FLAVONOIDS IN THE SPECIES OF THE FAMILY ARACEAE: A REVIEW

Sebuah tinjauan: Senyawa-senyawa flavonoid pada suku Araceae

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Abstrak


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 Gymnostachydoideae 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 farinoso exudates, bud wax, and so on. Flavonols are flavones that are attached to a hydroxyl group at 3-position (Figure 3).

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-hydroxyflavanones are requisite intermediates on the pathway to flavonoids by one route and to anthocyanins via flavan 3,4-diols by another (Figure 6).

Figure 1. Anthocyanin  
Figure 2. Flavone

Figure 3. Flavonol

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

Figure 5. Aurone

Figure 6. Flavanone (upper) and Dihydroflavanol (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, pterocarps, 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, Wolffielia) 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, If = leaf, pt = petiole, rz = rhizome, sp = spathe, st = stem, sx = spadix, tb = tuber, wp = whole plant.

### FLAVONOIDS IN THE SUBFAMILY

**GYMNOSTACHYDOIDEAE**

Gymnostachys aniceps 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-glycosyllflavones which were common flavonoids in the Araceae including Lemnaceae, however they were not present in this species.

![Figure 8. Kaempferol 3-sophoroside-7-rhamnoside](image)

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

<table>
<thead>
<tr>
<th>Gymnostachys aniceps R.Br.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavonol: kaempferol 3-sophoroside-7-rhamnoside (If) (Williams et al. 1971)</td>
</tr>
</tbody>
</table>
FLAVONOIDS IN THE SUBFAMILY ORONTOIDEAE

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 (lf) (Williams et al. 1981), isorhamnetin 3-galactoside, isorhamnetin 3-rhamnosylgalactoside, kaempferol 3-galactosylglucoside, quercetin 3-galactoside (lf) (Williams et al. 1981), and isorhamnetin 3-arabinosyl-(1→6)-galactoside (lf) (Whang & Lee 1999).

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

<table>
<thead>
<tr>
<th>Species</th>
<th>Flavonol</th>
<th>Anthocyanin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lysichiton camtschatcensis (L.) Schott</td>
<td>isorhamnetin 3-arabinosyl-(1→6)-galactoside, kaempferol 3-arabinosyl-(1→6)-galactoside, quercetin 3-arabinosyl-(1→6)-galactoside (lf) (Williams et al. 1981)</td>
<td></td>
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<tr>
<td>Orontium aquaticum L.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavonol</td>
<td>isorhamnetin 3-galactoside, isorhamnetin 3-rhamnosylgalactoside, kaempferol 3-galactosylglucoside, quercetin 3-galactoside (lf) (Williams et al. 1981)</td>
<td></td>
</tr>
<tr>
<td>Symplocarpus foetidus (L.) Salisb. ex W.P.C.Barton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavonol</td>
<td>kaempferol 3-diglucoside, kaempferol galactosylglucoside, quercetin galactosylglucoside (lf) (Williams et al. 1981)</td>
<td></td>
</tr>
<tr>
<td>Symplocarpus renifolius Schott ex Tzvelev</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flavonol</td>
<td>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 &amp; Lee 1999)</td>
<td></td>
</tr>
</tbody>
</table>
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 Wolffsiella 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 Wolffsiella 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-glycosylflavonones, 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-malyl-glucoside (wp) (Akhtar et al. 2010),
- C-Glycosylflavone: isoorientin, isoorientin 7-glycoside, isovitexin, isovitexin 4´-glucoside, apigenin 6-C-(malonylglucoside)-glucosyl-malyl-glucoside, luteolin 6-C-(malonylglucoside)-glucosyl-malyl-glucoside, orientin, vitexin (wp) (McClure & Alston 1966, Veen 1975, Akhtar et al. 2010)

**Lemna japonica** Landolt
- Flavone: chrysoeriol, luteolin 7-glucoside (wp),

**Lemna minor** L.
- C-Glycosylflavone: apigenin 6,8-di-C-glycoside, isoorientin, isoorientin 7-glycoside, isovitexin, isovitexin 4´-glucoside, luteolin 6,8-di-C-glycoside, orientin, vitexin (wp) (McClure & Alston 1966, Veen 1975)

**Lemna minor** (as **Lemna minima** Thull. 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 validiviana** 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-diglucoside (wp) (McClure & Alston 1966),
- C-Glycosylflavone: apigenin 6,8-di-C-glycoside, isoorientin, isoorientin 7-glycoside, 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.
- Flavonone: eriodictyol 7-glucoside, hesperetin 7-glucoside (wp) (Quiao et al. 2011),
- Flavonol: quercetin diglucoside, quercetin diglucosylxylloside (wp),
- C-Glycosylflavonone: naringenin 6,8-di-C-glucoside (wp) (Quiao et al. 2011),
SPirodea punctata (G.Mey.) C.H.Thomps. (as Llandotia 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,isorientin, isovitexin, orientin, vicenin-2, vitexin (wp) (Wang et al. 2014a)

SPirodea punctata (G.Mey.) C.H.Thomps. (as Spirodea biperforata W.Koch) (McClure & Alston 1966)
Flavone: apigenin 7-glycoside, luteolin, luteolin 7-glycoside (wp),
C-Glycosylflavone: isoorientin, isoorientin 7-glycoside, orientin, vitexin (wp) (McClure & Alston 1966)

SPirodea punctata (as Spirodea intermedia W.Koch) (McClure & Alston 1966, McClure 1968, Saunders & McClure 1976)
Anthocyanin: cyanidin 3-glycoside (wp),
Flavonol: kaempferol, kaempferol 3-glycoside, quercetin, quercetin 3-glycoside (wp) (McClure & Alston 1966, McClure 1968),

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 colombiana 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 globosa (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 POTHIOIDEAE

The subfamily Pothioideae 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 cytiside (Figure 26) 3´-rhamnoside, and isocytisoside (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-glycosyflavones, 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).
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 (lf) (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 (sp),
**Flavone:** apigenin glucoside, chrysoeriol arabinosylglucoside, eucalyptin benzoylglucoside, luteolin glucoside, methylapigenin rhamnosylglucoside, methyleucalyptin benzoylglucoside, sideroxylin benzoylglucoside (sp),
**Flavonol:** kaempferol acetylmalonylglucoside, kaempferol 3-rhamnoside-7-(acetylabinoside), 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

Anthurium regale Linden

Anthurium schlechtendalii Kunth
Anthocyanin: cyanidin 3-rutinoside (fr) (Williams et al. 1981)

Anthurium versicolor Sodiro
C-Glycosylflavone: cytisoside 3′-rhamnoside, isocytisoside 3′-apiopuranoside, isocytisoside 3′-rhamnoside, isocytisoside 6′-xyloside, vitexin (lf) (Aquino et al. 2001)

Pothos chinensis (Raf.) Merr.
Flavone: chrysoeriol 7-rhamnosylglucoside (ap), C-Glycosylflavone: 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 flavanol (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 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 nematicidal 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, Affifi 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
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).

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. sasicola containing four flavonols (isorhamnetin 3-glucoside, isorhamnetin 3-rutinoside, quercetin 3-glucoside and quercetin 3-rutinoside), and apiagen and luteolin C-glycosides (Williams et al. 1981).
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).

Williams et al. (1981) analyzed the flavonoids of many Aroideae species, e.g. *Aglaoenema 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.*, *Synandrospadix 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**

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<td><em>Aglaoenema modestum</em> Schott ex Engl.</td>
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<td><em>Alocasia cucullata</em> (Lour.) G.Don</td>
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<td><strong>Anthocyanin</strong></td>
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<td><em>Alocasia cuprea</em> K.Koch</td>
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<td><strong>Anthocyanin</strong></td>
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<td><em>Plectracheta curcifolia</em></td>
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<td><strong>Flavonol</strong></td>
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*Note: lf, flavonol; tf, flavonoid; If, isoflavonoid.*
Amorphophallus abyssinicus (A.Rich.) N.E.Br.
**Anthocyanin:** cyanidin 3-rutinoside (lf),
**Flavonol:** quercetin (lf) (Williams et al. 1981)

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

Amorphophallus paeoniifolius (Dennst.) Nicolson (Amorphophallus campanulatus Decne)
**Anthocyanin:** cyanidin 3-glucoside, cyanidin 3-diglucoside, pelargonidin 3-glucoside (lf) (Iwashina et al. 2015),
**Flavonol:** 3,5-diacetetylumbin, 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 (lf) (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, pelargonidin 3-coumaroylglucoside, peonidin 3-glucoside, peonidin 3-rutinoside (sp, sx) (Gallori et al. 2004, Iwashina et al. 2015),
**Flavone:** chrysosierol 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:** isoscparin 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 diffinis (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)
**Arum orientale** M.Bieb.
Flavone: apigenin (If),
Flavonol: querctin, querctin 3-rhamnoside, querctin 3-rutinoside (If, If) (Koleva 1984),
C-Glycosylflavone: isoorientin, isovitexin, luteolin 7-glucoside, orientin, vitexin (If) (Koleva 1982, 1984)

**Arum palaestinum** Boiss.
Flavone: apigenin, chrysoeriol, luteolin (ap, If, lf),
Flavonol: querctin, querctin 7,3,4′-trimethyl ether (ap, If, lf) (Farid et al. 2015, Afifi et al. 2016),
C-Glycosylflavone: isoorientin, isovitexin, vitexin (ap, If, lf) (Afifi et al. 1999, 2016, Farid et al. 2015)

**Arisarum vulgare** O.Targ.Tozz.

- **Arisaema erubescens** (Wall.) Schott
  - C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)
- **Arisaema serra**
  - C-Glycosylflavone: orientin, vitexin (If) (Pagani 1982)
- **Arisaema 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, querctin (If) (Williams et al. 1981)

**Arisarum neglectum** (Rz, tb) (Du et al. 1981)

**Arisarum serra var. immaculatum** (Schott) Schott var. immaculata Schott (Williams 1980, 1981)

**Arisaema serra var. immaculatum** (Schott) Watanabe

- **Arisaema erubescens** var. immaculatum
  - C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema erubescens** var. immaculatum Schott var. immaculata Schott
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra**
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra var. immaculatum**
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra var. immaculatum** Schott var. immaculata Schott
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra var. immaculatum** Schott var. immaculata Schott
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra var. immaculatum** Schott var. immaculata Schott
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra var. immaculatum** Schott var. immaculata Schott
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra var. immaculatum** Schott var. immaculata Schott
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arisaema serra var. immaculatum** Schott var. immaculata Schott
- C-Glycosylflavone: apigenin 6,8-di-C-galactoside, isocorymboside, isoschaftoside, neoecorymboside, schaftsoside, vicenin-2 (rz, tb) (Du et al. 2005, 2011)

**Arum italicum** Mill. subsp. italicum
Flavone: chrysoeriol, luteolin (If) (Williams et al. 1981),
C-Glycosylflavone: isovitexin 7-glucoside (rz) (Phouphas 1956)

**Arum italicum** subsp. neglectum (F.Towns.) Prime
Flavone: chrysoeriol (If) (Williams et al. 1981)

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

**Arum orientale** M.Bieb.
Flavone: apigenin (If),
Flavonol: querctin, querctin 3-rhamnoside, querctin 3-rutinoside (lf) (Koleva 1984),
C-Glycosylflavone: isoorientin, isovitexin, luteolin 7-glucoside, orientin, vitexin (If) (Koleva 1982, 1984)

**Asterostigma riedelianum** (Schott) Kunz
- 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′′-(caffeoylglycoside), isomolludistin 2′′-(caffeoylglycoside), isomolludistin 2′′-glucoside (lf) (Markham & Williams 1980, Williams et al. 1981)

**Asterostigma tenuifolium** (L.) Schott
- Flavone: chrysoeriol, luteolin (If) (Williams et al. 1981),
- C-Glycosylflavone: isovitexin 7-glucoside (rz) (Phouphas 1956)

**Calla palustris** L.
- Flavone: apigenin, chrysoeriol, luteolin (lf) (Williams et al. 1981)

**Colla palustris** L.
- Flavane and Proanthocyanidin: procyanidin (lf) (Williams et al. 1981)

**Carlephyton madagascariense** Jum.
- Flavane and Proanthocyanidin: procyanidin (lf) (Williams et al. 1981)

**Cerestisia afzelii** Schott
- Flavane and Proanthocyanidin: procyanidin (lf) (Williams et al. 1981)

**Cerestisia congesta** Engl.
- Flavane and Proanthocyanidin: procyanidin (lf) (Williams et al. 1981)

**Cerestisia mirabilis** (N.E.Br.) Bogner (as Rhektophyllum mirabile N.E.Br.) (Williams et al. 1981)
- Anthocyanin: cyanidin 3-gentiobioside (pt),
- Flavane and Proanthocyanidin: propelargidonidin (lf) (Williams et al. 1981)
Cryptocoryne spiralis (L.) Schott

**Anthocyanin:** cyanidin 3-glucoside, cyanidin 3-rhamnoside, pelargonidin 3-glucoside (Chañ J. & 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:** querectin (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, vicenin-2, vitexin, vitexin X′-glucoside (lf, st) (Iwashina et al. 1999, Leong et al. 2010, Ferreres et al. 2012, Li et al. 2014)

Cryptocoryne willisii Reitz

**C-Glycosylflavone:** 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 ×willisii 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 regelli Vved.

**Flavone:** luteolin (lf),
**Flavonol:** querectin (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)

Helicodiceros muscivorus (L.f.) Engl.

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

Homalomena pendulata (Blume) Bakh.f. (as Homalomena coeulescens 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:** querectin (lf) (Williams et al. 1981)

Peltandra virginica (L.) Schott

**Flavan and Proanthocyanidin:** procyanidin (lf),
**Flavonol:** querectin (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*: isorhamnetin, 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 smithii** (Hook.) Sweet ex Kunth
*Flavan and Proanthocyanidin*: procyanidin (lf) (Williams et al. 1981)

**Philodendron smithii** Engl.
*Flavan and Proanthocyanidin*: procyanidin (lf),
C-Glycosylflavone: isoschaftoside, schaftoside (lf) (Williams et al. 1981)

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

*Philodendron undulatum* Engl. (as *Philodendron eichleri* Engl.) (Williams et al. 1981)
**Flavan and Proanthocyanidin:** procyanidin (lf), **C-Glycosylflavone:** isoorientin, isovitexin, orientin, schaftoside (lf) (Williams et al. 1981)

*Philodendron verrucosum* L. Mathieu ex Schott
**Anthocyanin:** cyanidin 3-glucoside, cyanidin 3-rutinoside (lf, pt) (Williams et al. 1981)

*Pinellia tripartita* (Blume) Schott
**Anthocyanin:** cyanidin 3-rutinoside (st) (Williams et al. 1981)

*Pistia stratiotes* L.
**Anthocyanin:** cyanidin 3-glucoside (wp) (Zennie & McClure 1977, Tripathi et al. 2016), **Flavone:** chrysoeriol 4’-glucoside, luteolin, luteolin 7-glucoside (wp) (Zennie & McClure 1977, Liu et al. 2008, Tripathi et al. 2016), **C-Glycosylflavone:** apigenin 6,8-di-C-glycoside, luteolin 6,8-di-C-glycoside, orientin, vitexin (wp) (Zennie & McClure 1977, Tripathi et al. 2016)

**Anthocyanin:** cyanidin 3-rutinoside (st), **Flavone:** chrysoeriol, luteolin (lf) (Williams et al. 1981)

*Stylochaeton borumensis* N.E.Br.
**Flavonol:** quercetin (lf) (Williams et al. 1981)

*Stylochaeton lancifolius* Kotschy & Peyr.
**Anthocyanin:** cyanidin 3-rutinoside (st), **Flavan and Proanthocyanidin:** procyanidin (lf), **Flavonol:** kaempferol, quercetin (lf) (Williams et al. 1981)

*Synandrospadix vermitoxicus* (Griseb.) Engl.
**C-Glycosylflavone:** isoorientin, isovitexin, isovitexin 7-glucoside, orientin, vitexin (lf) (Sosa et al. 1978)

*Syngonium auritum* (L.) Schott
**Flavan and Proanthocyanidin:** procyanidin (lf) (Williams et al. 1981)

*Syngonium podophyllum* Schott
**C-Glycosylflavone:** isoschaftoside (lf) (Gomes et al. 2014)

*Typhonium flagelliforme* (Lodd.) Blume
**C-Glycosylflavone:** isovitexin (lf) (Farida et al. 2012)

*Typhonodorum lindleyanum* Schott
**Anthocyanin:** cyanidin 3-glucoside, cyanidin 3-rutinoside (lf), **Flavan and Proanthocyanidin:** procyanidin (lf) (Williams et al. 1981)

*Xanthosoma brasiliense* (Desf.) Engl.
**Flavonol:** quercetin (lf) (Williams et al. 1981)

*Xanthosoma helleborifolium* (Jacq.) Schott
**Anthocyanin:** cyanidin 3-rutinoside, pelargonidin 3-rutinoside (st) (Williams et al. 1981)

*Xanthosoma sagittifolium* (L.) Schott
**Flavan and Proanthocyanidin:** procyanidin (lf) (Williams et al. 1981)

*Xanthosoma violaceum* Schott (Williams et al. 1981, Picerno et al. 2003)
**Anthocyanin:** cyanidin 3-rutinoside (lf) (Williams et al. 1981), **C-Glycosylflavone:** apigenin 6-C-glucoside-8-C-apiofuranoside, isovitexin, isovitexin 6”-glucoside, isovitexin 4’-rhamnoside, vitexin, vicenin-2 (lf) (Picerno et al. 2003)

*Zantedeschia aethiopica* (L.) Spreng.
**Flavan and Proanthocyanidin:** procyanidin (fl), **Flavone:** apigenin, luteolin (fl), **Flavonol:** kaempferol, quercetin (fl) (Martens et al. 2003), **C-Glycosylflavone:** isoorientin, isovitexin, orientin, swertiajaponin, swertisin, vitexin (fl, lf, sp) (Martens et al. 2003, Luzzatto et al. 2007, Nakayama et al. 2015)

**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).
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 Lemnoidae, flavones and flavonols occurred in the genera *Lemna*, *Spirodela* and *Wolffia*. On the other hand, flavonols was absent in *Wolffilea*. 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 Lemnoidae was not surveyed for flavan and proanthocyanidins except for *Spirodela punctata*. Flavanones were isolated from *Spirodela polyrrhiza* in subfamily Lemnoidae 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 polyrrhiza* 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

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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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