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Review

Flavonoids Profile, Taxonomic Data, History of Cosmetic Uses, Anti-Oxidant and Anti-Aging Potential of *Alpinia galanga* (L.) Willd

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Abstract: *Alpinia galanga* is a well-known medicinal plant in Southeast Asia and has been used for a long time as food and medicine. A large number of flavonoid phytochemical compounds have been identified in various parts of this medicinal herb. Flavonoids are commonly known as attractive compounds that can be applied to cosmetic or cosmeceutical product development because of their antioxidant, anti-aging and many other potential biological activities. This recent review aims to illustrate and update the taxonomic status as well as the species description that will be helpful for a rigorous identification and authenticate the raw material or living specimen from *A. galanga*. The flavonoid phytochemical compounds and the bioactivity of this medicinal plant are also provided. The future perspectives and research directions of *A. galanga* and its flavonoids are pointed out in this study as well.

Keywords: *Alpinia galanga*; flavonoids; taxonomy; traditional use; cosmetic uses; antioxidant activity; anti-aging activity

1. Introduction

Alpinia galanga (L.) Willd. is a terrestrial flowering medicinal plant species belonging to the family Zingiberaceae. *Alpinia galanga* is native to the Southeast Asian region and has been used as an active ingredient for many formulas in traditional medicines to relieve indigestion, vomiting, stomach pains, ringworm and to treat skin diseases. In addition, a large number of Southeast Asian foods consist of this medicinal plant [1]. A large number of phytochemical compounds, e.g., flavonoids, phenolic acids and volatile compounds, from several parts, such as leaves, rhizome and seeds, of *A. galanga* have been analyzed and many potential phytochemicals have been reported [2–6]. Flavonoids of *A. galanga* are continuously discovered from various parts of this medicinal herb [2–9]. The flavonoid phytochemical compounds from *A. galanga* may possibly be an interesting alternative choice of bioactive molecules for cosmetic or cosmeceutical sectors—e.g., antioxidant skin care, anti-inflammatory cream/lotion and other botanicals. This recent study aims to exhibit the potential of *A. galanga* and its flavonoids for further cosmetic application. The taxonomic description and essential taxonomic data of *A. galanga*, its flavonoids, the uses of this plant in cosmetics, antioxidant and anti-aging activities of flavonoids from *A. galanga* as well as future perspectives and research directions on this species are provided.

2. The Taxonomic Description of *Alpinia galanga* (L.) Willd

Alpinia Roxb. is the largest genus in the family Zingiberaceae with 230 species mostly distributed in the Malesian region, and with about 60 species in China and Indo-Chinese Region [10–13]. *Alpinia* is the type genus of the tribe *Alpinieae* A. Rich. of the family Zingiberaceae, and *Alpinia galanga* (L.) Willd. is the type species for the genus *Alpinia*.

Schumann [14] proposed an infrageneric classification of *Alpinia* in his account of the Zingiberaceae dividing it into five subgenera and twenty-seven sections; however, eight of those sections have presently been placed in different genera. After more than half a century, Smith [15] revised the classification and recognized two subgenera in 1990 based on characters of the labellum. *Alpinia galanga* is assignable to subgenus *Alpinia* section *Alpinia* subsection *Alpinia*. A recent phylogenetic study of *Alpinia* by Kress et al. [11] revealed the genus is polyphyletic and noted that a new classification system should be proposed based on the molecular data.

Alpinia galanga, so called "the greater galangal", is characterized by many-branched inflorescence with numerous small and green flowers [16,17]. Two infraspecific taxa, var. *galanga* and Var. *pyramidata* (Blume) K. Schum., are occasionally recognized [10]. Var. *pyramidata* is distinguished by abaxially pubescent lamina and pubescent panicle rachis.

Alpinia officinarum Hance, termed the lesser galangal, is sometimes confused with *A. galanga*, but *A. officinarum* is easily distinguished from *A. galanga* by larger flowers and ovate white labellum with red streaks.

Alpinia galanga (L.) Willd., Sp. Pl., ed. 4, 1: 12 (1797); Rev. Hand. Fl. Ceylon 4: 516 (1983); Larsen et al., Gingers Malay. Pen. and Singapore: 66 (1999); Wu and Larsen, Fl. China 24: 343 (2000); Larsen and Larsen, Gingers Thailand: 107 (2006); Leti et al., Fl. Photo. Cambodge: 536 (2013).

- *Maranta galanga* L., Sp. Pl. ed. 2: 3 (1762).
- *Galanga major* Garsault in Figure Pl. Méd.: t. 16 a (1764).
- *Heritiera alba* Retz. in Observ. Bot. 6: 17 (1791).
- *Alpinia alba* (Retz.) Roscoe in Trans. Linn. Soc. London 8: 346 (1807).
- *Zingiber galangal* (L.) Stokes in Bot. Mat. Med. 1: 72 (1812).
- *Alpinia viridiflora* Griff., Not. Pl. Asiat. 3: 423 (1851).
- *Alpinia rheedii* Wight, Icon. pl. Ind. orient. 6: 19, t. 2026 (1853).
- *Alpinia zingiberina* Hook.f. in Bot. Mag.: t. 6944 (1887).
- *Alpinia bifida* Warb. in Bot. Jahrb. Syst. 13: 275 (1891).
- *Languas galanga* (L.) Stuntz in Bull. Bur. Pl. Industr. U.S.D.A. 261: 21 (1912).

Species Description (Figure 1): Robust rhizomatous herb, forming large clumps, up to 3 m tall. Rhizomes whitish externally, pale yellow internally, 2–4 cm in diameter with strong odor. Ligule suborbicular, ca. 5 mm; petiole ca. 5 mm; lamina oblong or lanceolate, 20–35 cm long, 5–10 cm wide, glabrous or abaxially pubescent, base attenuate, apex acute or acuminate. Inflorescence terminal, panicle, 12–20 cm long; rachis glabrous or pubescent; richly branched, many-flowered; bracts and bracteoles persistent; bracteoles lanceolate, 5–8 mm long. Flowers greenish white, fragrant. Calyx tubular, 0.6–1 cm long, persistent. Corolla tube about the same length as calyx tube, light greenish; lobes oblong, 1.6–1.8 cm long; lateral staminodes red, subulate or linear, 2–5 mm long; labellum white with reddish stripes, obovate to spatulate, ca. 2 cm long, apex 2-cleft. Stamen 1.5–1.7 cm long; filament, 1 cm long, light yellow; anther 5–7 mm long, creamy white. Capsule oblong, slightly contracted at middle, dark red, 1–1.5 cm long, 5–7 mm wide. Seeds black.

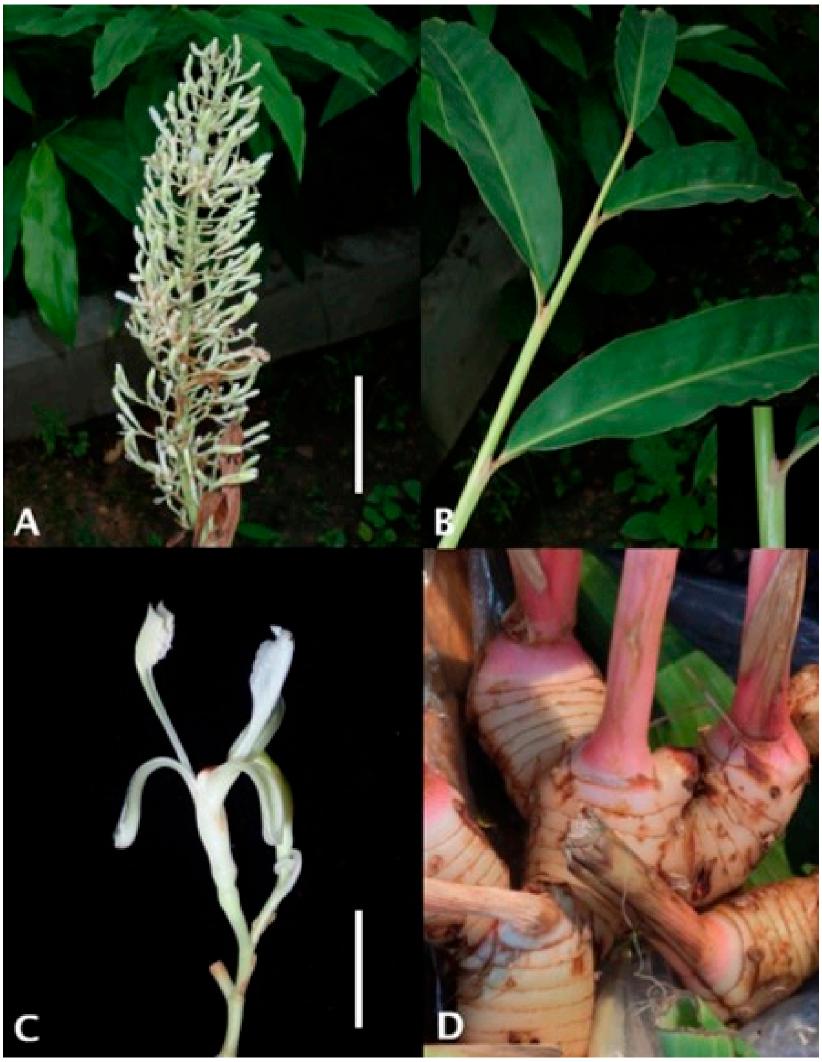

Figure 1. *Alpinia galanga* (L.) Willd. (**A**) Inflorescence. (**B**) Leafy shoot. (**C**) Close-up of a single flower. (**D**) Rhizomes. Scale bars: 5 cm for (**A**). 1 cm for (**C**). Pictures by Nobuyuki Tanaka.

Habitat and Ecology: It grows in the understory of tropical and subtropical forests with low- to mid-elevations. Flowering May to August. Fruiting September to November.

Distribution: Bangladesh, Cambodia, China, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. Introduced to India and Sri Lanka.

3. Flavonoids Profile of *A. galanga*

Eleven flavonols, four dihydroflavonols, and one flavan 3-ol and flavanone were isolated and identified from the rhizomes and seeds of *A. galanga* (Table 1). These flavonoids were found as aglycones but not glycosides. Of eleven flavonols, galangin (3,5,7-trihydroxyflavone, Figure 2A) is a major compound and was named from the scientific name of this species. Although kaempferol (Figure 2B), quercetin (Figure 2C) and myricetin (Figure 2D) are popular non-methylated flavonols in the plant kingdom, galangin 3-methyl ether (Figure 2E), kaempferide (Figure 2F), isokaempferide (Figure 2G), kumatakenin (Figure 2H), isorhamnetin (Figure 2I) and quercetin 3-methyl ether (Figure 2J) are methoxylated flavonols [2–7,18]. The occurrence of some methoxylated flavonols may be a character of *A. galanga*. Jaju et al. [19] isolated polyglycosylated flavonol from this species and named it galangoflavonoside. Although it was characterized as 6-hydroxykaempferol which attached each of the four moieties of glucose and arabinose to the 7-position and 4′-position, respectively, and octadecenoate to the 6-position of flavonol molecule, it may be a misidentification.

Four dihydroflavonols and a flavanone were isolated from the seeds of this species. Of their compounds, three dihydroflavonols were identified as pinobanksin 3-acetate (Figure 2K) and 3-cinnamate (Figure 2L) [6]. Another dihydroflavonol, and flavanone were identified as alpinone (Figure 2M) and pinocembrin (Figure 2N). A common flavan 3-ol, catechin (Figure 2O) was found in the rhizomes of this species [2]. Their flavonoids were isolated from the underground parts (roots and rhizomes) and seeds. However, they are not reported from the aerial parts—e.g., leaves and flowers. These flavonoids—which have been reported for *A. galanga* since two flavonols, galangin and galangin 3-methyl ether, have not attached the hydroxyl group in B ring—are comparatively rare in plants [20]. Similarly, pinobanksin 3-acetate and two 3-cinnamates are also rare in plants [20].

Table 1. Reports of the flavonoids from *Alpinia galanga*.

Dihydroflavonol	(2*R*,3*R*)-Alpinone (sd) [6], Pinobanksin 3-acetate, (2*R*,3*R*)-Pinobanksin 3-cinnamate, (2*R*,3*S*)-Pinobanksin 3-cinnamate (sd) [6]
Flavan 3-ol	Catechin (rz) [2]
Flavanone	Pinocembrin (sd) [6]
Flavonol	Galangoflavonoside? [19], Galangin (rz, rt) [3–7,18], Galangin 3-methyl ether (rt, sd) [6,18], Kaempferide (rz) [4,5,7], Isokaempferide, Kumatakenin (sd) [6], Myricetin [2], Kaempferol (rz) [3,4,7], Isorhamnetin, Quercetin 3-methyl ether (rz), Quercetin (rz) [4,7]

rt = roots, rz = rhizomes, sd = seeds.

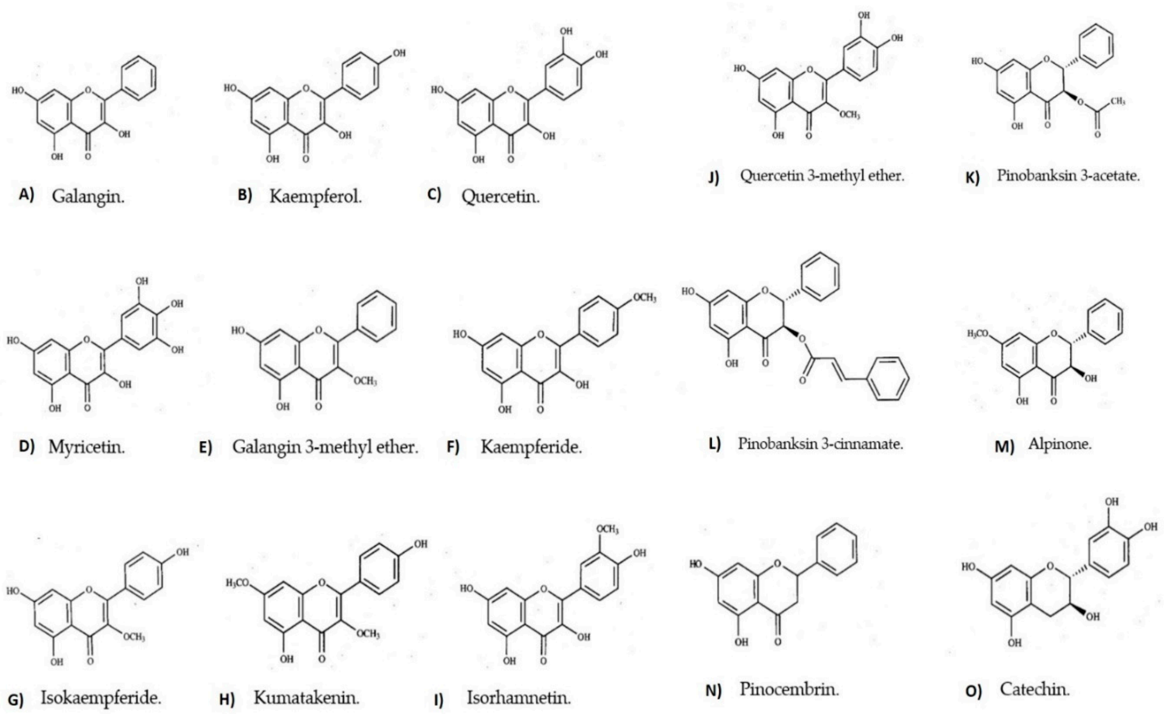

Figure 2. Flavonoid phytochemical compounds from *A. galanga*: (**A**) Galangin, (**B**) Kaempferol, (**C**) Quercetin, (**D**) Myricetin, (**E**) Galangin 3-methyl ether, (**F**) Kaempferide, (**G**) Isokaempferide, (**H**) Kumatakenin, (**I**) Isorhamnetin, (**J**) Quercetin 3-methyl ether, (**K**) Pinobanksin 3-acetate, (**L**) Pinobanksin 3-cinnamate, (**M**) Alpinone, (**N**) Pinocembrin, (**O**) Catechin.

4. Cosmetic Uses (Past to Present)

From ancient times, local people in several Asian countries, particularly in Thailand, Vietnam and many Southeast Asian countries, have used this medicinal plant as a cosmetic ingredient for body care—e.g., body soap and some others topical skin care products. These traditional products from *A. galanga* are usually developed to use among the family using easy extraction methods—for example, by using hot water as the solvent. Nowadays, local communities in Thailand, China and many other Asian nations also develop shampoo, conditioner and other cosmetic products containing the extract from this medicinal plant species. The water as well as ethanol are commonly used as the solvent for extraction. The uses of solvent vary depending on the preparation of each family, and the leaves and rhizomes are the most popular parts to be used for this purpose. Most of the cosmetics and/or cosmeceuticals from this medicinal species are locally made for sale or exchange within the community and neighbors. The *A. galanga* extract is also sold as a cosmetic ingredient. Currently, people can order the dried plant or the extract easily via online markets. However, it is very difficult to identify and authenticate whether these samples are *A. galanga* or not. For the development of *A. galanga* as a raw plant material for the cosmetic and cosmeceutical sectors, the authentication process as well as the bioactive ingredient identification need to be carried out before starting the product development processes [8,21]. In addition, the extracts from leaf, rhizome and the whole plant of *A. galanga* are registered in the European Commission database for information on cosmetic substances and ingredients (CosIng) (https://ec.europa.eu/growth/tools-databases/cosing/index.cfm?fuseaction=search.results, accessed date 24/10/2020) and their skin conditioning functions, but there is still a lack of "Identified INGREDIENTS or substances" information in CosIng. However, the research on the potential of extracts and/or phytochemicals from this medicinal plant is insufficient; a greater number of studies focusing on flavonoid identification of the potential extracts from this medicinal plant should be conducted. Furthermore, its closely related species, e.g., *A. officinarum*, which is discussed in the taxonomic part of this work, should be investigated and a comparison of the cosmetic potential between flavonoid compounds should be made.

5. Potential Biological Activities: Antioxidant and Anti-Aging Activities of Flavonoids from *A. galanga* for Cosmetic Application

Flavonoids are one of the most common and popular bioactive compounds used for cosmetic applications and their biological activities are widely tested and reported in a huge number of medicinal plants—i.e., *Ocimum basilicum* L. [22], *Silybum marianum* (L.) Gaertn. [23], *Eclipta alba* L. [24], *Nymphaea lotus* L. [25], *Nelumbo nucifera* Gaertn. [26] and so forth. The objective of this potential biological activity section is to provide the research overview on the antioxidant and anti-aging activities of flavonoids from *A. galanga* and/or *A. galanga* extracts. The literature searches were conducted using both the present scientific name and various synonyms of *A. galanga*, flavonoid, and biological activity as the search terms. In total, 93 publications in ScienceDirect's database as well as 74 publications in PubMed's database in the present decade were found. Interestingly, after the intense review, less than 10% of these publications met our objective. It was clear that research studies on the potential of flavonoids from *A. galanga* for cosmetic application were not plenty, but the results from these previous studies illustrated the potential of this medicinal plant for cosmetic as well as cosmeceutical applications. However, the more detail should be obtained and the new biological activities should be investigated, in order to support the used of *A. galanga* as the raw plant material for the cosmetic sector.

Mickymaray and Al [9] focused their study on the antioxidant and anti-bacterial effects of 15 common species of medicinal plants in Saudi Arabia, and their results pointed out that methanolic extract of *A. galanga* is one of the four most potent in-vitro antioxidants examined by 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid (ABTS), total reducing power (TRP) as well as the iron (III) reducing antioxidant power (FRAP) assays and anti-bacterial agents (evaluated against *Enterobacter aerogenes*, *Staphylococcus aureus* and *Proteus mirabilis* using minimum inhibitory concentration values (MIC)) with high total phenols and flavonoid contents of the extract [9]. Ahlina and his research team studied the influence of the ethanolic extract of *A. galanga* on normal fibroblast cells (NIH 3T3 cells) in order to investigate the anti-aging potential of *A. galanga* ethanolic extract via a senescence inhibitory effect on NIH 3T3 fibroblast cells detected by a SA-βGal senescence-based assay. They found that the extract showed promising anti-aging potential to decrease cell senescence [27]. *A. galanga* extract has the potential to reduce the number of senescence cells in normal fibroblasts (NIH 3T3 cells) which are induced by stressors—e.g., doxorubicin and so forth. In addition, the previous study reported on galangin from a species member of this genus which is able to protect human dermal fibroblast cells from the senescence and reduced the expression of inflammatory factors [27,28]. Consequently, this team also suggested galangin, a flavonoid compound present in this plant, as an interesting candidate to develop natural anti-aging products for skin protection [27]. Moreover, galangin, a flavonol class of flavonoids, was also investigated in an animal model to examine its anti-inflammation and antioxidative stress potential by Shu and his research group; the mice models were randomly divided into four groups: control, vehicle, and galangin high- and low-dosage groups. The result showed that galangin administration help to decrease the biochemical parameters of oxidative stress and inflammation in a dose-dependent manner [29]. His team also illustrated that anti-inflammation and antioxidative stress effects of galangin were associated with the inhibition of nuclear factor (NF)-κB as well as the upregulation of heme oxygenase (HO)-1. Kicuntod and a Thai research team [30] conducted their research on pinostrobin which is an abundant flavonoid found in *A. galanga*'s rhizomes with antioxidative and anti-inflammatory effects, but a problem of pinostrobin is its extremely low water solubility which limits its potential pharmaceutical applications including in the development of cosmetic products. Aqueous solubility is an important physicochemical parameter used to assess skin absorption, which allows the bioactive compound in the cosmetic product to fully reach its efficacy. This research group discovered that the pinostrobin was able to form complexes with β-cyclodextrin (βCD) and its derivatives (2,6-dimethyl-βCD, 2-HPβCD, 6-HPβCD and 2,6-DHPβCD), which will help to improve water solubility and provide higher stability [30].

6. Future Perspectives and Research Directions

- To evaluate the type and amount of phytochemical compounds of *A. galanga* from various populations that grow in different habitats that may be affected by different geographic and environmental factors.
- To compare the flavonoid phytochemical profiles as well as the potential biological activities—for example, antioxidant, anti-aging and anti-wrinkle activities for cosmetic application—of *A. galanga* and its closely related species within the same genus such as *A. officinarum* Hance, *A. zerumbet* (Pers.) B. L. Burtt and R. M. Sm. and *A. chinensis* (Retz.) Roscoe, in order to increase the potential alternative choices of the flavonoid-rich bioactive compounds for various cosmetic proposals.
- To analyze the most promising part of *A. galanga* that contains high-quality and a large quantity of the target flavonoid phytochemicals, so as to decrease the cost of cosmetic/cosmeceutical product development.
- To apply the new innovative extraction techniques—for example, ultrasonic-assisted extraction (UAE), UAE combined with the macroporous resin adsorption, or other green chemistry techniques—to increase the yield of extraction of *A. galanga*'s flavonoids.
- To investigate the mechanism of interesting biological activities, especially the anti-aging and antioxidant activities of the known and promising flavonoids from *A. galanga* using both in-vitro and in-cellulo assays that will enhance the efficacy of cosmetic and/or cosmeceutical products.
- To examine the inhibition potential of flavonoid-rich extracts/compounds from *A. galanga* on major aging factors—e.g., enzymes such as tyrosinase, elastase, hyaluronidase, etc. This may be helpful to provide a new powerful anti-aging molecule for cosmeceutical products.
- To investigate the safety of the potential extract and/or pure flavonoid phytochemical compounds from *A. galanga* in cosmetic/cosmeceutical products, in order to confirm its safety and to provide the customer's confidence.

7. Conclusions

A. galanga is an attractive medicinal plant that can be promoted as a raw material in the cosmetic and/or cosmeceutical sectors due to its low price, abundance and because it is easy to grow. Furthermore, this plant species has long been used for cooking ingredients and traditional medicines, which will help the cosmetic industry to decrease cost for research and study on the toxicity. In addition, many customers are familiar with *A. galanga*, so they may take less time to decide to try the products made from *A. galanga* or its flavonoid bioactive compounds. However, additional studies of this medicinal species, especially concerning the biological activities of flavonoid-rich extracts/compounds, will help to progress the uses of this attractive raw plant material for future cosmetic/cosmeceutical applications.

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