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Nutrition Value and Phytochemical Screening of Gembolo (*Dioscorea bulbifera* L.) Bulbils and Tubers from Bogor, West Java

(Nilai Gizi dan Skrining Fitokimia Bulbil dan Umbi Gembolo (*Dioscorea bulbifera* L.) asal Bogor, Jawa Barat

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ABSTRACT

Gembolo is often cultivated in tropical areas, mainly for its bulbils (edible aerial bulbs) and tubers. This study will discuss the nutritional value and phytochemical screening of gembolo bulbils and tubers from Bogor, West Java. There is still little information and publication about this gembolo bulbils and tubers. In addition, to reintroduce and preserve this rare plant. The research was done by exploration, direct observation, and interview, followed by laboratory analysis and literature. The methods used in the proximate analysis include moisture content (AOAC), ash content (gravimetric), fat content (soxhlet), protein content (Kjeldahl), fibre (gravimetry), and carbohydrates as starch (titrimetry). Phytochemical screening was carried out qualitatively. The proximate test results showed that bulbils had higher water, fat, and fibre content than bottom tubers. Bottom tubers have higher ash, protein, and carbohydrates as starch content than bulbils. This confirms the assumption that bottom tubers are more recommended as a source of food than bulbils and because of their larger size than bulbils. The results of phytochemical screening showed that both bulbils and gembolo bottom tubers contained the same chemical compounds, namely alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, and glycosides.

Keywords: bulbil, *Dioscorea*, gembolo, proximate, tuber

ABSTRAK

Gembolo sering dibudidayakan di daerah tropis, terutama untuk bulbilnya (edible aerial bulbs) dan umbinya. Penelitian ini akan membahas nilai gizi dan skrining fitokimia bulbil dan umbi gembolo dari Bogor, Jawa Barat. Masih sedikit informasi dan publikasi tentang bulbil dan umbi gembolo ini. Selain itu, untuk mengenalkan kembali dan melestarikan tanaman yang sudah jarang diketemukan ini. Penelitian dilakukan dengan cara eksplorasi, observasi langsung, dan wawancara, dilanjutkan dengan analisis laboratorium dan studi pustaka. Metode yang digunakan dalam analisis proksimat meliputi kadar air (AOAC), kadar abu (gravimetri), kadar lemak (soxhlet), kadar protein (Kjeldahl), serat (gravimetri), dan karbohidrat sebagai pati (titrimetri). Skrining fitokimia dilakukan secara kualitatif. Hasil uji proksimat menunjukkan bahwa bulbil memiliki kandungan air, lemak, dan serat yang lebih tinggi dibandingkan umbi bagian bawah. Umbi bagian bawah memiliki kandungan pati, protein, dan karbohidrat sebagai pati yang lebih tinggi dibandingkan bulbilnya. Hal ini menegaskan asumsi bahwa umbi bawah lebih direkomendasikan sebagai sumber makanan dibandingkan bulbilnya dan karena ukurannya yang lebih besar daripada bulbil. Hasil penapisan fitokimia menunjukkan bahwa baik bulbil maupun umbi gembolo mengandung senyawa kimia yang sama yaitu alkaloid, saponin, tanin, fenolat, flavonoid, triterpenoid, dan glikosida.

Kata kunci: bulbil, *Dioscorea*, gembolo, proksimat, umbi

INTRODUCTION

Gembolo (D. *bulbifera* L.) is also known as air potato, air yam, aerial yam, potato yam, bitter yam, and yam shoe button. Gembolo, which is widely cultivated in the tropics and subtropics, is an aggressive invasive plant. Plants produce underground tubers that are edible and serve as food sources for local consumption or commercial purposes (Bhandari & Kawabata 2005). D. *bulbifera* is one of the most widely distributed food yams in hot and humid tropical regions (Global Invasive Species Database 2022). The aerial tubers (called bulbils) are pale, round to globose in shape, up to 13 cm wide, and formed in leaf axils. It is these bulbils that give D. *bulbifera* the common name "air potato". Gembolo, if released from the cultivated area, will quickly spread into natural forests, climb into the canopy of mature trees and form dense stands (Langeland et al 2008). Gembolo is a fast-growing plant because seeds, underground tubers, and bulbils can sprout to form new plants. In consequence, the probability of invasion of this species, especially in and near areas where it has been introduced for crop production, remains high.

Dioscorea bulbifera is one of the medicinal plants whose genetic resources in the world are getting into extinction due to habitat loss, climate change,

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overexploitation and poor natural regeneration since it is dioecious and chances of finding a fertile seed are automatically reduced (Otoo *et al.* 2015). Currently, D. *bulbifera* is widely naturalized and cultivated in tropical and subtropical areas of the Americas, the West Indies, and the Pacific Islands (Global Invasive Species Database 2022; USDA-ARS 2012). Gembolo is listed as a Category I invasive exotic plant in Florida, indicating it can altering native plant communities by displacing them and altering community structure or ecological function. Asexual propagation by bulbils that fall to the ground. Due to its ability to adapt and spread rapidly in a new climate, air potatoes were considered to be the most invasive plant species (Sandoval 2020).

D. *bulbifera* commonly used in traditional Indian, African and Chinese medicine in the treatment of sore throat (Sharma & Bastakoti 2009), type II diabetes mellitus (Ghosh *et al.* 2015), and breast cancer (Anandpara & Tirgar 2017). Through clinical trials, it has been found that D. *bulbifera* has proved effective in the treatment of sub-acute thyroiditis (Nam *et al.* 2006). This plant has long been used as traditional medicine, including analgesic, aphrodisiac, diuretic, and rejuvenating tonic. The steroid diosgenin, the active component of birth control pills, and the antifungal compound dihydrorodioscorine are extracted from this plant (Sms.si.edu. 2021). Some varieties of D. *bulbifera* contain the steroid diosgenin, a key ingredient in the manufacture of some synthetic steroid hormones, such as that used to manufacture the birth-control pill (Global Invasive Species Database 2022; Oboh *et al*. 2001). In traditional medicine, D. *bulbifera* has been used in Asia, Africa, and America Latin to treat diarrhea, dysentery, conjunctivitis, fatigue, and depression, among other ailments (ISSG 2022). In Cameroon and Madagascar, the pounded bulbils are applied to abscesses, boils and wound infections (Cogne 2002). *Dioscorea bulbifera* preparation has been used for memory enhancement, anti-aging, constipation and fever (Odugbemi 2008), and has also been used as an infusion to apply to cuts and sores due to its high composition of the tannin that is used to hasten healing of wounds in a flamed membrane (Anona *et al.* 2018). Root juice can help repel pinworms and germs (Manandhar 2002). The bulbil of D. *bulbifera* has also been identified to contain saponin steroidal phytochemical called diosgenin that possess anti-fertility activity (Shajeela *et al.* 2011) in addition to many other medicinal uses such as contraceptives, sexual vigour remedy and treatment of piles, dysentery, syphilis, ulcers, tuberculosis, leprosy, cough and diabetes (Ikiriza *et al.* 2019).

Mostly farmers planted *Dioscorea* spp. in an agroforest system and intercropped it with tree plants or in the land between rice fields without any particular agronomy practices. Due to its low economic value and lack of utilization, also by land conversion into sugar cane plantations, industrial land, and housing, so that *Dioscorea* spp. are vulnerable to extinction. Conservation by promoting the utilization of *Dioscorea* spp. is needed to keep the farmers prefer to cultivate them (in-situ/on-farm conservation). In addition, ex-situ conservation is required to conduct germplasm collection backup. *Dioscorea* spp. tubers can potentially be promoted and developed as local food sources. Processing techniques also need to be explored and developed subjected to Dioscorea tubers so that there will be alternative products that the younger generation will prefer, such as cakes, noodles, etc (Trimanto & Hapsari 2015). This research was conducted because information and publications regarding gembolo bulbils and tubers have too few found and published. In addition, it is also to reintroduce this almost rare plant and preserve the habit that once existed in the community to use gembolo as food. This effort can also help food diversification programs, especially food sources from tubers, prevent this gembolo plant from becoming extinct and have better impacts on its conservation and sustainability.

MATERIALS AND METHODS

Place and Time

Carried out field research was in May–August 2018 around Bogor, West Java. Gembolo planting was carried out in Bogor, West Java. Laboratory analysis was carried out in January–April 2019 at the Laboratory of the Research Institute for Spices and Medicinal Plants, Agricultural Research and Development Agency, Ministry of Agriculture, Bogor. Specimens of plants to be investigated, first identified in Herbarium Bogoriense, Research Center for Biology-LIPI, Bogor.

Materials

The material used in this study were bulbils (hanging/aerial tubers) and gembolo root tubers obtained from several areas in Bogor, West Java. The chemicals used were: Stiasny's reagent, Dragendorf's reagent, Libermann-Bouchard's reagent, and Mayer's reagent.

Procedures

The field research was conducted through exploration and direct observation in several locations in Bogor, West Java, namely Sindang Barang, Rancamaya, and Ciampea, to obtain gembolo bulbils and tubers. Then planted the seeds in the Baranangsiang area (Bogor), and then the bulbils and tubers were harvested for further analysis in the laboratory. Obtained information about gembolo was from experts and the surrounding community who know and have used this plant traditionally, followed by a literature study. The collection includes herbarium specimens which will later be used for plant identification and sampling of bulbils and tubers for further analysis in the laboratory.

Preparation of Simplicia

The tubers are cleaned of adhering dirt, then cut into small pieces and dried. The drying process is stopped when the sliced tubers break easily. There are efforts to keep the water content in the raw materials to 5–10%. It is estimated that at that water level, most fungi cannot grow. The dried material is then ground with a grinding machine to powder to facilitate the penetration of the solvent into the plant's structure of the plant, assist the dissolution of secondary metabolites and expanding the extraction area (Cannell 1998). Furthermore, the obtained powder is collected and stored in a closed container and ready to be used for further analysis.

Proximate Analysis

Proximate analysis was carried out each with three replications.

- **Moisture Content Measurement** (Cunniff 1995)

Weighed 2 g of thinly sliced tubers in a weighing bottle with a lid whose weight was known. The sample was dried in an oven at 105°C for 3 hours, cooled in a desiccator, and then weighed. The above steps were repeated until obtained a constant weight.

- **Ash Content Measurement (Gravimetric Method)**

Weighed 2 g of the sample in a porcelain dish of known weight, evaporated on a water bath to dry. The sample was placed in an electric furnace at an initial temperature of 400°C for 4 hours; then, the temperature is raised to 800°C for 4 hours. Cooled in a desiccator and weighed to constant weight.

- **Lipid Content Measurement (Soxhlet Method)**

Samples of plants as much as ±5 g are inserted into a paper sleeve. The sleeve is then inserted into a soxhlet apparatus connected to a fat flask plus a boiling stone (the weight is known). The hexane extract was used as a solvent. The extract was dried in an oven at 105°C, cooled, and weighed.

- **Protein Content Measurement (Kjeldahl Method)**

Put as much as 0.5 g of plant samples into a digestion flask, plus 5 mL of concentrated H2SO4 and selena catalyst. Left overnight to avoid excessive foaming. After that, it is heated at about 300°C until the liquid is clear greenish. Then cooled and diluted in a 100 mL volumetric flask with distilled water (concentrated digestion liquid). Pipette 10 ml of concentrated destruction liquid, added a little boiling stone, diluted with distilled water to 50 mL. Added 10 mL of 30% NaOH and immediately connected to a distillation apparatus, distilled for 10 minutes after the first drop. The distillate was accommodated in a 100 mL erlenmeyer containing 10 mL of 1% boric acid and 3 drops of indicator. The distilled distillate was titrated with 0.05 N H2SO4 until the color changed from green to pink (AOAC 1995).

- **Fiber Content Analysis (Gravimetric Method)**

Weighed 2–4 g of the sample. Free the fat by soxhlet extraction or by stirring, over-pouring the sample in an organic solvent 3 times. Dried the sample and put it in a 500 mL erlenmeyer. Added 50 mL of 1.25% H2SO4 solution, and boiled for 30 minutes in an soxlet condensor. Added 50 mL of 3.25% NaOH and boiled again for 30 minutes. In hot conditions, filtered through a funnel containing whatman 54, 41, or 541 ashless filter paper dried and weighed. Washed the precipitate on the filter paper successively with 1.25% hot H2SO4, hot water, and 96% ethanol. Removed the filter paper and its contents, put it in a weighing box with a known weight, dried at a temperature of 105°C, cooled and weighed until constant weight. If the crude fiber content is more than 1%, the filter paper and its contents are ashed and weighed until constant weight.

- **Analysis of Carbohydrate Content as Starch (Titrimetry)**

Weighed 5 g of the sample in a 500 mL erlenmeyer, added 200 mL of 3% HCl solution, then boiled for 3 hours in an soxlet condensor. Cooled and neutralized with 30% NaOH and added 3% CH3COOH so that the solution was slightly acidic. Transfered to a 500 mL volumetric flask, then filtered. Pipette 10 mL filter into a 500 mL volumetric flask, added 25 mL luff solution, boiling stone, and 15 ml distilled water. Simmer for 10 minutes, then cooled quickly in a tub of ice. Added 15 mL of 20% KI solution and 25 mL of 25% H2SO4 slowly. Titr as soon as possible with 0.1 N tio. This is also done for the blank solution.

Phytochemical screening (qualitative)

- **Alkaloids**

The extract was added with dragendorf reagent, an orange precipitate if it was positive; added the extract with bauchardat reagent, there was a brown precipitate if it was positive.

- **Saponins**

The extract was added with hot H2O, cooled, and then shaken vigorously. If it is positive, it will form foam and will not disappear when adding hydrochloric acid.

- **Tannins**

The extract was added with FeCl3; if it was positive, the color became dark blue or blackish green.

- **Phenolics**

The extract was added with FeCl3 reagent in ethanol, the appearance of a strong green, red, purple, blue, or black color indicated the presence of phenolic compounds.

- **Flavonoids**

The extract was added with FeCl3 and HCl(p); if it was positive, there was a red color.

- **Glycosides**

Extract was added with glacial acetic acid; extract was added with FeCl3; extract was added with H2SO4(p); if positive, each reaction will produce a purple ring.

- **Triterpenoids**

Extract was added with ether; extract was added with anhydrous acetic acid; Extract was added with H2SO4(p); if positive, each reaction would produce a red/purple color.

- **Steroids**

Extract was added with ether; extract was added with anhydrous acetic acid; extract was added with H2SO4(p); if positive, each reaction would produce a green color.

RESULTS AND DISCUSSION

Nutrition Values

D. *bulbifera* has a faint odour and a bitter-salty taste. It contains a higher nutritional value compared to other Dioscorea species (Anona *et al.* 2018), with the highest levels of calcium, magnesium, sodium and zinc, highest values of vitamins B1, B3 and C and highest protein content. In spite of the great medicinal application and nutritional value of D. *bulbifera*, food preference is largely given to the flavour of other yam species. It has been left to the diabetic patients and people with other health conditions like obesity since they are more nutritious and less sweet (Okeke 2008).

Table 1 below is the proximate test results of gembolo bulbils and tubers to determine the nutritional value of both of them. Proximate analysis is a chemical analysis method to identify the nutritional content such as protein, carbohydrates, fat, and fibre in a food substance from feed or food ingredients (Fitriani 2019). The proximate test results showed that gembolo bulbils had higher water, fat, and fibre content than tubers. Tubers have much higher ash, protein, and carbohydrates as starch compared to bulbils. This strengthens the assumption that tubers are more recommended as a food source than bulbils, and because of their larger size. Gembolo bottom tubers are usually larger than hanging tubers; the rounded shape is more uneven with slightly rough skin.

Plant Morphology

The morphology of the gembolo plant that is easy to observe is that this plant includes herbs that propagate or twist and are not thorny. The leaves are thin, soft, alternate, heart-shaped, flat leaf edges, tapered ends, grooved base, and long petioles. Bulbils are small (approximately the size of a table tennis ball) with a smoother skin surface, while tubers are larger, and the skin surface is uneven due to the presence of roots and shoots (Figure 1).

Dioscorea spp are usually unpalatable, taste bitter, produce inflammation and show occasional toxicity (Bhandari & Kawabata 2005). Cooking of *Dioscorea* does not seem to have degraded the nutrients significantly except for the remarkable increase in the

Table 1 Proximate test results of gembolo bulbils and tubers

Testing type	Bulbils (%)	Tubers (%)	Method
Moisture content	88.62	77.98	Authauser
Ash	0.35	0.72	Gravimetry
Fat	0.22	0.16	Soxhlet
Protein	0.81	1.99	Titrimetry
Fibre	0.56	0.37	Gravimetry
Carbohydrates as starch	6.64	16.64	Titrimetry

Figure 1 Gembolo plant morphology.

rate of sugars. The antinutritional factors varied in the tubers after cooking in boiling water: the cyanogenic substance was partially destroyed, alkaloids were soluble in water, the reduction of the sapogenins content, and oxalic acid was decomposed by heating. The antinutritional factors contents decreased significantly after the cooking process (Sahore & Amani 2013).

The chief means of reproduction in gembolo is asexual and is dependant on vegetative growth from underground tubers and above-ground bulbils (Figure 2). From this study, gembolo began to produce bulbils after 5 months of planting. According to the literature that this yam is popular in household gardens mainly because it produces a crop after only four months of growth and continues producing for the life of the vine—as long as two years. Moreover, the bulbils can be easily harvested for eating after boiling at any time (Konkolongo 2018) and some people processed it by thin slicing then fried (Trimanto & Hapsari 2015). Bulbils can last a year or more on the ground and still sprout, and soil contact is unnecessary for sprouting. They also float so that they may be dispersed by floodwaters and by rodents so that they may travel farther from their parent plants than those dispersed by gravity alone (Mizuki & Takahashi 2008). Tubers and bulbils generally sprout in the spring, and the new shoots often climb the dead stems of the previous year to reach the tree canopy. In the summer (June–July), many new bulbils are produced, which fall to the ground in late August. By the time seasonal stem die-back begins around October, a single vine may have put out as many as 200 bulbils (VAL202 2015).

Figure 2 Gembolo bulbs: (a) tubers; (b) bulbils.

Table 2 Phytochemicals of gembolo bulbils and tubers

Phytochemical test	Bulbils	Tubers
Alkaloids	+	+
Saponins	+	+
Tannins	+	+
Phenolics	+	+
Flavonoids	+	+
Triterpenoids	+	+
Steroids	-	-
Glycoside	+	+

Phytochemicals

Table 2 below is the result of the phytochemical screening of gembolo bulbils and tubers. Phytochemical screening was carried out to determine the chemical content (secondary metabolites) of the simplicia from gembolo qualitatively. Phytochemical screening is a preliminary stage that can provide an overview of the content of certain compounds in natural materials to be studied. The use of plants as ingredients for medicine, cosmetics and aromatics is related to the chemical compounds in these plants. Phytochemical screening can be done, either qualitatively, semi-quantitatively, or quantitatively according to the desired objectives. A qualitative phytochemical screening method can be done through a color reaction using a certain reagent. Chemical compounds contained in plants can be extracted optimally when extracted in solvents with an appropriate polarity level. Therefore, phytochemical screening needs to be done using solvents at various levels of polarity, so that it is expected that all chemical compounds in plants can be extracted properly.

The results of phytochemical screening showed that both hanging tubers and gembolo bottom tubers contained alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, and glycosides. Based on Ghosh (2015) research, the phytochemical analysis of D. *bulbifera* reveals the presence of saponins, tannins, flavonoids, sterols, polyphenols, glycosides, and according Tapondjou (2013) plus steroidal saponins. The phytochemicals present vary according to the geographical location, parts of a plant, and the extraction solvents used.

Alkaloids are present as secondary metabolites in about 20% of plant species impart a defensive role against herbivores and pathogen attacks (Summons 2006). A large number of biologically active alkaloids have been isolated from plants. At the cellular level, the action of alkaloids is quite variable. Some affect the nervous system; the protein synthesis, and others affect membrane transport and enzyme activities (Yao 2004).

Saponins are complex amphipathic glycosides of steroids and triterpenoids widely produced by plants (Sparg *et al.* 2004; Vincken 2007) and certain marine organisms, such as starfish and sea cucumbers (Tang *et al.* 2009; Van Dyck *et al.* 2010). Derived from sapo (Latin), which means soap because it has surfactant properties that form a soap-like foam that is stable by shaking in an aqueous solution. The term saponins are a group of high molecular weight glycosides consisting of a glycan moiety bound to an aglycone called genin or sapogenin (Hostettmann & Marston 2005).

The group of unambiguously characterized tannins includes more than 1000 natural products. In extensive biological tests, many representatives of the tannins exhibited antiviral and antibacterial properties, but especially prominent was the anti-tumor activity. Certain tannins, for example, can inhibit HIV replication selectively (Khanbabaee & Ree 2001), as astringents (digestive tract and skin), anti-diarrhoeal drugs. Tanin's physiological and pharmacological effects are due to its ability to form complexes, both with proteins and polysaccharides (Mahtuti & Yohani 2004).

Phenolic compounds and flavonoids function as antioxidants. According to Pokorny (Pokorny 2007), antioxidants can neutralize free radicals. Flavonoids are plant secondary metabolites with a polyphenolic structure, found in many fruits, vegetables, and certain beverage components. Flavonoids have various beneficial biochemical and antioxidant effects associated with various diseases such as cancer, Alzheimer's disease (AD), and atherosclerosis (Ovando *et al.* 2009; Lee *et al.* 2009)..

Terpenes comprising 30-C are triterpenes, which are a large class arised from squalene, formed by coupling of two farnesyl diphosphate units (Abe 2007; Tantillo 2011). Most triterpenoid compounds have prominent physiological activities, are widely used to treat diabetes, menstrual disorders, snake venom, skin disorders, liver damage, malaria, antifungal, insecticide, anti-predatory, anti-bacterial, and anti-viral26. Glycosides are organic compounds derived from the extraction of plants or animals. On enzymatic or acid hydrolysis, these compounds give one or more sugar moiety (glycone) and non-sugar moiety (aglycone or genin). Chemically, these glycosides are acetals or sugar ethers formed by the interaction of the hydroxyl group of the non-sugar moiety and the sugar with the loss of a water molecule (Bohé & Crich 2014; Khattak & Khan 2018).

CONCLUSIONS

Proximate analysis and phytochemical screening were carried out to add information on the nutritional value and content of secondary metabolites of gembolo, a food ingredient that is rarely found. The proximate test results showed that bulbils had higher water, fat, and fibre content than bottom tubers. Bottom tubers have a much higher ash, protein, and carbohydrates as starch content than bulbils. This confirms the assumption that bottom tubers are more recommended as a source of food than bulbils and because of their larger size than bulbils. The results of phytochemical screening showed that both gembolo bulbils and tubers contained the same chemical compounds, namely alkaloids, saponins, tannins, phenolics, flavonoids, triterpenoids, and glycosides.

REFERENCES

Abe I. 2007. Enzymatic synthesis of cyclic triterpenes. *Natural Product Reports.* 24: 1311–1331. https://doi.org/10.1039/b616857b.

Anandpara RC, Tirgar PR. 2017. Investigation of therapeutics benefits of *Dioscorea bulbifera* in breast cancer. *Journal of Chemical and Pharmaceutical Research.* 9(6): 313–326.

Anona CA, Ezeabara, Regina O. 2018. Comparative analyses of phytochemical and nutritional compositions of four species of Dioscorea. *Acta Scientific Nutritional Health*. 2(7): 90–94.

Cunniff PA. 1995. Official Methods of Analysis of Association of Official Analytical Chemists International (AOAC). 16th ed. AOAC International. Arlington Virginia USA.

Bhandari MR, Kawabata J. 2005. Bitterness and toxicity in wild yam (*Dioscorea* spp.) tubers of Nepal. *Plant Foods for Human Nutrition*. 60(3): 129–135. [Internet]. Cyted from http://springerlink. metapress.com/link.asp? id=102980. https:// doi.org/10.1007/s11130-005-6841-1. On June 28, 2021.

Bohé L, Crich D. 2014. *Synthesis of Glycosides* A2-Comprehensive Organic Synthesis II. 2nd ed. pp: 1-33. Editors-in-Chief: Paul Knochel, Gary A Molander. Elsevier 2014. Amsterdam, Boston, Heidelberg, London, New York, Oxford, Paris, San Diego, San Francisco, Singapore, Sydney, Tokyo.

Cannell RJP. 1998. *Natural Products Isolation*. New Jersey (US): Human Press Inc. pp. 165–208. https://doi.org/10.1007/978-1-59259-256-2.

Cogne AL. 2002. Phytochemical investigation of plants used in African traditional medicine: *Dioscorea sylvatica* (Dioscoreaceae), *Urginea altissim*a (Liliaceae), *Jamesbrittenia fodina* and *Jamesbrittenia elegantissima* (Scrophulariaceae). 208.

Fitriana. 2019. Pelatihan analisa proksimat. [Internet]. [Internet]. Cyted from Lppt.ugm.ac.id/ 2019/02/14/pelatihan-analisa-proksimat. On June 12, 2021. Laboratorium Penelitian dan Pengujian Terpadu, Universitas Gadjah Mada.

Ghosh S. 2015. Phytochemsitry and therapeutic potential of medicinal plant: Dioscorea bulbifera. *Medicinal Chemistry*. 5(4): 160–172. https://doi.org/ 10.4172/2161-0444

Hostettmann K, Marston A. 2005. *Saponins*. Cambridge (US): Cambridge University Press, https://doi.org/10.1016/B0-12-369397-7/00548-3

Global Invasive Species Database. 2022. Species profile: *Dioscorea bulbifera*. [internet]. Diakses pada 18 Juli 2022. Tersedia pada: http://www.iucngisd.org/gisd/species.php?sc=1220.

Ikiriza H, Ogwang PE, Peter EL, Hedmon O, Tolo CU, Abubaker M, Abdalla AAM. 2019. *Dioscorea bulbifera*, a highly threatened African medicinal plant, a review. *Cogent Biology*. 5(1). https://doi.org/10.1080/23312025.2019.1631561.

Kankolongo AM. 2018. Root and Tuber Crops in Food Crop Production by Smallholder Farmers in Southern Africa. Cyted from https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/dioscorea-bulbifera. On Sept 25, 2021.

Khanbabaee K, Ree Tv. 2001. Tannins: Classification and definition. The Royal Society of Chemistry. *Natural Product Report.* 2001(6): 641–649. https://doi.org/10.1039/b101061l.

Khattak S, Khan H 2018 Phyto-glycosides as therapeutic target in the treatment of diabetes. *Mini-Reviews in Medicinal Chemistry.* 18(3): 208–215. *https://*doi.org/10.2174/1389557516666160909112751.

Langeland KA, Cherry HM, McCormick CM, Craddock Burks KA. 2008. *Identification and Biology of Non-native Plants in Florida's Natural Areas*. Gainesville. Florida (US): University of Florida IFAS Extension.

Lee YK, Yuk DY, Lee JW, Lee SY, Ha TY, Oh KW, Yun YP, Hong JT. 2009. Epigallocatechin-3-gallate prevents lipopolysaccharide-induced elevation of β-amyloid generation and memory deficiency. *Brain Research* 1250: 164–174. https://doi.org/10.1016/j.brainres.2008.10.012.

Mahtuti, Yohani E. 2004. Pengaruh Daya Antimikroba Asam Tanat terhadap Pertumbuhan Bakteri Salmonella typhi Secara In Vitro: Penelitian Eksperimental 14 Etnomedisin dan Etnofarmakologi Tinjauan Pemanfaatan Tradisional dan Potensi Medis Laboratoris. [*Thesis*]. Surabaya (ID): Post Graduate Airlangga University.

Manandhar NP. 2002. Plants and People of Nepal. Portland (US): Timber Press.

Mizuki I, Takahashi A. 2009. Secondary dispersal of *Dioscorea japonica* (Dioscoreaceae) bulbils by rodents. *Journal of Forest Research*. 14(2). https://doi.org/10.1007/s10310-008-0106-4.

Nam HS, Cho SS, Kim CJ. 2006. The effects of *Dioscorea bulbifera* L. on hyperthyroidism of rats. *Journal of Korean Oriental Medicine*. 27(3): 179–187.

Oboh G, Akindahunsi AA, Ekperigin MM. 2001. Studies on the steroid hormone precursors of two tropical wild yams (*Dioscorea bulbifera* and *Dioscorea manganotiana*). Preprint: A*bdus Salam International Centre for Theoretical Physics.* The United Nations Educational, Scientific and Cultural Organization International Atomic Energy Agency.

Okeke EC, Eneobong HN, Uzuegbunam AO, Ozioko AO, Kuhnlein H. 2008. Igbo traditional food system: Documentation, uses and research needs. *Pakistan Journal of Nutrition*. 7(2): 365–376. https://doi.org/10.3923/pjn.2008.365.376.

Otoo E, Opoku Agyeman M, Dansi A, Aboagye LM, Acheremu K, Tetteh JP. 2015. Increasing farmers and breeders access to yam (*Dioscorea* Spp) Diversity: The case of forest-savannah transition agroecology. *African Journal of Agricultural Research*. 10(8): 772–782. https://doi.org/10.5897/AJAR

Ovando AC, Hernandez MDLP, Hernandez MEP, Rodriguez JA, Vidal CAG. 2009. Chemical studies of anthocyanins: a review. *Food Chemistry* (113): 859–871. https://doi.org/10.1016/j.foodchem.2008.09.001

Pokorny J. 2007. Are natural antioxidants better and safer than synthetic antioxidant*. European Journal of Lipid Science and Technology*. 109 (6): 629–642. https://doi.org/10.1002/ejlt.200700064

Sahore AD and Amani NG. 2013. Cooking in the water effect on some wild yam species tuber. *International Journal of Education and Research*. 1(2).

Sandoval JR, Ackerman JD, Tremblay RL. 2020. Island biogeography of native and alien plant species: contrasting drivers of diversity across the Lesser Antilles. *Diversity and Distribution*. 26(11): 1539–1550. https://doi.org/10.1111/ddi.13139

Shajeela PS, Mohan VR, Louis Jesudas L, Tresina Soris P. 2011. Antifertility acitivity of ethanol extract of *Dioscorea esculenta* (L.) schott on male albino rats. *International Journal of PharmTech Research CODEN*. 3(2): 946–954.

Sharma LN, Bastakoti R. 2009. Ethnobotany of Dioscorea L. with emphasis on food value in chepang communities in Dhading District, Central Nepal. *Journal of Plant Science*. 6(2009): 12–17. https://doi.org/10.3126/botor.v6i0.2905

Sparg SG, Light ME, van Staden J. 2004. Biological activities and distribution of plant saponins. *Journal of Ethnopharmacology.* 94 (2–3): 219–243. https://doi.org/10.1016/j.jep.2004.05.016

Summons RE, Bradley AS, Jahnke LL, Waldbauer JR. 2006. Steroids, triterpenoids and molecular oxygen. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 361: 951–968. https://doi.org/10.1098/rstb.2006.1837

Tang HF, Cheng G, Wu J, Chen XL, Zhang SY, Wen AD, Lin HW. 2009. Cytotoxic asterosaponins capable of promoting polymerization of tubulin from the starfish Culcita novaeguineae. *Journal of*

Natural Products. 72(2): 284–289. https://doi.org/10.1021/np8004858

Tantillo DJ. 2011. Biosynthesis via carbocations: Theoretical studies on terpene formation. *Natural Product Reports*. 28: 1035–1053. https://doi.org/10.1039/c1np00006c

Tapondjou LA, Jenett-Siems K, Böttger S, Melzig MF. 2013. Steroidal saponins from the flowers of *Dioscorea bulbifera* Var. sativa. *Phytochemistry*. 95. 341–350. https://doi.org/10.1016/j.phytochem.2013.07.020

Trimanto, Hapsari L. 2015. Diversity and utilization of *Dioscorea* spp.tuber as altern ative food source in Nganjuk Regency, East Java. *Agrivita.* 37(2). https://doi.org/10.17503/Agrivita-2015-37-2-p097-107

USDA ARS-GRIN. 2012. United States Department of Agriculture. Agricultural Research Service. The Germplasm Resources Information Network. Online Database. Beltsville, Maryland, USA (US): National Germplasm Resources Laboratory. https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomysearch.aspx.

VAL202. 2015. *Dioscorea bulbifera*. [Internet]. Diakses pada 26 Agustus 2021. Tersedia pada: https://hyattractions.wordpress.com/2015/11/18/dioscorea-bulbifera/.

Van Dyck S, Gerbaux P, Flammang P. 2010. Qualitative and quantitative saponin contents in five sea cucumbers from the Indian Ocean. *Mar Drugs* 8: 173–189. https://doi.org/10.3390/md8010173

Vincken JP, Heng L, de Groot A, Gruppen H. 2007. Saponins, classification and occurrence in the plant kingdom. *Phytochemistry* 68: 275–297. The Phytochemical Society of Europe. Elsevier Ltd. https://doi.org/10.1016/j.phytochem.2006.10.008

Yao LH, Jiang YM, Shi J, Tom´as-Barber´an FA, Datta N, Singanusong R, Chen SS. 2004. Flavonoids in food and their health benefits. *Plant Foods Human Nutr.* 59(3): 113–22. https://doi.org/10.1007/s11130-004-0049-7