RESEARCH ARTICLE | MAY 25 2021

Alpinia galanga (L.) willd: Plant morphological characteristic, histochemical analysis and review on pharmacological

Trimanto Trimanto ✉; Lia Hapsari; Dini Dwiyanti

AIP Conference Proceedings 2353, 030021 (2021)
https://doi.org/10.1063/5.0052687

Alpinia galanga (L.) Willd: Plant Morphological Characteristic, Histochemical Analysis and Review on Pharmacological

Trimanto Trimanto[1, a], Lia Hapsari[1], and Dini Dwiyanti[2]

[1]*Purwodadi Botanic Garden – Research Center for Plant Conservation and Botanic Gardens, Indonesian Institute of Sciences (LIPI), Jl. Surabaya – Malang Km 65, Pasuruan, 67163, East Java, Indonesia*

[2]*Graduated from Department of Biology, Faculty of Mathematics and Natural Sciences, University of Brawijaya, Veteran Street, Malang, 65145, East Java, Indonesia*

[a]Corresponding author: trim006@lipi.go.id

Abstract. *Alpinia galanga* is an important rhizomatous plant widely used as an aromatic cooking spice and herbal medicines. This study aims to describe the plant morphological characteristic of. *A. galanga*, examine the presence of chemical components in rhizomes through histochemical analysis and review its pharmacological potentials. *A. galanga* is characterized as a perennial herb; rhizome cylindrical and branched, hard, reddish brown or pale yellow-green, strong aroma; pseudostem erect, leaves lanceolate-oblong, alternate; inflorescence terminal, erect, many flowers, white or yellowish, fragrant; fruit globose to the ellipsoidal capsule, yellow-orange to red. Histochemical analysis showed that the rhizome contains starch, protein, lipid, alkaloids, flavonoids and tannins. Among the primary metabolites, lipid size is larger than protein and starch. However, the density of starch secretory cells is higher than protein and fat, approximately 23.14 ± 3.01 cells/mm^2. Among secondary metabolites, alkaloids size higher than tannins and flavonoids. Nevertheless, the density of secretory cells of flavonoids is higher than alkaloids and tannins, approximately 2.24 ± 1.44 cells/mm^2. This current review indicates that almost all parts of the *A. galanga* plant contain many bioactive compounds, including antimicrobial, antioxidant, anti-ulcer, antibacterial, antitumor, anti-HIV, antifungal, anti-inflammatory, anti-allergic and antidiabetic.

INTRODUCTION

Alpinia galanga (L.) Willd. is a monocotyledonous rhizomatous plant belong to the Zingiberaceae family, commonly known as galangal or great galangal (English), lengkuas (Indonesia, Malay), Kulanjan (Hindi), etc. It is widely cultivated in Asian countries such as Indonesia, Thailand, Malaysia, India, and China [1,2]. This plant has underground stems called rhizomes. This rhizome is very aromatic. *A galanga* has spicy taste which makes it popularly used in Asian cuisines for spice and flavoring. The leaves, stems, rhizomes and roots of the *A. galanga*, also extensively used in the traditional systems of medicine to treat various diseases in Thai, Indian, Chinese, Javanese, etc. [3-5].

A. galanga grows in open, sunny places, forests and brushwoods, and is now widely cultivated in the backyard as homegarden element [6]. The plant morphology almost resembles that of ginger plant. It grows from rhizomes in clumps of upright stalks up to 2 m in height with abundant long leaves and aromatic. In Western countries, however, *A. galanga* is not well known, at least in recent days. It is also sometimes confused with other species of the ginger family by common people [7,8]. Commonly in Indonesia, it is recognized that there are 3 variants of galangal which scattered throughout the archipelago, namely white galangal, red galangal and intermediate between white and red. They possibly differ in hotness flavors [3]. Thus, a study to describe a complete morphological features of *A. galanga* is important to conduct for a better identification.

Many Zingiberaceae species contains of primary and secondary metabolites which responsible for the aromatic odour and medicinal uses [9-12]. The secretory structure is a cell or tissue of plant that has serve a place of secretion

International Conference on Life Sciences and Technology (ICoLiST 2020)
AIP Conf. Proc. 2353, 030021-1–030021-10; https://doi.org/10.1063/5.0052687
Published by AIP Publishing. 978-0-7354-4096-8/$30.00

of metabolite compounds such as resins, essential oils, gums, alkaloids, glycosides, etc. [13]. Histochemical analysis of secretory structures is usually used to detect both primary and secondary metabolites; essential to study the potentially medicinal plants. It can be used in the identification and localization of specific substances in plant tissue. Stains, indicators and microscopes are used to identify chemical constituents in plant tissue. Histochemical method depends on the chemical reaction between the reagent and plant tissue [14]. The application this technique is simple and cheap, with some tests being more general and others more specific [15].

This study aims to describe the morphological characteristics of *A. galanga* specimens collected from the natural forest of Sulawesi and conduct anatomy and histochemical analysis to detect the primary metabolites include starch, protein and lipid, also secondary metabolites include alkaloids, flavonoids and tannins in *A. galanga* rhizome. A literatures review of the pharmacological potentials of *A. galanga* based on current researches is also presented in this paper. The results of this study are expected to provide a more comprehensive information of *A. galanga* from the morphological aspects, histochemical, and pharmacological potentials for further development as medicinal plant.

EXPERIMENTAL DETAILS

Plant Material

Wild plant of *A. galanga*, a living collection of Purwodadi Botanic Garden/PBG, Pasuruan, East Java is used in this study. The specimen was originally collected from Kolaka, South East Sulawesi in 2009, with registration number P2009080200, located at Vak V.E.I.95 [16].

Morphological Characterization

Morphological characteristics observed includes habitus, rhizome, leaves, inflorescence, flowers, fruits and seeds. In addition, information regarding phenology and propagation were also discussed.

Anatomy and Histochemical Analysis

The anatomy and histochemical analysis were conducted at Plant Taxonomy and Microtechnique Laboratory, Biology Department, University of Brawijaya (Malang, East Java). The primary metabolites observed includes starch, protein and fat; while the secondary metabolites observed includes alkaloids, flavonoids and tannins [14]. The plant part used was the mature rhizome. The microscopic slide was prepared using fresh preparation method and wet mounted. The flesh was taken using cork bore, then it is sliced by hand microtome with ±15 μm in thick and fixed in alcohol 70% for further analysis.

Anatomical observation was conducted in wet mount using distilled water. The starch test was carried out using a 1% lugol solution. A positive reaction of starch was marked in dark purple color. Protein test was performed using a picric acid solution, the rinse thoroughly with 100% EtOH. A positive reaction of protein was marked in yellow color. The lipid test was carried out using a Sudan III solution. A positive reaction of lipid was marked in red color. Wagner reagent was used for alkaloids test. The presence of alkaloids was characterized by red-brown color. The solution of $FeCl_3$ 1% was used for tannins test. The presence of tannins was showed by brown color. Flavonoids test was carried out using 10% NaOH solution. Detection of flavonoid compounds was showed by red color. All specimen observations were made using a microscope with magnification of 100× and 400× [17- 21].

Secretory cell density calculations were performed per unit area. The area unit of the microscope is in a circle form. A micrometer scale (μm) is used to determine the radius of a circle on a microscope [22]. Ocular micrometer scale values are calibrated using the formula [23]. The observation was conducted in three replications. The density was measured by calculating the secretory structure density (SSD), using the following formulae:

$$\mathrm{SOC} = \frac{X}{Y}\, SOB;\;\; SSD = \frac{\Sigma\ \text{Secretory cell/n}}{\text{Area of view (mm}^2\text{)}}$$

Note: SOC= ocular micrometer scale; SOB= objective micrometer scale (1 scale = 0.01 mm = 10 μm); SSD= Secretion Structure Density; n: number of fields of view per sample.

Review on Pharmacological *A. galanga*

Study on review was carried out by collecting published papers including Google Scholar, Science Direct, Scopus, etc. The focus of review is study of biological and pharmacological of *A. galanga*. The papers published between 1990 to 2019 were searched using keywords of *A. galanga*, bioactive, pharmacology, and phytochemical. All relevant papers including research articles were comprehensively studied.

RESULTS AND DISCUSSION

Plant Morphological Characteristics of *A. galanga*

The morphological characteristics of the wild *A. galanga* specimen examined from Sulawesi are slightly different to cultivated *A. galanga* specimen from Java. It has higher pseudostem height approximately 2 to 3 m, meanwhile specimen from Java is smaller reached up to 2 m high. The rhizome has intermediate character (white with reddish skin), whilst specimen from Java has white rhizome with brownish skin. Further, plant specimen from Sulawesi is regularly flowering all year round, whereas *A. galanga* from Java almost never flowering (remain in vegetative stage). According to our observation in PBG, it is flowering and fruiting from September to October.

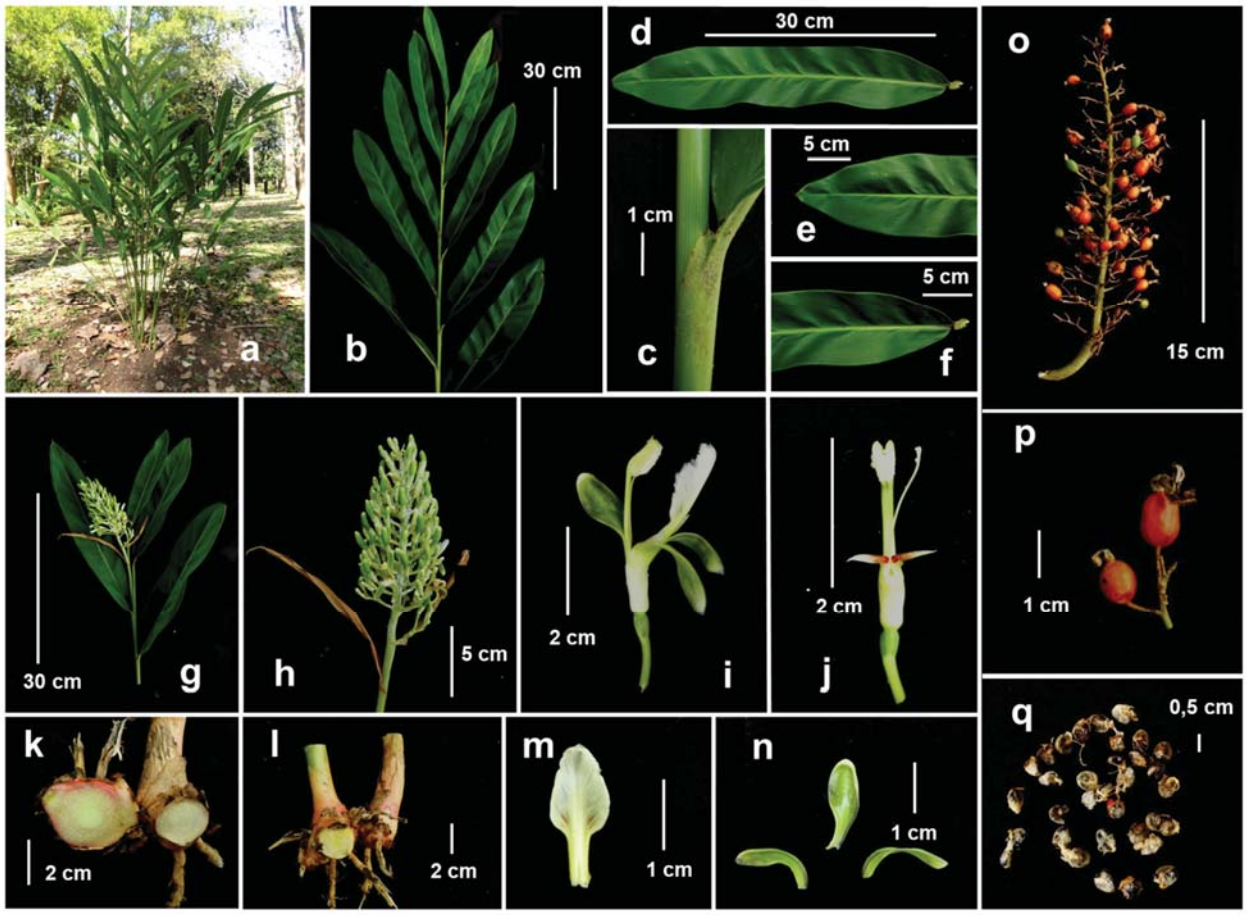

FIGURE 1. Plant morphological characteristics of *A. galanga*. a) Clump, b) Leaves, c) Ligule, d) Upper leaf surface, e) Leaf apex, f) Leaf base, g & h) Inflorescences, i & j) Flowers, k & l) Rhizomes, m) Labelum, n) Dorsal and side lobes, o Infructescence, p) Fruits, and q) seeds

We added information that wild *A. galanga* from Sulawesi produces fruit regularly, thus it can be propagated by seeds. Generally, *A. galanga* is propagated vegetatively by rhizomes, the leafy shoot will be sprouting from the rhizome in 2 weeks after planting. Whilst, the seed will be germinating in 2 months after planting. The seed coat (exocarp) of *A. galanga* is hard, thus it needs longer time to germinate. It can be stimulated by soaking in warm water and scarified the seed coat. The optimum propagation media is sand, soil and compost (1 : 1 : 1).

The complete description of *A. galanga* plant is perennial herbs; *leafy shoots* reaching 2.1 - 3 m tall, erect, with 10 - 11 leaves; *pseudostem* green and glabrous, 1.5 - 2 cm in diameter; *base of leafy shoot* reddish-green; young shoots reddish. *Rihizome* subterete, length 6 - 7 cm, diameter 2 - 4.5 cm, hard, fibrous, shiny, cylindrical, branched, 4 - 5 segments, outer skin color reddish brown, pale greenish yellow when old, inner rhizome is white, hard-textured, strong aroma. *Ligule* 2 mm long, apex rounded, green, pubescent; *petiole* short ca. 3 mm, green, pubescent; *leaf sheath* green with margin light green, glabrous in adaxial and pubescent in abaxial; *leaf* lanceolate-oblong, 26 - 53 cm × 8 - 10 cm, shiny on both surfaces, adaxially green, surface prominently plicate, abaxially pale green, base cuneate, apex acuminate, margin entire white (thin line), undulating, slightly plicate. *Bract* opens to the base. *Inflorescence* is terminal, racemose, green-white or yellowish, 10 - 30 cm × 5 - 7 cm, pubescent, densely set, *peduncle* 7 - 10 cm long, greenish, shiny; a cincinnus with 2 until 6 flowers; *bracts* 7 - 17cm, base truncate, apex acuminate, cilliate 1 cm, light brown; flowers fragrant, 2.5 - 4 cm long, yellow-white; *pedicel ca. 0.*5 - 1 cm long, shiny and white; tubular calyx, white, ca. 1 cm long; *corolla lobe* 3, 1.5 × 0.6 cm, margins ciliate, oblong lanceolate, greenish-white, recurved, dorsal lobe erect; *labellum* petaloid, 2 - 2.5 cm × 0.7 - 0.9 cm, white veined, undulate, spatulate, apex recurved; *Stamen* white, shiny, erect; *filament* ca. 1.2 cm long; *anther* incurved; white, ca 0.6 cm long, white; no anther crest; *lateral staminodes* 2, 6 - 8 mm long, position at base of the labellum, subulate lobes, reddish at base; *Style* slightly longer than stamen, stigma obtriangular. *Style* ca. 1.5 cm long, white; *stigma* yellowish-white, ca. 1 mm long. *Ovary* ovate, light green, 2 × 4 mm. Fruit is green when young then yellow to orange, and red when ripen, globose to ellipsoidal capsule, size 9 - 1.2 cm × 0.6 - 0.8 cm, 0.6-1 cm in diameter. Seed dark brown, 5 - 6 seed in a fruit, subglobose, weight 0.4 - 0.06 g/seed, ca. 5 mm in diameter, enclosed in translucent white aril (Figure 1).

Histochemical Analysis and Anatomy of *A. galanga* Rhizome

The anatomical structure of *A. galanga* rhizome consists of epidermis, parenchyma and transport beam include xylem and phloem vascular bundles. The epidermis consists of single layered oval to rounded, thin walled parenchymatous cells with very thick outer walls. Numerous transport beam/vascular bundles closely scattered in the parenchyma tissue. The vascular bundles are nearly circular in shape and consists of groups of xylem and small patch of phloem. It is enclosed within a sheath of 3 - 4 layers of fibres and considered as closed collateral type. Ground tissue comprises of polygonal, oval to rounded, thin walled parenchymatous cells. Furthermore, several oval starch/amylum grains were found clearly visible scattered in the parenchyma tissue (Figure 2). Results of histochemical analysis showed that *A. galanga* rhizome was positively contains of starch, protein and lipid (primary metabolites), also alkaloids, flavonoids and tannins (secondary metabolites) (Table 1).

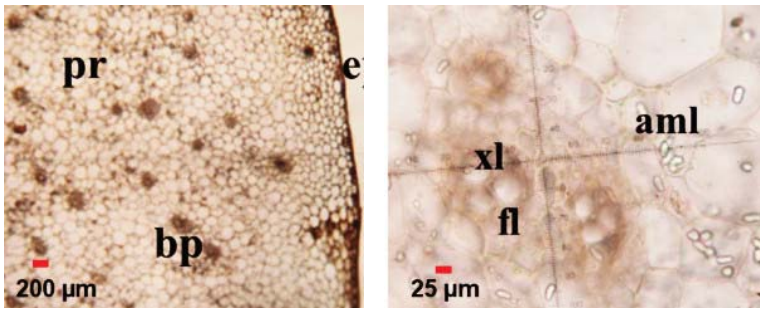

FIGURE 2. Anatomical structure of *A. galanga* rhizome: 40× magnification (a) and 400× magnification (b). Note: ep= epidermis, pr= parenchyma, bp= transport beam, xl= xylem, fl= phloem, aml= starch grains.

Starch is the main energy reserved as a product of photosynthesis in plants and can be found mostly in seeds, roots, tubers, stems, leaves, and fruits. A positive starch test using lugol in *A. galanga* rhizome was indicated by a bluish-black chemical reaction in the tissue (Figure 3.a & 3.c). The form of starch grain was oval, with size ±12.5 - 25 µm

(Table 1) and categorized as medium size[24]. Previous studies also reported that starch grain in A. *galanga* is simple, elongated and oval. The starch grain shapes in Ziberaceae are varied from oval, elliptical, rounded, flat and triangular [12,25]. The starch grain size also variable among species. The starch grain of *A. galanga* tends to be smaller than in *Curcuma longa* which range 15-25 µm [26] and *Zingiber officinale* which can be up to 50 µm [25]. Further, the starch grains were found spreads as the main component of the rhizome of *A. galanga,* with high density of starch grains approximately 23.14 ± 3.01 cells/mm^2. However, it was considered lower than starch density in the tuberous plant such as *Colocasia esculenta* (66.33 ± 14.78 cells/mm^2), *Manihot esculenta* (61 ± 4.58 cells/mm^2), *Ipomoea batatas* (48.67 ± 8.08 cells/mm^2), and *Dioscorea hispida* (30.67 ± 6.11 cells/mm^2 [27].

TABLE 1. Primary and secondary metabolites secretory cells size and density of *A. galanga* rhizome

Metabolite		Secretory Cell Size (µm)	Secretory Cells Density (cells/mm^2)
Primary	Starch	±12.5 - 25	23.14 ± 3.01
	Protein	±112.5	0.87 ± 0.49
	Lipid	±75	0.37 ± 0.12
Secondary	Alkaloids	± 5	0.087 ± 0.41
	Flavonoids	±30	2.24 ± 1.44
	Tannins	±67.5	0.96 ± 1.23

Protein is a complex organic compound consisting of one or more amino acid chains in a specific sequence. Protein has an important function in the structure and regulation of cells, tissues, and organs. The protein secretory cells stained in yellow color was considered positive for protein test using picric acid solution, scattered in the parenchyma tissue (Figure 3.b & 3.e). The protein secretory cell size in *A. galanga* rhizome was large ±112.5 µm, with low density 0.87 ± 0.49 cells/mm^2. Nevertheless, the density of protein secretory cell is higher than lipid (Table 1). Further, the protein secretory cell size in *A. galanga* was also considered larger than *Curcuma* species (±100 µm) [25]. The content of protein and starch on galangal causes an insoluble part in alcohol so that it can be used for antifungal soap formulas [28].

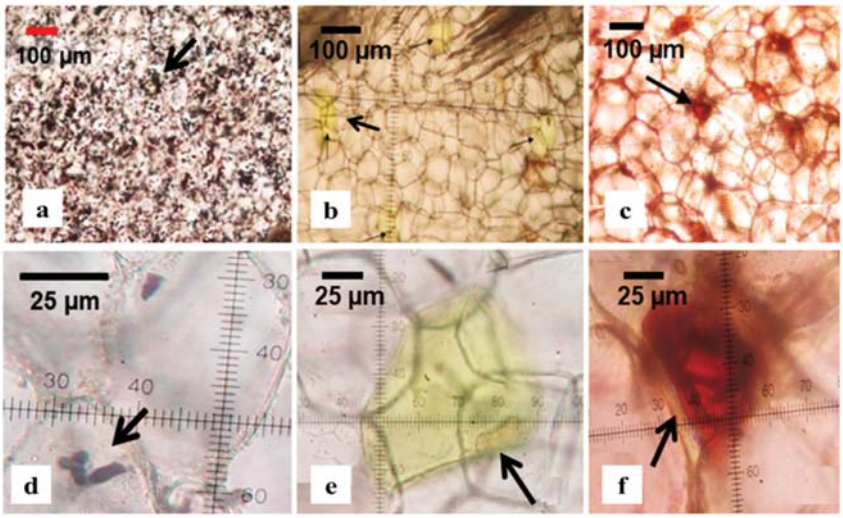

FIGURE 3. Primary metabolite histochemical analysis on *A. galanga* rhizome: a & d) Starch; b & e) Protein; and c & f) Lipid

The rhizome of *A. galanga* have strong aroma, which possibly contributed by the essential oils' contents. Test results for *A. galanga* for lipid/oil droplet showed positive reaction as indicated by cells in red color (Figure 3.d & 3.f). The lipid secretory cells are also scattered in the parenchyma cells. The lipid cells size was medium approximately ±75 µm, with low density 0.37 ± 0.12 cells/mm^2). Further, mature rhizome contains more lipids than in young rhizome [12]. The lipid content in dried rhizome also contains higher lipid compared to fresh rhizome. There are about 51 components in essential oil obtained by hydrodistillation of the dried rhizome of *A. Galanga* [29].

The three primary metabolite substances (starch, protein and lipid) in Zingiberaceae rhizome were mostly found in parenchyma tissue. Qualitatively, secretory cells of primary metabolites content in rhizome were larger than root

and leave. Leaves have the lowest value because they function as photosynthetic and disseminate products through all plant organs. Leaves has the lowest because it serves as a photosynthetic organ and disseminate through all in the plant's organs [11]. Based on the secretory cell size, result of this study showed that the protein size in *A. galanga* rhizome was larger than lipid and starch. However, the density of starch secretory cells is higher than protein and lipid (Table 1). Further research to measure the quantitative amount of each primary metabolite in A. *galanga* rhizome is needed to conduct for a more comprehensive study. Alkaloids consist of weight nitrogen containing compounds and low molecular. The function of alkaloid enhances plant reproductive rates. Alkaloids have various pharmacological effects. The function of alkaloids is defense compounds in plants. Alkaloids are also efficient against pathogens and predators due to their toxicity [30]. The rhizome of *A. galanga* in this study showed positive alkaloid test using Wagner reagent as secretory cells marked in red-brown color (Figure 4.a & 4.d). The alkaloid secretory cells were small ±5 µm with a low density of 0.087 ± 0.41 cells/mm^2 (Table 1). Alkaloids in *A. galanga* reported also existed in the stem and leaf veins [31].

Flavonoids belong to a group of phenolic compounds with low molecular weight. They play various roles such as protecting plants from the stress of different environmental factors, the formation of color and aroma in plants etc. Further, they provide biological activity associated with potential medicine to various diseases [32]. The rhizome of *A. galanga* in this study showed positive to flavonoid test as secretory cells marked in red color (Figure 4.b & 4.e). The flavonoid secretory cells were medium ±30 µm with density 2.24 ± 1.44 cells/mm^2 (Table 1). The flavonoid secretory cell density in *A. galanga* rhizome was larger than alkaloid and tannin. *A. galanga* rhizome contains significant flavonoids compared to other methanol extracts [31]. Flavonoids mostly impart pigmentation in plants, and reported to be associated with antimicrobial, anticancer and antidiarrheal activities [33].

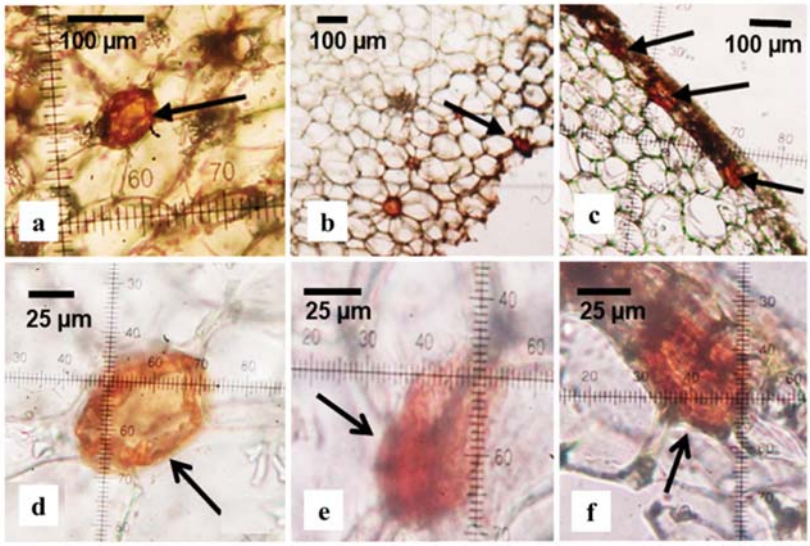

FIGURE 4. Secondary metabolite of *A. galanga* rhizome: a & d) Alkaloids; b & e) Flavonoids; c & f) Tannins

Tannins are included in the astringent group; their function is to bind and precipitate various organic compounds including amino acids and alkaloids. They play fundamental role in the defense of the plant against predation and in plant growth [34]. They are also considered as one of the effective components contributing to lower the risk of the various disease, improve the welfare of ruminants, etc. [35,36]. The rhizome of *A. galanga* in this study showed positive to tannins test as secretory cells marked in brown color (Figure 4.c & 4.f). The tannins secretory cells were large ±67.5 µm with density 0.96 ± 1.23 cells/mm^2 (Table 1). The tannins secretory cell size in *A. galanga* rhizome was larger than alkaloids and flavonoids. In another study, stem extracts of *A. galanga* showed moderate amounts of tannins [31].

Most of the plants in the Zingiberaceae family contain alkaloids, flavonoids and tannins. Among the secondary metabolites; based on the secretory cell size, result of this study showed that the tannin secretory cell size in *A. galanga* rhizome was larger than flavonoids and alkaloids. However, the density of flavonoids secretory cells is higher than tannins and alkaloids (Table 1). Further research to measure the quantitative number of secondary metabolites in *A. galanga* rhizome is needed to conduct for a more comprehensive study.

Review on Pharmacological of *A. galanga*

A. galanga has been utilized for miscellaneous purposes by people since a long time ago. The rhizome is commonly use as food flavoring in many Asian traditional cuisines. It is also an important herb plant for traditional medicines as an empirical knowledge and cultural heritage to treat various diseases. There are many scientific studies to explore and bioprospect the pharmacological potentials of *A. galanga*. Some plant parts of *A. galanga* were studied its bioactive compounds and fractions showed high performances against various pharmacological challenges. Further, those bioactivities are scientifically supported by the bioactive compounds found in the plant parts of *A. galanga* (Table 2).

TABLE 2. Bioactivity and bioactive compounds of *A. galanga*

Plant Part	Bioactivity	Name of Compounds	Reference
Rhizome	Anticancer, anti-inflammatory, anti-diabetic, antitumor, antioxidant, anti-HIV, antimalarial, anti-allergic, insecticides, immunomodulatory	5,7-dihydroxyflavone, 1′ δ -1′-acetoxychavicol acetate and 1′ δ -1′-acetoxyeugenol acetate, flavonoids, Methanolic extract, Trans-cinnamic acid	[29,37-45]
Leaf	Antioxidant, antibacterial	1'-acetoxychavicol acetate, essential oil, methanol, acetone and diethyl ether extracts	[46-48]
Root	Anti-inflammatory, antifungal, antitumor and antioxidant	Acetoxychavicol acetate, hydroxychavicol acetate, ethanolic extract, (E)-8β,17-epoxylabd- 12-ene-15, 16-dial	[49-51]
Flower	Antimicrobial	Acetoxyeugenol acetate, OD ethanol extract	[52,53]
Fruit	Melanogenesis inhibitory	Labdane-type diterpenes and galangal diterpenes A–C (1–3)	[54]
Seed	Anti-ulcer, neuroprotective effects	1’ δ -1’-acetoxychavicol acetate and 1’δ -1’-acetoxyeugenol, (2R, 3S)-pinobanksin-3-cinnamate (PNC)	[55,56]

The essential oil of the rhizome is responsible for the antimicrobial activity. *A. galanga* were reported as effective antimicrobial. There are eight bacterial isolates, namely *Bacillus subtilis, B.thuringiensis, Micrococcus luteus, Pseudomonas aeruginosa, P. merobilis, Staphylococcus aureus Escherichia coli* also *Salmonella typhi* which was inhibited by *A. galanga* extract [57]. The bioactive compounds of ether and ethyl acetate extracts has efficacy against *Staphylococcus aureus* [58], *Staphylococcus epidermidis* and *Listeria monocytogenes* [59]. *A. galanga* shows a real inhibition against various fungal human pathogens. Diterpene compound enhanced the antifungal activity of quercetin and chalcone against of *Candida albican* [50]. Antifungal activity of *A. galanga* inhibits fungal growth like *Cryptococcus neoformans* and *Microsporum gypseum* [48]. Root oil of *A. galanga*, also showed best antifungal of *Rhizoctonia solani* [60].

A. galanga has anti-inflammatory properties and probably acts by blocking histaminic and serotonin pathways [49]. P-hydroxycinnamaldehyde from *A. galanga* has the potential medicine for the treatment of osteoarthritis [61]. *A. galanga* possesses significant anti-inflammatory activity in rats with previous studies supporting the presence of flavonoids and nitric oxide free radical scavenging [62]. Rhizome extract of *A. galanga* has the potential effect as anti-inflammatory [63]. The extract of *A. galanga* shows significant anti-ulcer activity [64]. The ethanolic extract of *A. galanga* reduced the gastric mucosal, so it is responsible for its antiulcer activity [65].

A. galanga has a potential treatment for co-chemotherapy, they can induce senescence toward metastatic breast cancer [66]. Further, *A. galanga* has potential in the treatment of breast cancer [67]. The ethanolic extract of *A. galanga* could effectively reduce the growth and multiplication of the tumor cells [51]. Cytotoxicity and apoptosis in human lung are induced by Chrysin [37]. Antitumor activity was found in *A. galanga*. In an animal model system, 1′-acetoxychavicol acetate and 1′-acetoxyeugenol acetate isolated from *A. galanga* rhizome extract has antitumour properties [41]. Testing of Galangin, the components of *A. galanga* also proved capable of inhibiting 73.51%. tumor growth. The test was performed on Swiss Albino mice induced with carcinoma cells. Chemical compounds of *A.galanga* have the possibility to induce apoptosis in tumor cells [68].

A. galanga shows strong inhibitory activity against HIV or Human Immunodeficiency Virus. Methanolic extract of *A. galanga* and 1'δ-1'-Acetoxychavicol acetate showed strong inhibitory action against HIV-1. 1'δ-1'-Acetoxychavicol acetate against HCMV (human cytomegalovirus) [69]. The crude chloroform extracts of *A. galanga* and their bioactive compounds are suggested to treatment AIDS patients. Combination 1′δ-1′-acetoxychavicol acetate

(ACA) with other anti-HIV drugs may be an alternative in new treatments for HIV infection [43]. Galangal extract is equally effective in minimizing lipid oxidation. Galangal also possible as natural antioxidant for meat products [70]. Dried *A. galanga* powder has a protective effect against lipid oxidation of meatballs [71]. 1'-acetoxychavicol acetate and other compounds in *A. galanga* have been reported as antioxidant activity [46].

Anti-allergic activity also has been reported from *Alpinia galanga* extract. This extract has been shown to inhibit the release of β-hexosaminidase as a degranulation marker [44]. 1′ δ-1′-acetoxychavicol acetate (1) has eficacy against antiallergic activity caused by also strongly inhibited the production of antigen-IgE-mediated TNF-α and IL-4 [72]. Methanol extract of *A. galanga* tested on diabetic rats was proven to be effective in controlling blood glucose and improving lipid profiles [39]. Ethyl acetate (EA) fractions of *A. galanga* had significant antihyperglycemic activity by inhibiting carbohydrate digesting enzymes namely α-amylase and α-glucosidase also inhibiting glycation reaction [73]. Rhizome *A. galanga* were evaluated for inhibition of lipase activities and alpha-glucosidase, their shows beneficial for anti-hyperlipidemia and anti-diabetic activity [45]. Due to *A. galanga* contains secondary metabolites such as alkaloids, flavonoids, tannins, saponins and terpenoids, it is potential as a natural insecticide. The leaf extracts of *A. galanga* effective to kill of *Anopheles aconitus* larvae (vector of malaria), respectively [74]. Likewise, *A. galanga* contain of trans-cinnamic acid as bioactive compound to control the vector of dengue fever, malaria and filariasis include *Aedes aegypti*, *Anopheles dirus* B and *Culex quinquefasciatus* [45].

SUMMARY

A. galanga is rhizomatous medicinal plant with diverse properties. Key taxonomic morphological features of *A. galanga* are perennial herbs terminal inflorescence, cincinnus flowers, bract open to the base, labellum petaloid, and subulate lateral staminodes. The anatomical structure of *A. galanga* rhizome consists of epidermis, parenchyma and transport beam include xylem and phloem vascular bundles. The primary metabolite substances and secondary metabolites are detected from *A. galanga* rhizome. The starch has the highest density of secretory cells among primary metabolites, whereas flavonoids have the highest density of secretory cells among secondary metabolites. All of plant parts of *A. galanga* from roots to fruits have rich pharmacological potentials. *A. galanga* contains of many biochemical compounds, in which one type of biochemical compound present in the plant also shows wide spectrum of pharmacological spectrums. Due to its vast biological and pharmacological potentials, further research and evaluation of *A. galanga* specimens from various regions in Indonesia and from all parts of the plants to isolate and identify bioactive compounds and efficacy of their properties is required by humans in the future.

ACKNOWLEDGMENTS

The authors would like to thank Dr. Serafinah Indriyani for the supervision and all the valuable discussions during the study. Author's contribution: All authors declare that Trimanto is main author of this article.

REFERENCES

1. M. Chitra and J.E. Thoppil, Ancient. Sci. Life. **27**(4), 9–21 (2004).
2. N. S. Bermawie, Purwiyanti, Melati, and N. L. W. Meilawati, Bul Littro. **23**, 125 (2012).
3. E. Sinaga, *Alpinia galanga* (L.) Willd (Pusat Penelitian dan pengembangan Tumbuhan Obat, Universitas Nasional, Jakarta, 2013), pp. 1.
4. T.P. Girija, and S. A. B. Rema, Int. J. Herb. Med. **2**(2), 38 (2014).
5. B. K. Sushma, K.S. Ashalatha, P. Ray, H.R. Raveesha, J. Med. Plants **3**0(4), 1-13 (2020).
6. Purnomo, J. Batoro and A. Hakim, JITODE **7**(1), 50-55 (2019).
7. T. Ponmozhi and K. Kalaiselvi, Bioch. Ind. J. **5**(2), 109-114 (2011).
8. C. Maya and N. S. P. Kumar, Int. J. Life Sci. **6**(2), 353-356 (2018).
9. P. Akhtar, M. Ali, M.P Sharma, H. Farooqi, S.R. Mir, M. Yusuf and H.N. Khan. Curr. Bot. **1**(1), 04-09 (2010).
10. A.A. Akinola, S. Ahmad, and M. Maziah, Afr. J. Trad. Comp. Alt. Med. **11**(3), 7-13, (2014).
11. S. Indriyani, *Secretory structure and histochemistry test of some Zingiberaceae plants*, In AIP Conference Proceedings 1908, (AIP Publishing, 2017), pp. 1-6.
12. H. Liu, C.D. Specht, T. Zhao and J. Liao. Hortsci. **1**, 1-4 (2020).
13. W.G. Dickison, *Integrative plant anatomy* (Academic press, California, 2000), pp. 383-397.
14. J.D. Bancroft, *Histochemical Techniques*, (Butterworth & Co (Publishers) Ltd, London, 1975), pp. 68-223

15. D. Demarco, *Histochemical Analysis of Plant Secretory Structures Methods on Molecular Biology*, (Humana Press, New York, 2017), pp. 313-330.
16. W. Lestarini, Matrani, Trimanto, Fauziah & A.P. Fiqa. *An alphabetical list of plant species cultivated in Purwodadi Botanic Garden*, Purwodadi Botanic Garden, Pasuruan, 2012), pp. 7.
17. D.A. Johansen, *Plant Microtechnique*, (McGraw-Hell Book Company, Inc, USA, 1940), pp.530
18. S. Mulyani, and L. Toga, Majalah Obat Tradisional **16** (3), 109 – 114(2011).
19. S. Lalitha, S., K.V. Krishnamurthy, S. John, and V. Padma, J. SWAMY BOT-CL. **29**, 9-12 (2012).
20. Ohio, *Experimental anatomy of plant development laboratory* 1. (https://www.ohio.edu/plantbio/staff/rothwell/. Accessed on 17 September 2015).
21. D. Novitasari, *Study of the anatomy, secretory structure, and histochemistry of Aglaonema simplex: anti-diarrhea medicinal plants in Bukit Duabelas Jambi National Park* (Bogor Agricultural Institute, Bogor, 2015), pp. 1-32.
22. E.M. Kuntorini, D.A Maria, and M. Norma. Bioscientiae **8**(1), 28–37 (2011).
23. S. Aloysius, and Sukirman, *Biologi* (Yudhistira, Yogyakarta, 2008)
24. N. Lindeboom, P.R. Chang and R.T Tyler, Starch. **56**, 89–99 (2004).
25. O.T Fatokum, *Micrometrics and morphological properties of starch, chemical properties of starch*. (Martins Emeje, IntechOpen, 2019).
26. T. Trimanto, D. Dwiyanti, D., and S. Indriyani, Berita Biologi **17**(2), 123-133(2018).
27. A.K. Sari, S. Indriyani, G. Ekowati, J. Batoro, Biotropika **5**(1), 14-21 (2017).
28. H. Hernani, T.K. Bunasor and F. Fitriati, Buletin Penelitian Tanaman Rempah dan Obat **21**(2), 192-205 (2016).
29. Y. Wu, Y. Wang, Z.H. Li, J. Y. Wei, X. L. Li, P. J. Wang, Z. F. Zhou, S.S. DU, D.Y Huang and Z. W. Deng, Bull. of Insect. **67**(2), 247-254 (2014).
30. H.N. Matsuura and A.G. Fett-Neto, Plant Toxins, 1-15 (2015).
31. B. K. Sushma, K. S. Ashalatha, P. Ray and H. R. Raveesha, European J. Med. Pl., 1-13 (2019).
32. A.N. Panche, A.D. Diwan AD and S.R. Chandra, J. Nutrition. Sci. **5**(e47), 1-15 (2016).
33. N. A. Reshi, M. S. Sudarshana, K. S. Deepu and P. Dorothy, Indo. Am. J. Pharm. Res **5**(10), 3358-3364 (2015).
34. O.N. Ogbeboro and H.O. Edeoga, African J. Agr. Res. **4**, 324-326 (2008).
35. J.P Salminen and M. Karonen. Functional Ecology **25**, 325-338 (2011).
36. A. Pizzi, Biomolecules **9**, 344 (2019).
37. S. Lakshmi, S. Suresh, B. S. Rahul, R. Saikant, V. Maya, G. Gopi, Padmaja and P. Remani, Med. Chem Res. **28**(1), 39-51(2019).
38. A. Unnisa and T. D. Parven, Der. Pharm. Sinica **2**(2), 361-367 (2011).
39. R. K. Verma, G. Mishra, P. Singh, K. K. Jha and R. L. Khosa, Ayu **36**(1), 91(2015).
40. P. Heera, L. Inbathamizh L and J. Ramachandran, Net India Pharmacog. J. 2, 1-10 (2014).
41. H. Itokawa, H. Morita, T. Sumitomo, N. Totsuka, K. Takeya. Planta Med. **53**(1), 32-3 (1987).
42. A. Pal Jain A, P. R. Singh, S. Lodhia and A. Singhaia, Pharmacog. Com. **2**(3), 30-7(2012).
43. Y. Ye and B. Li, J. Gen. Virol. **87**, 2047 (2006).
44. H. Matsuda, T. Morikawa, H. Managi and M. Yoshikawa, Bio Med. Chem. Let. **13**(19), 3197-3202 (2003).
45. W. Poonsri, A. Pengsook, W. Pluempanupat, T. Yooboon and V. Bullangpoti, Chem. Bio. Tech. Agr. **6**(1), 17 (2019).
46. K. Kubota, Y. Ueda, M. Yasuda, A. Masuda, Roy. Soc. Chem. **274**(1), 601-10 (2001).
47. N. Mahae and S. Chaiseri, Kasetsart J. Nat. Sci. **43**, 358-369 (2009).
48. S. Tachakittirungrod and S. Chowwanapoonpohn, J. Nat. Sci. **6**(1), 31-42 (2007).
49. A. K. Ghosh, M. Banerjee and N. K. Bhattacharyya, Chron. Young Sci. **2**(3), 139 (2011).
50. H. Haraguchi, Y. Kuwata, K. Inada, K. Shingu, K. Miyahara and M. Nagao, Planta Med. **62**(4), 308-13 (1996).
51. S. Suja and P. Chinnaswamy, Anc. Sci. Life **27**(4), 33 (2008).
52. X. Tang, C. Xu, Y. Yagiz, A. Simonne, and M. R. Marshall, Food Chem. **255**, 300-308 (2018).
53. W.Y. Hsu, A. Simonne, A.Weissman and J.M. Kim, J. M., Food Sci. Biotech. **19**(4), 873-880 (2010).
54. Y. Manse, K. Ninomiya, R. Nishi, Y. Hashimoto, S. Chaipech, O. Muraoka and T. Morikawa, Molecules **22**(12), 2279 (2017).
55. H. Matsuda, Y. Pongpiriyadacha, T. Morikawa, M. Ochi, Eur. J. Pharm. **471**(1), 59-67 (2003).
56. B.R. Xin, J. F. Liu, JJ. Kang and W.P. Chan, Mol. & Cell. Toxicol. **10**(2), 165-172 (2014).
57. M. K. Pillai, R. Ismail, S. Sasidharan, M. Z. Asmawi, T. S. Choon, S. B. Mekbib, and S. J. Lachumy, Pharmacol. **1**, 366-375 (2019)
58. A. P. Raina, S. K. Verma and Z. Abraham, J. Essential Oil Res. **26**(1), 24-28 (2014).

59. P. Muniandy, M. Paramasivam, N. J. Y. Chear, D. Singh, and D. Kernain, J. Pharm. Sci. Res. **11**(8), 3061-3066 (2019).
60. L. Prasad, V. Rana and A. Raina, Ind. Phytopathol. **69**(4), 499-500 (2016).
61. T. Phitak, K. Choocheep, P. Pothacharoen, W. Pompimon, B. Premanode and P. Kongtawelert, Phytochem. **70**, 237–43(2009).
62. K. R. Subash, G. B. Prakash, K. V. C. Reddy, K. Manjunath, K. U. Rao, Nati. J. Phys. Phar. Pharmacol. **6**(5), 468-470 (2016).
63. D. E. B. Baldo and J. E. Serrano, J. Med. P. St. **4**(1), 72-77(2016).
64. I. I.R. Johnley, G. Somasundaram, K. J. Salwe, and K. Manimekalai, Bio. Pharm. J. **13**(1), 55-60 (2020).
65. M. A. Al-Yahya, S. Rafatullah, J.S. Mossa, A. M. Ageel, M. S. Al-Said and M. Tariq, Phyto. Res. **4**(3), 112-114 (1990).
66. F. N. F. Nur, N. Nugraheni, I. A. Salsabila, S. Haryanti, M. Da'i, and E. Meiyanto, APJCP **21**(1), 107 (2020).
67. A. Asri and S Winarko, J. Adv. Med. Pharm. Sci, 1-9 (2016).
68. F. Sandra, J. Sudiono, Trisfilha and P. Deviyanti, Indo. Bio. J. **9**, 23-28 (2017).
69. N. Sawangjaroen, S. Phongpaichit, S. Subhadhirasakul, M. Visutthi M, N. Srisuwan and N. Thammapalerd Parasitol. Res. **98**, 588–92 (2006).
70. P. B. Cheah and N. H. Abu Hasim, J. Sci. Food Agr. **80**(10), 1565-1571 (2000).
71. R. Palamutoğlu and C. Kasnak, MANAS J. Eng. **7**(2), 136-140 (2019).
72. T. Yasuhara, Y. Manse, T. Morimoto, W. Qilong, H. Matsuda, M. Yoshikawa and O. Muraoka, Bio. Med. Chem. Let. **19**(11), 2944-2946 (2009).
73. S. Nampoothiri, T. Esakkidurai and K. Pitchumani, Trends Phyto. Res. **1**(4), 227-234 (2017).
74. S. N. B. Husna, A. Priyono., A. Darwi, Unnes J. Life Sci.**1**, 1 (2012).