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Mini-Review: Antibacterial Products from Teak Leaf Extract (*Tectona grandis* L.)

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Abstract

Teak (*Tectona grandis* L.) is a plant that has a high resistance to weather changes and termite attacks. The dominant use of teak in the furniture industry left behind its leaf as agricultural waste (agro-waste). Several pharmacological activities have been identified in the teak leaf part. In this review article, the authors gathered information from previous studies regarding the potential use of teak leaf antibacterial compounds to be made into various antibacterial products, namely hand sanitizers, floor disinfectants, fruit and vegetable disinfectants, and deodorant. Literature searches are carried out through search engines and online journal databases. The results of the literature review show that there are at least eight antibacterial compounds from teak leaf that have been isolated, identified, and tested for their activity, namely anthratectone, naphthotectone, juglone, gallic acid, ellagic acid, rutin, quercetin, and sitosterol. Furthermore, it is known that the solvent that can be used for teak leaf extraction by providing the best antibacterial activity is ethanol. This information is used as a recommendation for optimization of teak leaf extraction as part of the author's suggestion in making antibacterial products. In addition, previous research related to the use of ethanol extract from the teak leaf as an antibacterial product for liquid soap was also included. The study shows that the teak leaf extract liquid soap has promising activity compared to its comparable commercial soap, thereby strengthening the author's idea to utilize teak leaf extract as a component of the active ingredient of other antibacterial products, namely hand sanitizers, floor disinfectants, fruit and vegetable disinfectants, and deodorant.

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INTRODUCTION

Teak (*Tectona grandis* L.) is one of the commercial plants which is often used in Indonesia. Globally, the total area of planted teaks reaches 3 million hectares, with about 31% of the land located in Indonesia (Palanisamy *et al.*, 2009). Most of the total planted area for teak in Indonesia is in Java Island (Hidayati *et al.*, 2013). Teaks are easy to plant, which allows for the sustainable development of their genetic material. This tree also has a high resistance to weather changes and termite attacks. The advantages of teaks are used for various needs, from furniture making to shipbuilding (Alabi and

Oyeku, 2018).

Parts other than wood from teaks that are not used in the furniture industry generally remain as agricultural waste (agro-waste) (Kembaren *et al.*, 2014). Teak parts are known to have various pharmacological activities, including antioxidant, antibacterial, anti-fungal, and antiviral properties (Devadiga *et al.*, 2015; Vyas *et al.*, 2019). These pharmaco-logical effects are supported by the bioactive compounds contained in this plant, including the leaf (Khera and Bhargava, 2013). Utilization of teak leaf in Indonesia is still based on hereditary experiences and has not directly utilized the properties of the active compounds contained therein. Initial researches related to the antibacterial activity of teak leaf extract were carried out by Krishna and Nair (2010) and Purushotham and Sankar (2013) which showed that the antibacterial activity of the leaf extract had promising results.

Chemical-based antibacterial products such as alcohol, hypochlorite, and chlorine tend to have detrimental effects such as irritating the skin and causing pathogen resistance. In addition, the long-term use of chemical antibacterial products can also leave residues that have the potential to harm health (Pandya *et al.*, 2017). The purpose of writing this narrative review article is to examine the potential use of antibacterial compounds in teak leaf extract as a component of active ingredients for antibacterial products such as hand sanitizers, floor disinfectants, fruit and vegetable disinfectants, and deodorant. The writing of this article is supported by literature studies on related studies that have been done previously. The antibacterial product formulation will provide a solution to the untapped teak leaf agricultural waste. In addition, this product also offers an alternative way with natural active ingredients to reduce bacteria in the body and the surrounding environment while simultaneously empowering existing local resources.

MATERIALS AND METHODS

Devices Used and Literature Resources

The tools used to study the literature for the preparation of this article are the HP Pavillion Laptop, the ASUS Idea-pad 320S-13IKB Laptop, and the HP 14-CM0XX Laptop. The literature used was obtained from the Google Scholar search engine (http://www.scholar.google.com) and the ScienceDirect database (http://www.sciencedirect.com), Researchgate (http://www.researchgate.net) , Indonesian Scientific Repository (http://www.neliti.com/id/), Semantic Scholar (http://www.semanticscholar.org) and National Library of Medicine (http://www.pubmed.ncbi.nlm.gov).

Literature Review

The research was conducted by conducting literature studies through the Google Scholar search engine and online journal databases (Researchgate, ScienceDirect, Indonesian Scientific Repository, and the National Library of Medicine). The chemical structures of the compounds mentioned were redrawn using ChemDraw 18.1 application. The selection of articles obtained mostly consists of research articles. Most of the articles used have a span of publication years for the last 10 years, namely from 2010-2020. Keywords used to obtain sources of literature studies include, "antibacterial activity of *Tectona grandis* L.", "antibacterial compounds of *Tectona grandis* L.", "anthraquinone compounds *Tectona grandis* L.", "compound content of teak leaf", and utilization of leaf extract *Tectona grandis* L." The collection of literature obtained was selected based on the discussion of the preparation of this article.

RESULTS AND DISCUSSION

Morphology of Teak leaf (*Tectona grandis* L.)

The morphology of a plant can be seen from the structure and shape of the plant. Leaf morphology has an important role in providing defense for a plant, including teak trees. The teak leaf is large, with an area of about 30cm x 20cm. These leaves have a network of vessels that are visible yellowish in color. The teak leaf has shiny sides on the top and has fine hair on the underside (Nidavani and Mahalakshmi, 2014). The fine hairs function to protect the teak trees from insect attack (Prasetyawati and Aida, 2019). The picture of teak leaf obtained from the research conducted by Prasetyawati and Aida (2019) can be seen in Figure 1.

Figure 1: Teak leaf (*Tectona grandis* L.)

Table 1: Antibacterial mechanism of the antibacterial compounds of the teak leaf (*Tectona grandis* L.)

Antibacterial compound	Antibacterial mechanisms
Anthratectone	Inhibits cell wall and nucleic acid synthesis.
Naphtotectone	Inhibits electron transport, decoupling phosphorylation oxidative, production of reactive oxygen species (ROS) in
Juglone	aerobic condition, inhibits DNA and RNA synthesis.
Rutin	Inhibits hydrolytic enzymes or other interaction that
Quercetin	activates microbial adhesion.
Gallic acid	
Ellagic acid	
Sitosterol	

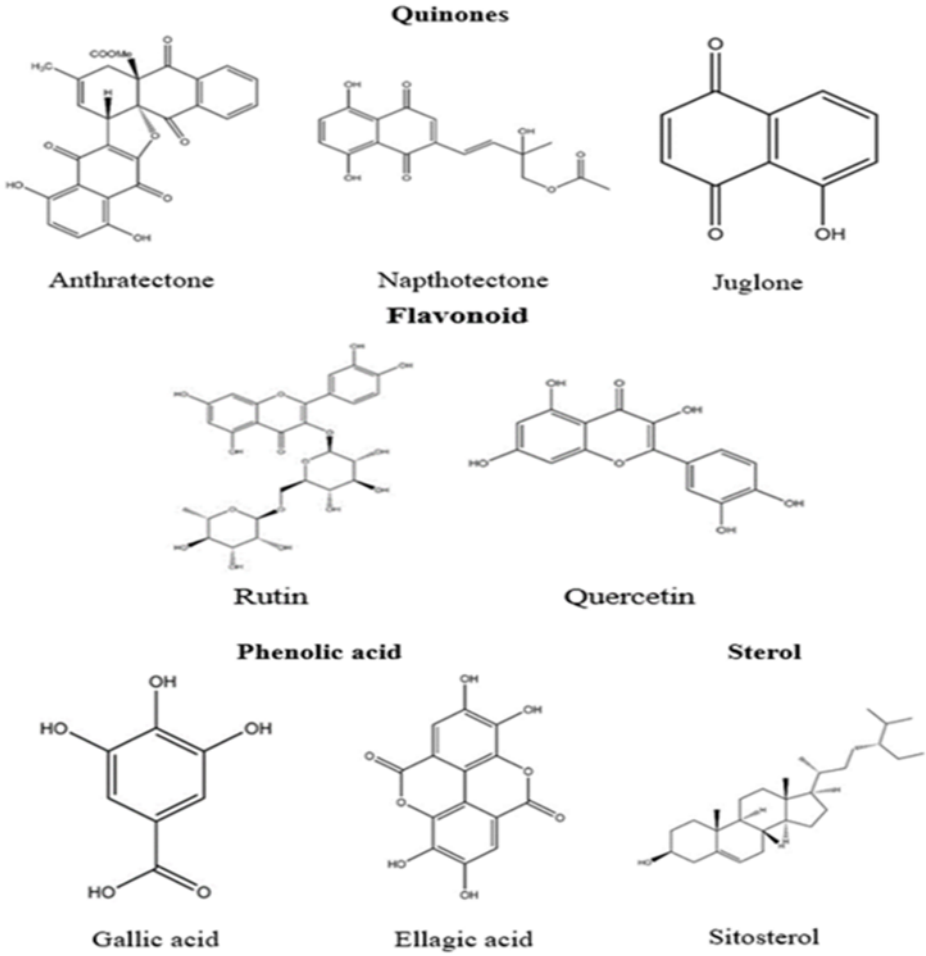

Figure 2: Antibacterial compounds of teak leaf extract (Tectona grandis L.)

Antibacterial Activity of Teak leaf (*Tectona grandis* L.)

Initial research related to the antibacterial activity of teak leaf was carried out by Krishna and Nair (2010). This study involved testing the antibacterial activity of teak leaf extract with four different solvents, namely hexane, chloroform, ethyl acetate, and methanol. The results showed that the chloroform extract had the most promising antibacterial activity with the zone diameter of inhibition against *Staphylococcus aureus* and *Klebsiella pneumoniae* of 14 mm and 8 mm, respectively. In addition, it was stated that the methanol extract of the teak leaf has powerful antibacterial activity against gram-positive and gram-negative bacteria. This property is not widely found in natural phytochemical compounds, so this is an advantage for the teak leaf.

Godghate and Sawant (2014) then conducted

research related to the analysis of phytochemical compounds in teak leaf extract with four different solvents. The test involves several tests of phytochemical compounds, including tannins, flavonoids, alkaloids, and anthraquinones. The study showed that the teak leaf extract contained all four groups of these compounds. The compounds of the tannin, flavonoid, alkaloid, and anthraquinone groups are known to be the types of compounds that are responsible for the antibacterial activity of teak leaf (Arief *et al.*, 2014).

Specific Antibacterial Compounds of Teak leaf (*Tectona grandis* L.)

So far, eight specific compounds for the antibacterial of the teak leaf have been identified. These compounds are anthratectone, naphthotectone, juglone, gallic acid, ellagic acid, rutin, quercetin, and sitosterol. Krishna and Nair (2011) research isolated two specific antibacterial compounds that are only found in the teak leaf, which were further identified by Lacret *et al.* (2011) as anthratectone and naphthotectone.

The research carried out a method of gradual extraction of compounds using hexane, chloroform, ethyl acetate, and methanol. Anthratectone and naphthotectone were tested against *S. aureus* and *K. pneumoniae*. The results showed that the antibacterial activity of the two compounds was better than the positive control, ciprofloxacin. In addition, Lanka and Parimala (2017) state that there's another antibacterial compound in teak leaf, namely 5-hydroxy-1,4-naphthalendion (juglone).

Nayeem and Karvekar (2011) then isolated several other antibacterial compounds on the teak leaf. These compounds are rutin, quercetin, gallic acid, ellagic acid, and sitosterol. The study used methanol extract of the teak leaf, which was tested against *S. aureus*, *Bacillus subtilis*, *Escherichia coli*, and *K. pneumoniae* by the disc diffusion method. The group of compounds and the chemical structure of the eight-teak leaf antibacterial compounds can be seen in Figure 2.

Isolation Method and Work Mechanism of Teak Leaf Antibacterial Compounds

Each teak leaf antibacterial compound that has been identified has different isolation stages. Anthratectone and naphthotectone compounds can be extracted with dichloromethane (CH_2Cl_2) and ethyl acetate (EtOAc), then extracted the remaining material with methylene chloride (DCM) and methanol. The DCM extract was chromatographed with silica gel and then purified (Macías *et al.*, 2010). Juglone compound can be obtained by the maceration method using organic solvents, and then the solvent was evaporated (Strugstad and Despotovski, 2013). Rutin compounds, quercetin, gallic acid, ellagic acid, and sitosterol can be extracted by fractionating and eluting the mobile phase column with increased polarity (Nayeem and Karvekar, 2011). A summary regarding the antibacterial mechanisms of each compound can be seen in Table 1. The antibacterial mechanism of anthratectone inhibits cell wall and nucleic acid synthesis (Malmir *et al.*, 2017). The antibacterial mechanism through inhibiting electron transport, decoupling phosphorylation oxidative, production of reactive oxygen species (ROS) in aerobic condition, inhibiting DNA and RNA synthesis were reported for naphtotectone and juglone compounds (Babula *et al.*, 2009; Wang *et al.*, 2016). Nayeem and Karvekar (2011) said the antibacterial mechanism through inhibiting hydrolytic enzymes or another interaction that activates microbial adhesion were reported for rutin, quercetin, gallic acid, ellagic acid, and sitosterol compounds.

Teak Leaf Extraction Solvent with the Best Antibacterial Activity

After knowing the specific compounds that are responsible for the antibacterial activity of teak leaf extract, then a search is carried out regarding the solvent for teak leaf extraction, which provides the best antibacterial activity. Lanka and Parimala (2017) tested the antibacterial activity of teak leaf extract with four different solvents, namely ethanol, methanol, ethyl acetate, and water. Unlike the case with the initial research conducted by Krishna and Nair (2010), the study of Lanka and Parimala (2017) included data on the diameter of the zone of inhibition of each solvent so that comparisons could be made. The results showed that ethanol had the best antibacterial activity with zones of inhibition against *Pseudomonas aeruginosa*, *S. aureus*, and *B. subtilis*, respectively, 18 mm, 16 mm, and 21 mm. The determination of the best solvent can then be used as a reference for the optimization of the teak leaf extraction method as part of the manufacture of various antibacterial products.

Previous research related to the use of the teak leaf as antibacterial products

Chastelyna *et al.* (2017) research has used ethanol extract of the teak leaf as one of the active ingredients in liquid soap product. These preparations were made with different extract concentrations, with the lowest concentration being 0% and the highest being 0.03%. In addition, this study also compared the antibacterial activity of teak leaf extract soap against commercial soap. The results

showed that the higher the concentration of teak leaf extract in liquid soap, the better the antibacterial activity that is performed. Apart from that, the ethanol extract of the teak leaf also showed higher antibacterial activity than the comparable commercial soap. This reinforces the idea that the teak leaf extract antibacterial compounds have the potential to be made into other antibacterial products, namely hand sanitizers, floor disinfectant, fruit and vegetable disinfectant, and deodorant.

Utilization of Teak Leaf Extract as a Hand Sanitizer

The use of teak leaf extract as an additional antibacterial agent in hand sanitizers can reduce the use of alcohol and triclosan active ingredients which can irritate the skin. The formulation of a gel hand sanitizer based on teak leaf extract can refer to the research of Asngad *et al.* (2018) with a mixture that includes alcohol, triclosan, triethanolamine (TEA), glycerin, and carbopol-94. Alcohol acts as a disinfectant with bactericidal activity and helps dissolve triclosan. Triclosan can slow down bacterial growth, has antifungal and antiviral properties. TEA acts as a pH balancer for hand sanitizer gel preparations to match the skin pH (4.5-6.5). Glycerin plays a role in preparing to appear clear and helps hand sanitizer preparations retain moisture. Carbopol-94 acts as a thickening agent (Asngad *et al.*, 2018).

Utilization of Teak Leaf Extract as Floor Disinfectant

Disinfectants are used to neutralize pathogenic organisms and prevent the spread of infectious or infectious diseases (Quinn *et al.*, 2015). Based on the active ingredients, disinfectants can be divided into two types, namely chemical disinfectants and natural disinfectants. Chemical disinfectants based on alcohol, hypochlorite, and chlorine tend to have detrimental effects such as irritating the skin, causing pathogen resistance, and can leave residues that have the potential to harm health (Pandya *et al.*, 2017). Natural disinfectants are an alternative form and an environmentally friendly solution. This type of disinfectant is safer, non-corrosive, and biodegradable (Khanam and Afsar, 2013).

According to Al-Hunaiti *et al.* (2017), the bacteria that are mostly found on the floor are *Bacillus* sp., *Pseudomonas* sp., and *Staphylococcus* sp. Research conducted by Purushotham and Sankar (2013); Krishna and Nair (2010); Lanka and Parimala (2017) show that teak leaf extract can kill and inhibit the growth of various bacterial species, including the three bacterial species, so that teak leaf extract has the potential to be used as an active ingredient in floor disinfectant.

Utilization of Teak Leaf Extract as a Fruit and Vegetable Disinfectant

The antibacterial properties of teak leaf extract can be used as a fruit and vegetable disinfectant. Martin-Belloso and Fortuny (2010) stated that antimicrobial chemical compounds when used in the right levels and mixed with water, can help reduce contaminant agents on the surface of fruits and vegetables. The application of teak leaf extract for this product is important, considering that fresh food products such as fruits and vegetables tend to be susceptible to bacterial contamination.

This contamination can be combated with disinfectants that are safe for the body. Bacterial contamination of fruits and vegetables can occur at the stage of growth, harvesting, and product processing. The use of water for the production of fruit and vegetables can be a source of pathogenic bacteria such as *E. coli*, *Salmonella* sp., *Vibrio cholera*, and *Shigella* sp. Siddiqui (2018)

One example of a chemical compound used as a disinfectant for fruits and vegetables is paracetic acid (PA). PA has been patented since 1950 as a surface disinfectant for fruits and vegetables, both in the form of a solution or spray. The antibacterial compounds of the teak leaf, naphthoquinone and juglone, have an antibacterial mechanism similar to PA compound, namely producing reactive oxygen species (ROS). When the antibacterial compounds enter bacterial cells, these compounds will interfere with cell function by oxidizing proteins, enzymes, DNA, and bacterial metabolite compounds. This process then leads to a disruption of the function of bacterial life, resulting in bacterial death (Siddiqui, 2018).

Utilization of Teak Leaf Extract as a Deodorant

Deodorant is a cosmetic product used to reduce body odor problems. The bacteria that cause body odor include *S. aureus*, *P. aeruginosa*, and *Staphylococcus epidermidis*. This product can be made with the addition of natural ingredients as an alternative material that is relatively safer than synthetic materials (Lailiyah and Rahayu, 2019). Rusli and Zulhipri (2016); Lailiyah and Rahayu (2019) conducted research on deodorant production using natural ingredients, namely kaffir lime (*Citrus hystrix* D.) and hibiscus leaf (*Hibiscus tiliaceus* L.). The research utilized the flavonoid and tannin class antibacterial compounds contained in the natural ingredients used.

Teak leaf extract is known to contain flavonoid and tannin class compounds (Arief *et al.*, 2014), and its specific antibacterial compounds have been shown

to inhibit the growth of *S. aureus* and *P. aeruginosa* bacteria (Nayeem and Karvekar, 2011; Krishna and Nair, 2011). This reinforces the idea that teak leaf extract has the potential as a natural ingredient that can be used to make deodorant. The formulation of a teak roll-on deodorant dosage refers to the research of Lailiyah and Rahayu (2019). The components of the formulation include carbopol as a thickener, triethanolamine (TEA) as a pH neutralizer, Butylated hydroxytoluene (BHT) as an antioxidant, sodium metabisulfite as a preservative, and propylene glycol and distilled water as a solvent (Lailiyah and Rahayu, 2019).

CONCLUSIONS

Teak leaf extract (*Tectona grandis* L.) has been shown to have antibacterial activity with specific antibacterial compounds, namely anthratectone, naphthotectone, juglone, rutin, quercetin, gallic acid, ellagic acid, and sitosterol. The solvent for teak leaf extraction that is known to provide the best antibacterial activity is ethanol. There have been studies using ethanol extract of teak leaves as an active ingredient in antibacterial product liquid soap. The liquid soap has been proven to kill and inhibit bacterial growth, thereby strengthening the hypothesis of the potential of teak leaf ethanol extract as a component of the active ingredient of other antibacterial products, namely hand sanitizer, floor disinfectant, fruit and vegetable disinfectant, and deodorant.

Furthermore, research can be carried out related to the use of teak leaf antibacterial compounds into antibacterial products by making hand sanitizer, floor disinfectant, fruit and vegetable disinfectant, and deodorant. This research can include teak leaf extraction using the extraction method that has been suggested to obtain the best antibacterial activity (using ethanol solvent), extract formulations into hand sanitizer gel product, floor disinfectant and fruit and vegetable disinfectant, and deodorant. In addition, further research may include testing the antibacterial activity of finished product preparations, as well as tests that are relevant to the product (pH test, organoleptic test, etc.).

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Conflict of Interest

The authors declare that they have no conflict of interest for this study.

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