: cyanidin 3-rutinoside, pelargonidin 3-rutinoside (st) (Williams <i>et al.</i> 1981)</p> <p><i>Xanthosoma sagittifolium</i> (L.) Schott</p> <p>Flavan and Proanthocyanidin: procyanidin (lf) (Williams <i>et al.</i> 1981)</p> <p><i>Xanthosoma sagittifolium</i> (as <i>Xanthosoma violaceum</i> Schott) (Williams <i>et al.</i> 1981, Picerno <i>et al.</i> 2003)</p> <p>Anthocyanin: cyanidin 3-rutinoside (lf) (Williams <i>et al.</i> 1981), C-Glycosylflavone: apigenin 6-C-glucoside-8-C-apiofuranoside, isovitexin, isovitexin 6''-glucoside, isovitexin 4'-rhamnoside, vitexin, vicenin-2 (lf) (Picerno <i>et al.</i> 2003)</p> <p><i>Zantedeschia aethiopica</i> (L.) Spreng.</p> <p>Flavan and Proanthocyanidin: procyanidin (fl), Flavone: apigenin, luteolin (fl), Flavonol: kaempferol, quercetin (fl) (Martens <i>et al.</i>, 2003), C-Glycosylflavone: isoorientin, isovitexin, orientin, swertiajaponin, swertisin, vitexin (fl, lf, sp) (Martens <i>et al.</i> 2003, Luzzatto <i>et al.</i> 2007, Nakayama <i>et al.</i> 2015)</p>
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FLAVONOIDS IN THE FAMILY ACORACEAE

Although the genus *Acorus* is now erected to its own family, it used to be a member of the Araceae. Of two *Acorus* species, *A. calamus* was surveyed for flavonoids and a C-glycosylflavone, lucenin-2 (Figure 50), was found (Él'yashevich *et al.* 1974).

Figure 50. Lucenin-2

Table 8. Reports on the flavonoids from the species of the family Acoraceae

Acorus calamus L.

C-Glycosylflavone: Lucenin-2 (ap) (Él'yashevich et al. 1974)

The occurrence of flavonoid classes among the genera of Araceae and the related Acoraceae was shown in Table 9. The presence of anthocyanins, flavones, C-glycosylflavones, flavonols, flavan and proanthocyanidins, flavanones and C-glycosylflavanone were recognized. However, dihydroflavonol, chalcone, dihydrochalcone, aurone, isoflavonoid, and so on were not reported as far as I know. C-Glycosylflavones seem to be major flavonoids in the Araceae. Although Williams *et al.* (1981) showed the presence of C-

glycosylflavones in almost species, they were not isolated and characterized. Of six subfamilies of the Araceae, C-glycosylflavones were not found in Gymnostachydoideae and Orontioideae. Instead, flavonols were major flavonoids in both subfamilies. In subfamily Lemnoideae, flavones and flavonols occurred in the genera *Lemna*, *Spirodela* and *Wolffia*. On the other hand, flavonols was absent in *Wolffia*. Flavan and proanthocyanidins were also major flavonoids and present in 46 species. They were procyanidins except for propelargonidin in *Cercestis mirabilis* (as *Rhektophyllum mirabile*), but insufficiently identified (Williams *et al.* 1981). Subfamily Lemnoideae was not surveyed for flavan and proanthocyanidins except for *Spirodela punctata*. Flavanones were isolated from *Spirodela polyrrhyza* in subfamily Lemnoideae and *Anthurium binotii* in subfamily Pothodeae, and identified as eriodictyol and hesperetin 7-glucosides (Quiao *et al.* 2011), and hesperetin 7-rutinoside (Brunswik 1921), respectively. C-Glycosylflavanone was isolated from *Spirodela polyrrhyza* and identified as naringenin 6,8-di-C-glucoside (Quiao *et al.* 2011). The family Araceae s.l. (including Lemnaceae) consists of more than 3645 species of ca. 144 genera (Boyce & Croat 2011 onwards). However, flavonoids were surveyed in 146 species of 48 genera only. Further flavonoid survey must be performed in the Araceae.

Table 9. The occurrence of flavonoid classes among the genera of Araceae

	No.	An	Fv	Fn	CG	FP	Fa	Cf
Subfamily Gymnostachydoideae								
<i>Gymnostachys</i>	1			1				
Subfamily Orontioideae								
<i>Lysichiton</i>	1			1				
<i>Orontium</i>	1			1				
<i>Symplocarpus</i>	2	1		2				
Subfamily Lemnoideae								
<i>Lemna</i>	8	3	4		8			
<i>Spirodela</i>	3	3	3	3	3	1	1	1
<i>Wolffia</i>	5		3	2	3			
<i>Wolffillea</i>	3			3				
Subfamily Pothoideae								
<i>Anthurium</i>	22	16	2	5	3	8	1	
<i>Pothos</i>	1		1		1			
Subfamily Monsteroideae								
<i>Scindapsus</i>	1		1	1				
Subfamily Lasioideae								
<i>Dracontium</i>	1	1			1			
<i>Lasia</i>	1			1	1			
Subfamily Aroideae								
<i>Aglaonema</i>	1					1		
<i>Alocasia</i>	7	6		4		2		
<i>Amorphophallus</i>	5	5	1	3	3			
<i>Anchomanes</i>	2	1				1		
<i>Anubias</i>	1					1		
<i>Apobalis</i>	1	1		1		1		
<i>Arisaema</i>	2	1			1			
<i>Arisarum</i>	1				1			
<i>Arophyton</i>	1					1		
<i>Arum</i>	6	1	6	3	5			
<i>Asterostigma</i>	1	1			1			
<i>Biarum</i>	1		1		1			
<i>Caladium</i>	1	1		1				
<i>Calla</i>	1					1		
<i>Carlephyton</i>	2					2		
<i>Cercestis</i>	3	1				3		
<i>Colocasia</i>	1	1	1	1	1	1		
<i>Cryptocoryne</i>	9		1		8			
<i>Culcasia</i>	1				1			
<i>Dracunculus</i>	2	1	1		1			
<i>Eminium</i>	2		2	1	1			
<i>Helicodiceros</i>	1	1						
<i>Homalomena</i>	2	1		1		1		
<i>Peltandra</i>	1			1		1		
<i>Philodendron</i>	26	11		11	4	16		
<i>Pinellia</i>	1	1						
<i>Pistia</i>	1	1	1		1			
<i>Sauromatum</i>	1	1	1					
<i>Stylochaeton</i>	2	1		2		1		
<i>Synandropadix</i>	1				1			
<i>Syngonium</i>	2				1	1		
<i>Typhonium</i>	1				1			
<i>Typhonodorum</i>	1	1				1		
<i>Xanthosoma</i>	3	2		1	1	1		
<i>Zanthodeschia</i>	1		1	1	1	1		
Family Acoraceae								
<i>Acorus</i>	1				1			
Total	146	64	30	51	55	46	2	1

No. = number of the species from which flavonoids were reported. An = anthocyanins, Fv = flavones, Fn = flavonols, CG = C-glycosylflavones, FP = flavan and proanthocyanidins, Fa = flavanones and Cf = C-glycosylflavanone.

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REFERENCES

- Afifi FU, Khalil E, Abdalla S. 1999. Effect of isoorientin isolated from *Arum palaestinum* on uterine smooth muscle of rats and guinea pigs. *Journal of Ethnopharmacology* 65: 173–177.
- Afifi FU, Abu-Dahab R. 2012. Phytochemical screening and biological activities of *Eminium spiculatum* (Blume) Kuntze (family Araceae). *Natural Product Research* 26(9): 878–882.
- Afifi FU, Kasabri V, Litescu SC, Abaza IM. 2016. In vitro and in vivo comparison of the biological activities of two traditionally and widely used *Arum* species from Jordan: *Arum dioscoridis* Sibth & Sm. and *Arum palaestinum* Boiss. *Natural Product Research* 30(16): 1777–1786.
- Akhtar TA, Lees HA, Lampi MA, Enstone D, Brain RA, Greenberg BM. 2010. Photosynthetic redox imbalance influences flavonoid biosynthesis in *Lemna gibba*. *Plant, Cell and Environment* 33: 1205–1219.
- Alfa M, Maccarone E, d'Alcontres GS. 1987. The anthocyanins of *Philodendron hastatum*. *Annali di Chimica* 77: 691–695.
- Andersen ØM, Markham KR (eds.). 2006. *Flavonoids. Chemistry, Biochemistry and Applications*. Taylor and Francis, Boca Raton.
- Aquino R, Morelli S, Lauro MR, Abdo S, Saija A, Tomaino A. 2001. Phenolic constituents and antioxidant activity of an extract of *Anthurium versicolor* leaves. *Journal of Natural Products* 64(8): 1019–1023.
- Bai HH, Wang NN, Mi J, Yang T, Fang DM, Wu LW, Zhao H, Li GY. 2018. Hydroxycinnamoyl-malated flavone C-glycosides from *Lemna japonica*. *Fitoterapia* 124: 211–216.
- Boyce PC, Croat TB. (2011 onwards). The Überlist of Araceae, totals for published and estimated number of species in Aroid Genera. <http://www.aroid.org/genera/180211uberlist.pdf>
- Brunswik H. 1921. Über Hesperidinsphärite im lebenden Hauptgewebe von *Anthurium binotii* Linden. *Berichte der Deutschen Botanischen Gesellschaft* 39: 208–212.
- Chang N, Collins RP, Knaak LE. 1970. Anthocyanins in *Symplocarpus foetidus* (L.) Nutt. (Araceae). *Botanical Journal of the Linnean Society* 63: 95–96.
- Chan Jr. HT, Kao-Jao THC. 1977. Anthocyanin composition of taro. *Journal of Food Science* 42: 19–21.
- Clark BR, Suzuki JY, Bliss BJ, Borris RP. 2012. Flavone C-glycosides from *Anthurium andraeanum*. *Natural Product Communications* 7(6): 747–748.
- Cody V, Middleton Jr. E, Harborne JB (eds.). 1986. *Plant Flavonoids in Biology and Medicine. Biochemical, Pharmacological, and Structure-activity Relationship*. Alan R. Liss, Inc. New York.
- Cody V, Middleton Jr. E, Harborne JB, Beretz A (eds.). 1988. *Plant Flavonoids in Biology and Medicine II. Biochemical, Cellular, and Medicinal Properties*. Alan R. Liss, Inc. New York.
- Du SS, Lei N, Xu YC, Wei LX. 2005. Study on flavonoids of *Arisaema erubescens*. *Journal of Chinese Pharmaceutical Journal* 40(19): 1457–1459.
- Du SS, Zhang HM, Bai CQ, Wang CF, Liu QZ, Liu ZL, Wang YY, Deng ZW. 2011. Nematocidal flavone-C-glycosides against the root-knot nematode (*Meloidogyne incognita*) from *Arisaema erubescens* tubers. *Molecules* 16: 5079–5086.
- Él'yashevich EG, Drozd GA, Koreshchuk KE, Bezuglaya NI, Manych VI, Shestak LI. 1974. *Acorus calamus* – A new source of C-diglycosides. *Chemistry of Natural Compounds* 10: 96–97.
- Farid MM, Hussein SR, Ibrahim LF, El Desouky MA, Elsayed AM, El Oqlah AA, Saker MM. 2015. Cytotoxic activity and phytochemical analysis of *Arum palaestinum* Boiss. *Asian Pacific Journal of Tropical Biomedicine* 5(11): 944–947.
- Farida Y, Wahyudi PS, Wahono S, Hanafi M. 2012. Flavonoid glycoside from the ethyl acetate extract of Keladi tikus *Typhonium flagelliforme* (Lodd) Blume leaves. *Asian*

- Journal of Natural and Applied Sciences 1(4): 16–21.
- Ferreres F, Gonçalves RF, Gil-Izquierdo A, Valentão P, Silva AMS, Silva JB, Santos D, Andrade PB. 2012. Further knowledge on the phenolic profile of *Colocasia esculenta* (L.) Schott. Journal of Agricultural and Food Chemistry 60: 7005–7015.
- Forsyth WGC, Simmonds NW. 1954. A survey of the anthocyanins of some tropical plants. Proceedings of the Royal Society of London, Series B 142: 549–564.
- Franke K, Hoffmann M, Schmidt J, Porzel A, Arnold N, Wessjohann L. 2006. 2''-O-Glucosyl-vitexin, a chemotaxonomic marker for the genus *Cryptocoryne* (Araceae). Biochemical Systematics and Ecology 34: 546–548.
- Gallori S, Giccherini C, Bilia AR, Mulinacci N, Vincieri FF. 2004. Identification of anthocyanins in *Amorphophallus titanum* (Becc.) Becc. Chromatographia 59(9/10): 647–651.
- Gomes ACC, da Silva Sampaio L, da Silva PA, Lamas ME, Sakuragui CM, Junior CBB, Simas NK, Kuster RM. 2014. In vitro effect of isoschaftoside isolated from *Syngonium podophyllum* on pig kidney Na⁺, K⁺-atpase. Quimica Nova 37(10): 1606–1609.
- Harborne JB, Mabry TJ, Mabry H (eds.). 1975. The Flavonoids. Chapman and Hall, London.
- Harborne JB, Mabry TJ (eds.). 1982. The Flavonoids: Advances in Research. Chapman and Hall, London.
- Harborne JB (ed.). 1988. The Flavonoids. Advances in Research since 1980. Chapman and Hall, London.
- Harborne JB. (ed.). 1994. The Flavonoids. Advances in Research since 1986. Chapman and Hall, London.
- Hong Van NT, Minh CV, De Leo M, Siciliano T, Braca A. 2006. Secondary metabolites from *Lasia spinosa* (L.) Thw. (Araceae). Biochemical Systematics and Ecology 34: 882–884.
- Iwashina T, Konishi T, Takayama A, Fukuda M, Ootani S. 1999. Isolation and identification of the flavonoids in the leaves of taro. Annals of the Tsukuba Botanical Garden 18: 71–74.
- Iwashina T. 2000. The structure and distribution of the flavonoids in plants. Journal of Plant Research 113: 287–299.
- Iwashina T. 2003. Flavonoid function and activity to plants and other organisms. Biological Sciences in Space 17(1): 24–44.
- Iwashina T, Peng CI, Kokubugata G. 2010. Flavone O- and C-glycosides from *Pothos chinensis* (Araceae). Bulletin of the National Museum of Nature and Science, Series B 36(1): 27–32.
- Iwashina T, Uehara A, Kitajima J, Yukawa T. 2015. Anthocyanins and other flavonoids from *Amorphophallus titanum* having largest inflorescence in plant kingdom, and other two species. Bulletin of the National Museum of Nature and Science, Series B 41(1): 33–44.
- Iwashina T, Destri, Rahayu S, Tsutsumi C, Yuzammi, Mizuno T, Widyatmoko D. 2020. Flavonoids and xanthones from the leaves of *Amorphophallus titanum* (Araceae). Biochemical Systematics and Ecology. DOI: <https://doi.org/10.1016/j.bse.2020.104036>
- Iwata RY, Tang CS, Kamemoto H. 1979. Anthocyanins of *Anthurium andreanum* Lindl. Journal of the American Society for Horticultural Science 104(4): 464–466.
- Jurd L, Geissman TA, Seikel MK. 1957. The flavonoid constituents of *Spirodela oligorrhiza*. II. The flavone constituents. Archives of Biochemistry and Biophysics 67: 284–297.
- Khan A, Rahman M, Islam MS. 2008. Antibacterial, antifungal and cytotoxic activities of 3,5-diacetyltambulin isolated from *Amorphophallus campanulatus* Blume ex Decne. Daru 16(4): 239–244.
- Kim J, Lee I, Seo J, Jung MY, Kim Y, Yim N, Bae K. 2010. Vitexin, orientin and other flavonoids from *Spirodela polyrrhiza* inhibit adipogenesis in 3T3-L1 cells. Phytotherapy Research 24: 1543–1548.
- Koleva M. 1982. Assessment of the polyphenol content in *Arum orientale* M.B. leaves. Problemi na Farmatsiia 10: 53–57.
- Koleva M. 1984. Assessment of the polyphenol composition of *Arum orientale* M.B. Problemi na Farmatsiia 12: 35–38.
- Krause J, Strack D. 1979. Malonyl cyanidin 3-monoglucoside in *Spirodela polyrrhiza* (L.) Schleiden. Zeitschrift für Pflanzenphysiologie 95: 183–187.
- Lei X, Feng Y, Liang S, Zheng XW. 2014. Chemical components of the tuber of *Alocasia cucullata*. Chemistry of Natural Compounds

- 50(1): 133–134.
- Leong ACN, Kinjo Y, Tako M, Iwasaki H, Oku H, Tamaki H. 2010. Flavonoid glycosides in the shoot system of Okinawa Taumu (*Colocasia esculenta* S.). Food Chemistry 119: 630–635.
- Li C, Yang G, Huang S, Lü D, Wang C, Chen J, Yin J. 2013. Characterization of flavonoids in *Anthurium* spathes and their contribution to spathe colouration. Journal of Horticultural and Biotechnology 88(2): 208–215.
- Li HM, Hwang SH, Kang BG, Hong JS, Lim SS. 2014. Inhibitory effects of *Colocasia esculenta* (L.) Schott constituents on aldose reductase. Molecules 19: 13212–13224.
- List PH., Freud B. 1968. Geruchsstoffe der Stinkmorchel, *Phallus impudicus* L. 18. Mitteilung über Pilzinhaltsstoffe. Planta Medica (Supplement) 123–132.
- Liu HW, He LY, Gao JM, Ma YB, Zhang XM, Peng H, Chen JJ. 2008. Chemical constituents from the aquatic weed *Pistia stratiotes*. Chemistry of Natural Compounds 44(2): 236–238.
- Liu X, Wang CY, Shao CL, Wei YX, Wang BG, Sun LL, Zheng CJ, Guan HS. 2009. Chemical constituents from *Sargassum pallidum* (Turn) C.Agardh. Biochemical Systematics and Ecology 37: 127–129.
- Luzzatto T, Golan A, Yishay M, Bilkis I, Ben-Ari J, Yedidia I. 2007. Priming of antimicrobial phenolics during induced resistance response towards *Pectobacterium carotovorum* in the ornamental monocot calla lily. Journal of Agricultural and Food Chemistry 55(25): 10315–10322.
- Markham KR, Williams CA. 1980. C-Arabinosylapigenin methyl ethers from *Asterostigma riedelianum*. Phytochemistry 19: 2789–2791.
- Martens S, Knott J, Seitz CA, Janvari L, Yu SN, Forkmann G. 2003. Impact of biochemical pre-studies on specific metabolic engineering strategies of flavonoid biosynthesis in plant tissues. Biochemical Engineering Journal 14: 227–235.
- McClure JW, Alston RE. 1966. A chemotaxonomic study of Lemnaceae. American Journal of Botany 53(9): 849–860.
- McClure JW. 1968. Photocontrol of *Spirodela intermedia* flavonoids. Plant Physiology 43: 193–200.
- Nakayama M, Koshioka M, Kondo T, Imizu K. 2015. Flavone C-glucosides responsible for yellow pigmentation induced by low temperature in bracts of *Zanthodeschia aethiopics*. Natural Product Communications 10(3): 425–427.
- Ohba R, Igarashi K, Tsukui A. 2000. Anthocyanins. Food Color with Health Benefits. Kenpousha, Tokyo.
- Pagani F. 1982. Fitoconstituenti dell'*Arisarum vulgare* O. Targ.-Tozz. (Araceae). Bollettino Chimico Farmaceutico 121: 460–464.
- Phouphas MC. 1956. Sur la presence de saponaroside chez certaines Aracées. Comptes Rendus de l'Académie des Sciences, Paris 242: 1641–1643.
- Picerno P, Mencherini T, Lauro MR, Barbato F, Aquino R. 2003. Phenolic constituents and antioxidant properties of *Xanthosoma violaceum* leaves. Journal of Agricultural and Food Chemistry 51(22): 6423–6428.
- Proliac A, Chaboud A, Raynaud J. 1992. Isolement et identification de trois C-glycosylflavones dans les tiges feuillées d'*Arum dracunculus*. Die Pharmazie 47(8): 646–647.
- Quiao X, He W, Xiang C, Han J, Wu L, Guo D, Ye M. 2011. Qualitative and quantitative analysis of flavonoids in *Spirodela polyrrhiza* by high-performance liquid chromatography coupled with mass spectrometry. Phytochemical Analysis 22: 475–483.
- Reznik H, Menschick R. 1969. Flavonoide in Sommergliedern und Winterknospen von *Spirodela polyrrhiza* (L.) Schleid. Zeitschrift für Pflanzenphysiologie 61: 348–349.
- Rice-Evans CA, Packer L. 1998. Flavonoids in Health and Disease. Marcel Dekker, Inc., New York.
- Saunders JA, McClure JW. 1976. The distribution of flavonoids in chloroplasts of twenty five species of vascular plants. Phytochemistry 15(5): 809–810.
- Sharstry RA, Biradar SM, Mahadevan KM, Habbu PV. 2010. Isolation and characterization of secondary metabolite from *Amorphophallus paeoniifolius* for hepatoprotective activity. Research Journal of Pharmaceutical, Biological and Chemical Sciences 1(4): 429–437.
- Silybayeva B, Zharykbasova K, Musabayeva B, Omargalieva N, Kaygusuz O. 2014. Biologically active agents of *Eminium regelii*

- leaves and tubers grown in Kazakhstan. *Bothalia Journal* 44(5): 156–160.
- Sosa VE, Oberti JC, Juliani HR. 1978. Flavonoids of *Synandropadix vermitoxicus*. *Lloydia* 41(3): 277–278.
- Tripathi P, Kumar R, Sharma AK, Mishra A, Gupta R. 2016. *Pistia stratiotes* (Jalkumbhi). *Pharmacognosy Reviews* 4(8): 153–160.
- Ueno N, Takemura E, Hayashi K. 1969. Additional data for the paperchromatographic survey of anthocyanins in the flora of Japan (IV). Studies on anthocyanins, LXI. *Botanical Magazine, Tokyo* 82: 155–161.
- Veen J. 1975. Preliminary studies of the flavonoid pattern of *Lemna gibba* L. and *Lemna minor* L. *Aquatic Botany* 1: 417–421.
- Vladimirova IN, Georgiyants VA. 2013. Biologically active compounds from *Lemna minor* S.F. Gray. *Pharmaceutical Chemistry Journal* 47(11): 599–601.
- Wallace JW, Alston RE. 1966. C-Glycosylation of flavonoids. *Plant and Cell Physiology* 7: 699–700.
- Wallace JW, Mabry TJ, Alston RE. 1969. On the biogenesis of flavone O-glycosides and C-glycosides in the Lemnaceae. *Phytochemistry* 8(1): 93–99.
- Wallace JW. 1975. Biosynthetic studies on flavones and C-glycosylflavones: B-ring oxidation patterns. *Phytochemistry* 14(8): 1765–1768.
- Wang N, Xu G, Fang Y, Yang T, Zhao H, Li G. 2014a. New flavanol and cycloartane glucosides from *Landoltia punctata*. *Molecules* 19: 6623–6634.
- Wang N, Fang Y, Yang T, Li G, Zhao H. 2014b. Chemical constituents of *Wolffia globosa*. *Chinese Journal of Applied and Environmental Biology* 20(6): 1016–1019.
- Whang WK, Lee MT. 1999. New flavonol glycosides from leaves of *Symplocarpus renifolius*. *Archives of Pharmacal Research* 22(4): 423–429.
- Williams CA, Harborne JB, Clifford HT. 1971. Flavonoid patterns in the monocotyledons. Flavonols and flavones in some families associated with the Poaceae. *Phytochemistry* 10(5): 1059–1063.
- Williams CA, Harborne JB, Mayo SJ. 1981. Anthocyanin pigments and leaf flavonoids in the family Araceae. *Phytochemistry* 20(2): 217–234.
- Zeng LM, Wang CJ, Su JY, Li D, Owen NL, Lu Y, Lu N, Zheng QT. 2001. Flavonoids from the red algae *Acanthophora spicifera*. *Chinese Journal of Chemistry* 19: 1097–1100.
- Zennie TM, McClure JW. 1977. The flavonoid chemistry of *Pistia stratiotes* L. and the origin of the Lemnaceae. *Aquatic Botany* 3: 49–54.