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# Scoping Review: Metabolite and Pharmacological Activities in Lontar Fruit (*Borassus flabellifer* Linn.)

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## ABSTRACT

The development of medicine depends heavily on medicinal plants. They include various phytochemicals that can have physiological effects on people. Among them is the *Borassus flabellifer* Linn., also known as the lontar plant, which is a tropical plant in the Araceae family and is recognized for its medicinal qualities in traditional medicine. It is also referred to as the Palmyra palm. This study aims to gather information on the phytochemical compounds and pharmacological activities of palm fruit using a literature review. The literature search was conducted online using appropriate keywords and included both international and national indexed databases, covering the last 10 years (2014 - 2024). Tannins, saponins, glycosides, alkaloids, terpenoids, albuminoids, anthracene, betulinic acid, carotenoids, flavonoids, free anthraquinones, glucomannan, gums, lupeol, phlobatannin, phenols, quercetin, phytosterols, triterpenoids, quinones, cardiac glycosides, steroids, coumarins, and betacyanin have been identified as chemical components in palm fruit based on the 19 studies that were gathered. The pharmacological activities of palm fruit include antibacterial, antidiabetic, antihyperlipidemic, antihyperglycemic, antioxidant, and anticancer.
**Keywords:** *Borassus flabellifer* Linn.; lontar fruit; pharmacological activity; phytochemical screening

## INTRODUCTION

Plants have been beneficial to humanity for a long time, offering significant medicinal properties and helping to alleviate chronic diseases. Medicinal plants are crucial to the development of medicine, because many illnesses such as cancer, liver disease, and arthritis cannot be completely cured through symptomatic treatment alone. Medicinal plants contain bioactive chemicals that are employed as anti-inflammatory, chemotherapeutic, antidiabetic and antirheumatic agents, but modern medicine has yet to provide a fully satisfactory cure for these conditions. Many plants show great potential to fight diseases (Sumonsiri et al.,2021). Worldwide, there are thought to be approximately 40,000 different kinds of medicinal plants, 30,000 of which are found in Indonesia, and Indonesian people have been studying plant species that are effective in treating and preventing various types of diseases since ancient times. Community knowledge regarding the utilization of plants for medicinal purposes is limited to the interaction between the community and its environment (Isyraqi et al.,2020)

Plants typically contain metabolites involved in their metabolic processes. These compounds are categorized into two groups: secondary metabolite compounds and primary metabolite compounds. In living organisms, primary metabolic compounds like proteins, fats, and polysaccharides are crucial for the regulation of bodily functions. Additionally, compounds such as carotenoids and triterpenoids, although primary, serve as predator deterrents. The industrial sector uses secondary metabolic compounds for various purposes, including dyes, textiles, and medical and pharmacological applications. Notable groups of these compounds include terpenoids and steroids, flavonoids, alkaloids, tannins, and saponins (Julianto, 2019)

Researchers continue to study natural agricultural products and continue to study them for medical applications because they are more accessible, less expensive, and have fewer side effects than current medications. Because of their biological activity secondary metabolites like

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flavonoids have pharmacological characteristics like antibacterial, anti-inflammatory, antidiabetic, anticholesterolemic, antioxidant, and anticancer effects. Foods with high total phenolic content also have high flavonoid content. As a result, fruits high in phenol content can benefit human health (Stompor, 2020)

Numerous phytochemicals found in plants can affect human health. One of the most significant medicinal plants among them is *Borassus* flabellifer Linn. Various plant parts are used for their therapeutic qualities in traditional medicine. The lontar plant *Borassus flabellifer* Linn is a type of tropical plant that has grown and developed in tropical countries including Indonesia and can be used as food and medicine (Industri et al., 2023)

Many Arecaceae families, including *Borassus flabellifer* Linn ., are found in tropical countries. The lontar tree is also known as the tall bodied *Borassus flabellifer* Linn *Borassus* is derived from the Greek word meaning rough layer of fruit and *flabellifer* meaning fan-bearer. The tree reaches a height of approximately 30 m, with a black trunk and a crown of leaves at the top. The leaf diameter ranges from 0.9 to 1.5 m. It has large fruits; unisexual flowers; and stiff, pointed serrations with horns on the edges of the leaf stalk. This slow-growing perennial can live for up to 150 years and shows no signs of flowering. The leaves are large fan-shaped, gray-green leaves with horny, hard, pointed serrations on the petiole edges that cover the stems. In marginal biological environments, palm trees may shed 12 leaves annually or, more rarely, 1 leaf every 28 days. Every year, male palm trees yield 10-15 small flowers called florets. However, every female flower can have two to three branches, each of which can produce 100-150 fruits. Palmyra trees begin to flower and bear fruit during the dry season 15–20 years after germination (Pammi et al., 2021)

Palmyra plants are used for approximately 800 purposes, such as food, drink, medicine, wood and fiber. Various pharmacological properties, such as anti-inflammatory, intertritic, cytotoxic, antibacterial, analgesic, antioxidant, antipyretic and hypoglycemic effects, have been attributed to Palmyra products (Hutasuhut et al., 2022). The fruit of the palm tree is its most valued component. After pollination, the fruit grows with a diameter of 10-18cm and black to brown skin. Every fruit has one to three seeds. Unripe fruit seeds, or endosperm, can be consumed like fruit. The fibrous portion of the unripe lontar fruit must be removed before consumption because its rough skin, makes it extremely difficult to eat. Conversely the ripe fruit fibrous outer covering can be consumed raw, roasted, or boiled. The soft orange-yellow mesocarp, accounts for approximately 51.07% of the entire fruit, is the edible flesh of ripe lontar fruit (Maruddin et al., 2023)

In most countries, fresh pulp is used as animal feed. Palm fruit is rich in nutrients, The pulp from mature fruit is used in many conventional dishes and similar preparations. Although lontar fruit is seasonal, it has excellent chemical and physical properties. Palm fruit provides many health benefits because it contains bioactive compounds such as flavonoids (genkwanin, sakuranetin, and kaempferol), saponins (sterols and triterpenoids), alkaloids, tannins, carotenoids and betasitosterols. (Kumar and Boopathi, 2018)

Bioactive compounds found in palm fruit cause this plant to have pharmacological activity. Metabolite compounds found in lontar fruit are believed to produce the desired pharmacological effects. Therefore, phytochemical screening is necessary to determine the classes of metabolites in lontar fruit. This paper presents the results of a study of the literature on metabolite compounds contained in lontar fruit that are believed to cause desired pharmacological effects. This study identified the secondary metabolites compounds contained in lontar fruit and their pharmacological activities in vitro and in vivo based on scientific publications and thus it can be a source of information in the research and development of herbal medicines

## METHODS

### Data Source

The methodology framework proposed by Arskey and O'Molley served as the foundation for developing the scoping review (Peters et al., 2015). This research conducts in-depth analysis and identifies gaps in evidence-based articles that are relevant to a topic, Thus the articles used must have clear and reliable sources (Tricco et al., 2016). Searches on reputable national and international scientific articles were conducted in March 2024 systematically on PubMed, ScienceDirect, ResearchGate, Semantic Scholar and Google Scholar databases published in the last 10years (2014-2024). The initial database search strategy was predetermined using a combination of keywords related to the research topic and title ("palm fruit","palm fruit mesocarp", "*Borassus flabellifer* Linn "and" phytochemicalscreening" or "phytochemical screening and "pharmacology activity"or"pharmacology activity"). Following the guidelines in the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR), this scoping review was organized and carried out. PRISMA-ScR comprises multiple steps: (1) defining the review's query or aim; (2) finding pertinent articles; (3) selecting articles; (4) mapping data; and (5) assembling, summarizing, and reporting the findings. Articles assessed according to these criteria will be further reviewed in relation to phytochemical screening and the pharmacological activities of palm fruits. Then, the results will be presented and explained in narrative and followed by conclusions (Page et al., 2021)

**Data Selection (Inclusion and Exclusion Using Population, Intervention, Comparison, Outcomes, and Study [PICOS]**

In writing a scoping review, a literature search strategy is required to obtain relevant literature and data sources. Problem questions can be developed to facilitate the literature search process easier. The process of formulating problem questions can be based on the PICOS framework (since January 2020). Using the PICOS method, the library is uniform according to the predetermined criteria.

The list of references obtained through the initial search was then identified whether it met the predetermined inclusion criteria, including: (1) population, lontar fruit, reference journals in English or Indonesian; research journals of the original article type which are experimental studies; (2) intervention phytochemical screening and pharmacological activity; (3) comparison, compared with phytochemical screening and pharmacological activity of other parts of the lontar plant; (4) results, compounds of phytochemical content and antioxidant activity; (5) study design, using laboratory, clinical, in vivo and in vitro experimental study designs Additionally, there are several exclusion criteria in the selection of articles, including; (1) population, other parts of the lontar plant other than fruit; (2) intervention, not phytochemical screening and not pharmacological activity; (3) comparison, not compared with phytochemical screening and pharmacological activity of other parts of the lontar plant; (4) results, no compounds of phytochemical content and antioxidant activity; (5) study design, not using laboratory, clinical, in vivo and in vitro experimental study designs.

Using the findings of a review of the literature using the PICOS framework for the phytochemical screening and pharmacological activity of palm fruit. The search results from five databases obtained 1, 183 articles were obtained; covering the last 10 years (2014-2024) and 1,102 articles were deleted resulting in 81 articles. Of the 81 articles, 42 were excluded, including 9 review and 6 duplicate articles and 27 irrelevant articles based on the title. Furthermore, as many as 24 articles that were considered worthy of being used as references were thoroughly screened. From the results of the overall screening of articles, the suitability of the population, methods, and results, 19 articles that were considered to satisfy the inclusion and exclusion criteria were obtained and examinations were conducted in accordance with the criteria so that they could serve as a reference for scoping review (Figure 1).

## RESULTS

### Phytochemical Screening

On the basis of the 19 studies collected, compounds identified in palm fruit such as alkaloids, flavonoids, saponins, terpenoids, tannins, and phenols were obtained. The pharmacological effects of lontar fruit include antibacterial, antidiabetic, antihyperlipidemic, antihyperglycemic, antioxidant, and anticancer.

### Pharmacological Activity

Table II.

## DISCUSSION

### Phytochemical Screening

Phytochemistry is the study of the nature and interaction of chemical compounds in secondary plant metabolites. Secondary metabolites are biosynthetic compounds derived from primary metabolites and are generally produced by organisms that function in self-defense against the environment or against attacks by other organisms. Secondary metabolites are produced by other metabolic pathways that are necessary for plant growth but do not play important roles (Vishnukumar et al., 2018)

To determine whether lontar fruit contain secondary metabolites, phytochemical screening was performed When a plant extract is analyzed, phytochemical screening yields both qualitative and quantitative information on the amount of secondary metabolites present. Plants are used as medicine because of their compounds. Natural ingredients used in therapies comprise a group of secondary metabolites derived from plants. Secondary metabolite compounds are not essential for plant growth. In general, secondary metabolite compounds play an important role in self-defense against other organisms. The presence of secondary metabolites is limited to the source plant or strain. Compounds included in the secondary metabolite group include flavonoid and phenolic compounds. Flavonoid compounds are found in almost all parts of plants, including roots, leaves, flowers, fruits, and seeds. Phenolic compounds are widely found in plants, especially

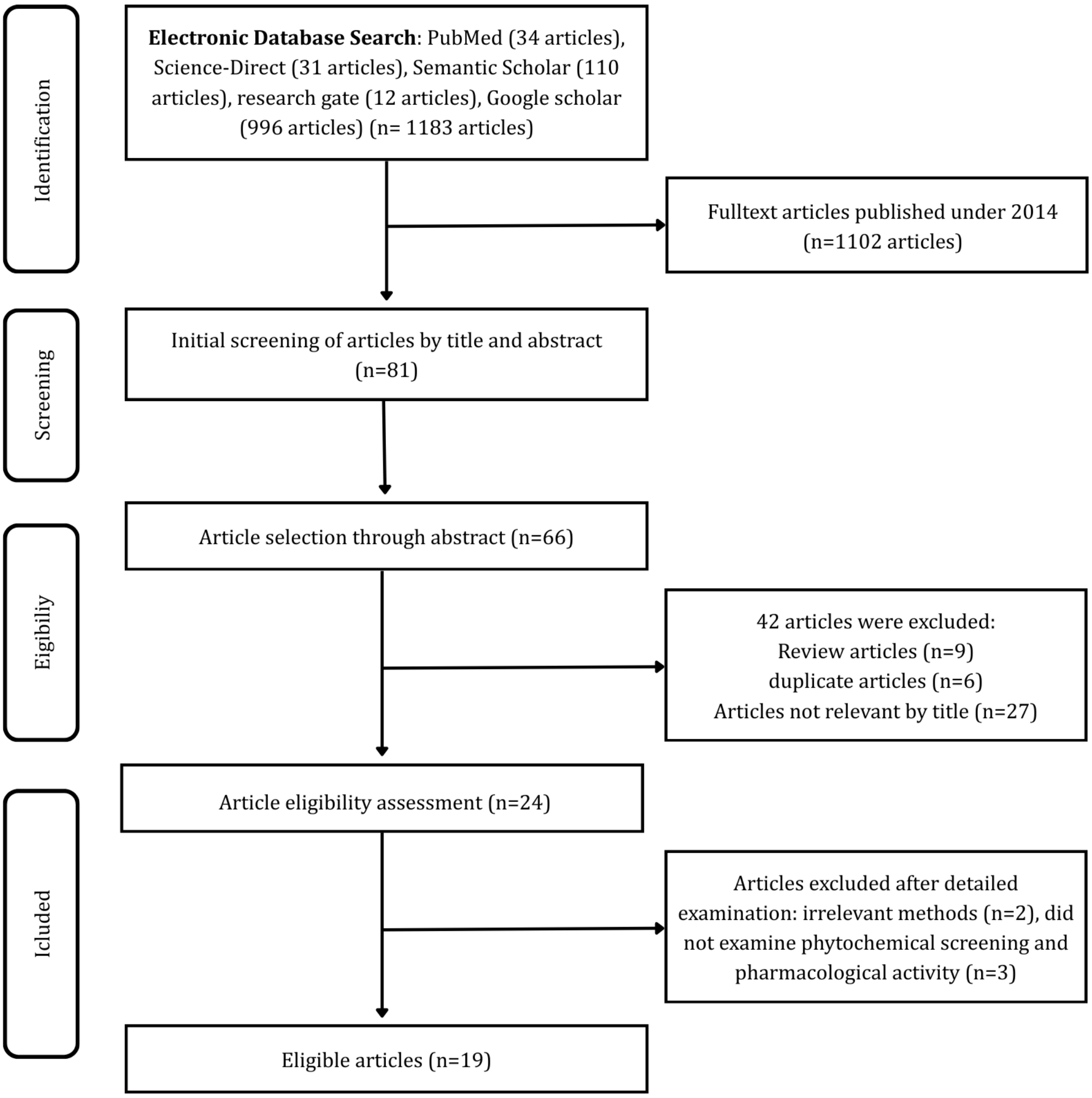


**Figure 1. PRISMA-ScR Literature Diagram**

those containing aromatic compounds with benzene and hydroxyl structures (Montané et al., 2020).

*Borassus flabellifer* Linn fruits that have been extracted contain carotenoids, polyphenols, alkaloids, and saponins. In addition to providing several other health, benefits bioactive chemicals are crucial for the prevention of numerous diseases like cancer and atherosclerosis. Rahman et al., (2021b) reported that *Borassus flabellifer* Linn . fruit contains, carbohydrate, crude fiber, crude protein, crude fat, ash, calcium energy, phosphorus, iron, copper, zinc, magnesium manganese, sodium, potassium, vitamin-C, (carotenoids, nonprotein nitrogen, protein solubility, free fatty acids. Additionally, some studies have shown that B. *flabellifer* fruit contains some saponins (Ngginak et al., 2021) tannins, flavonoids, saponins, glycosides and terpenoids (Alamelumangai et al., 2014) alkaloids, albuminoids, anthracene, betulinic acid, carotenoids, flavonoids, free anthraquinones, glucomannan, glycosides, gums, lupeol, phlobotanin, phenols, quercetin, reducing compounds, saponins, steroids, tannins, terpenoids (Rahman et al., 2021a) phytosterols, phytosterols, triterpenoids and phenols (Renuka et al., 2018), quinones, cardiac glycosides, steroids, coumarins, and betasianin (Rani et al., 2018).

Current technology indicates that unprocessed and heat-treated palm fruit pulp (SPFP) contains phytochemical compounds in addition to protein. Pulp contains a large number of phytochemicals such as glycosides,

**Table I. Phytochemical screening**

| Fruit part | Extraction method | Solvents used | Secondary metabolite content | Reference |
|---|---|---|---|---|
| Palm fruit ripe fiber | Maceration | Methanol | Saponins | (Ngginak et al., 2021) |
| Palm fruit flesh skin | Maceration | Ethanol | Flavonoids, tannins and terpenoids. | (Lenggu et al., 2020) |
| Seed coat of *Borassus* flabellifer palm fruit. | Maceration | Ethanol | Flavonoids, phenols, and tannins | (Sudiono, 2021) |
| Palm fruit ripe fiber | Maceration | Ethanol and Acetone | Fat, tannin total carotenoid and carotene | (Idayati et al., 2014) |
| Palm fruit ripe fiber | Maceration | Ethanol | Alkaloids, flavonoids, saponins, tannins, and terpenoids | (Febry Maakh et al., 2021) |
| *Borassus flabellifer* Linn . seed coat | Maceration | Ethanol and methanol | Tannins, flavonoids, saponins, glycosides and terpenoids. | (Alamelumangai et al., 2014) |
| Palm fruit ripe fiber | Maceration | Ethanol | Alkaloids, flavonoids, saponins, tannins, and terpenoids | (Konay et al., 2019) |
| Immature palm fruit (endosperm) | Maceration | Methanol and ethanol | Alkaloids, albuminoids, anthracene, betulinic acid, carotenoids,flavonoids, free anthraquinones, glucomannan, glycosides, gums, lupeol, phlobotanin,phenols, quercetin,reducing compounds, saponins, steroids, tannins, terpenoids | (Rahman et al., 2021a) |
| *Borassus flabellifer* Linn fruit powder | Maceration | Methanol | Carotene and phenol | (Wijewardana et al., 2016) |
| Palm fruit pulp *Borassus flabellifer* Linn . immature endosperm and germinated endosperm | Maceration | Methanol and ethanol | Carbohydrate, crude fiber, crude protein, crude fat, ash, energy calcium, phosphorus, iron, copper, zinc, magnesium, manganese, sodium, potassium, vitamin C (carotenoids, nonprotein nitrogen, protein solubility,free fatty acids | (Rahman et al., 2021b) |
| Immature endosperm *Borassus flabellifer* Linn | Maceration | Methanol | Saponins, phenols, alkaloids, flavonoids and tannins | (Mahendiran et al., 2021) |
| *Borassus flabellifer* Linn mesocarp (oil) | Maceration | Ethanol | Tannins, phenolics, and flavonoids | (Moon et al., 2020) |
| B. *flabellifer* Linn. fruit. | Maceration | Ethyl acetate | Glucosyl-(6-1)-glycerol, 5-hydroxymethyl-furfural, tyrosol, and a combination of α-sitosterol and stigmasterol. | (Length, 2017) |
| Immature palm fruit powder | Soxhlet | Ethanol | Alkaloids, tannins, glycosides, phytosterols, alkaloids, flavonoids, and phenols | (Renuka et al., 2018) |
| *Borassus flabellifer* Linn fruit water | Maceration | Ethanol | Betasianins, phenols, terpenoids, quinones, cardiac glycosides, steroids, and coumarins | (L, 2021) |

**Table II. Pharmacological activity**

| Pharmacologic activity | Study | Fruit part | Extract | Methods | Results | Reference |
|---|---|---|---|---|---|---|
| Antibacterial | In vitro | Palm fruit | Ethanol | Disk diffusion | The diameter of the inhibition zone obtained was 15.44 mm for Staphylococcus aureus at minimum concentration of 100%. | (Konay et al., 2019) |
| | In vitro | *Borassus* flabellifer seed coat | Water, ethanol and methanol | Agar well diffusion | The highest inhibitory power against *Aspergillus* brasiliensis and *Bacillus* subtilis with diameters of 22 and 23 mm respectively was observed in the ethanol extract of *Borassus flabellifer* Linn seed coats.<br>Moderate inhibition level of methanol extract against *Bacillus* subtilis (16-23 mm).<br>The antibacterial activity of the aqueous extract against all pathogens (10–15 mm) was minimal. | (Alamelumangai et al., 2014) |
| | In vitro | Palm fruit | Ethanol | Agar well diffusion | At 100 μg mL AgNP concentration, the zone of inhibition was largest for the gram-positive *Bacillus* subtilis (16±0.2mm), followed by the gram-negative Pseudomonas (15±0.11mm), the gram-positive Staphylococcus aureus (14±0.18 mm), and the gram-positive *Escherichia* coli. | (Vandarkuzhali et al., 2021) |
| | In vitro | B. *flabellifer* Linn. fruit seed coat powder | Ethanol | Agar well diffusion | Inhibiting action against 200 μg/mL (20 mm) of *Klebsiella* pneumoniae and 200 μg/mL (16 mm) of *Escherichia* coli, two gram-negative bacteria | (Mariam Banu et al., 2022) |
| Antihyperlipidemic | In vitro | *Borassus flabellifer* Linn ruit | Methanol | Western blot | In the BF-M extract, the IC50 value for inhibiting protein tyrosine phosphatase-1B enzyme activity was 23.98 lg/mL.<br>Compared with diabetic control rats, diabetic rats treated with 100 or 200 mg/kg BF-M had lower levels of free unsaturated fat and total cholesterol. | (Duraipandiyan et al., 2020) |

**Table II. (Continued)**

| Pharmacologic activity | Study | Fruit part | Extract | Methods | Results | Reference |
|---|---|---|---|---|---|---|
| Antidiabetic | In vivo | Palm fruit pulp (SPFP), immature endosperm (IE) and endosperm (GE). | | 5 groups of test animals, treated with positive control, comparator | Both the diabetic control and experimental groups experienced a significant reductions in fasting blood glucose (FBG) levels due to the antihyperglycemic effects of edible amounts of SPFP, IE, and GE. Regarding the antidiabetic effects, GE outperformed IE and SPFP. At the end of the sixth week, GE and IE had returned FBG levels to their usual levels. Diabetic mice treated with endosperm maintained normal FBG levels even after supplemental feeding was stopped. | (Rahman et al., 2020) |
| | In vitro | B. *flabeliffer* Linn fruit powder | | Inhibition of alpha amylase and alpha glucosidase | The highest inhibition of alpha amylase was found to be 30.39%±0.02% at 500 µg/mL, with an IC50 value of 822 µg/mL. Similarly, the greatest inhibition of alpha glucosidase was found to be 32.42%±0.02% at 500 µg/mL, with an IC50 value of 777 µg/mL. | (Mariam Banu et al., 2022) |
| Antihyperglycemia | Clinical | Unripe palm fruit | Ethanol and methanol | Case study conducted for 28 days 30 patients with diabetes (14 man and 16 woman) aged 25-50 years. Who were recommended to drink 100 mL of IESP juice two times a day, following a normal diet and blood glucose levels checked, weekly and on the first day. | In patients with a normal body mass index (18.5-24.9), the mean (FBG) level dropped significantly from week 1 (15.74 mmol/L) to week 4 (10.53 mmol/L). IESP worked better in female patients (p 0.001) than in male patients (p 0.05). | (Rahman et al., 2021b) |

**Table II. (Continued)**

| Pharmacologic activity | Study | Fruit part | Extract | Methods | Results | Reference |
|---|---|---|---|---|---|---|
| Antioxidant | In vitro | Palm fruit mesocarp | | 1,1-Diphenyl-2-picrylhydrazyl (DPPH) | Lontar fruit mesocarp is an antioxidant with a DPPH method of approximately 87%, so it has potential as an antioxidant compounds. | (Idayati et al., 2014) |
| | In vitro | Palm fruit seed coat | | DPPH | Strong antioxidant qualities were demonstrated by the ethanol extract of the *Borassus flabellifer* Linn seed coat, which had an average IC50 of 12.29 ppm. | (Sudiono,2021) |
| | In vitro | Young *B. flabellifer* fruit | Methanol | DPPH | The highest activity of the BF methanol extract was observed at 1,000 μg/mL for ABTS and DPPH, at 70.11% and 87.63%, respectively. | (Mahendiran et al., 2021) |
| | In vitro | B. *flabellifer* fruit oil | Ethanol | DPPH | The mesocarp extract of BF exhibited a higher antioxidant activity of 90% against DPPH free radicals | (Moon et al., 2020) |
| | In vitro | Fruit BF | ethanol | | α-Glucosidase inhibitory activity was found to be moderate and mild, with an IC50 of 1,041.5±205.5 μg/mL and 30% inhibition at 1,000 μg/mL. | (Length, 2017) |
| | In vitro | B. *flabellifer* seed coat | Ethanol | DPPH | At a dose of 50 μg g/mL, 1,1-diphenyl-2-picrylhydrazyl radical inhibition was determined to be at its maximum (95%) | (Muthukumaran, 2018) |
| Anticancer | In vitro | Palm fruit | Ethanol | 3-(4,5-Dimethylthiazol -2-yl)-2,5-diphenyl tetrazolium bromide is the colorimetric MTT method | Nanoparticles biosynthesized with palm fruit extract showed to cytotoxic effects of AgNPs and AuNPs or anticancer potential on the examined microorganisms and human breast cancer cells (MCF-7) with particle sizes between ~5-7 and ~7-9 nm and surface plasmon resonance absorption bands at 410 and 534 nm. | (Vandarkuzhali et al.,2021) |
| | In vitro | Palm fruit seed powder | | 3- HeLa and Vero cells are tested using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyl-2H-tetrazolium bromide assay. | The percentage of cancer cell viability creased by 30% (from 102.7±3.4 to 73.6±4.1) with increasing concentrations of palm fruit seed powder, showing a significant decrease ($p \geq 0.05$) in the sample capacity for killing cervical cancer cells in vitro. | (Mariam Banu et al. 2022) |

carbohydrates, steroids, sterols, and terpenes (Mariod, 2019). The authors found that there was no qualitative difference in phytochemical compounds between raw and heat-treated SPFP, and these phytochemical compounds could be used to develop drugs.

In a related investigation, two compounds were isolated, tyrosol-and -glycerol (6-1). Four compounds were found in *Borassus flabellifer* Linn pulp: glucosyl-(6-1)-glycerol, 5-hydroxymethylfurfural, a combination of sitosterol and stigmasterol, and tyrosol-were found in Borassus flabellifer pulp (Length, 2017). These substances exhibit moderate to mild α-glucosidase inhibitory effects (Tunit et al., 2022).

**Pharmacologic Activity**
**Antibacterial**

Therefore, it is important to identify new antibacterial drugs to combat drug-resistant bacteria. (Guo et al., 2017). Numerous studies have shown that certain herbal remedies and isolated natural ingredients can combat drug-resistant germs by possessing antibacterial properties. Recently, there has been great interest in herbal treatments for bacterial infections because they are affordable, easy to obtain, and have minimal side effects (AlFaris et al., 2021). It has been demonstrated that an ethanol extract of *Borassus flabellifer* Linn fruit seed coat powder is efficient against gram-negative bacteria, specifically *Escherichia coli* and *Klebsiella pneumoniae* (Mariam Banu, 2022).

Saponins, flavonoids, tannins, and alkaloids are compounds with antimicrobial properties found in palm fruit. Saponins are a group of glycoside compounds that act as carbohydrate stores, they work as antibacterial agents by decreasing the surface tension of the bacterial cell wall, thereby increasing cell permeability and allowing the leakage of intracellular compounds. Flavonoids and tannins work by causing bacterial cell walls, microsomes, and lysosomes to become less permeable when flavonoids interact, with DNA dissolves extracellular protein complexes, and remove peptidoglycan components in bacterial cells. prevents the complete formation of the cell wall layer and cause cell death (Isyraqi et al., 2020)

Various studies have been conducted on palm fruit extracts to investigate their antibacterial properties. Alamelumangai et al., (2014) demonstrated in vitro that the ethanol extract of *Borassus flabellifer* Linn seed coat exhibited maximum suppression against *Aspergillus brasiliensis*, which had a diameter of 22 mm, and *Bacillus subtilis*, which had a diameter of 23 mm, at a concentration of 50 mg/mL. The aqueous extract from 10 to 15 mm showed minimal and restricted antibacterial action against all pathogens (10-15mm), whereas the methanol extract demonstrated considerable inhibition against the pathogen *Bacillus subtilis* (16-23 mm). *Aspergillus brasiliensis* and *Bacillus subtilis* exhibited the highest degree of inhibition in *Borassus flabellifer* Linn ethanol and methanol extracts among all examined organisms.

Quercetin is a flavonoid compound with broad-spectrum antibacterial activity. It exhibits strong inhibitory activity against fungi in addition to its outstanding inhibitory action against bacteria. It primarily acts by disrupting the bacterial cell wall and altering cell permeability, affecting protein synthesis and expression, reducing enzyme activity, and inhibiting the production of nucleic acids. Furthermore, quercetin breaks or modifies cell membranes, inhibits efflux pumps, stops quorum-sensing signaling pathways, stops bacteria from adhering to surfaces, and stops nucleic acids formation. (Yang et al., 2020)

The in vitro study of Konay et al., (2019) proved that palm fruit extract with a well diffusion method has antibacterial activity against Staphylococcus *aureus*. The minimum inhibitory level (KHM) on S.*aureus* bacteria of 15.44 mm inhibited the growth of S.*aureus* bacteria with a minimum concentration of 100%.

The study of Vandarkuzhali et al. (2021) using palm fruit extract and the well diffusion method demonstrated that Bacillus *subtilis* (gram positive) had the highest zone of inhibition at 16±0.2 mm at 100μg/mL concentration of silver nanoparticles (AgNPs), followed by *Pseudomonas aeruginosa* (gram negative) at 15 ± 0.11 mm, *S. aureus* at 14±0.18 mm, and Escherichia *coli*.

**Antidiabetic**

High blood glucose levels are the hallmark of diabetes, a metabolic disease caused by the body's incapacity to produce or react to the pancreatic hormone insulin. A medication's ability to decrease blood sugar levels by promoting insulin production and glucose uptake into cells is known as its antidiabetic action (Hossain et al., 2021)

Protein kinase and cyclooxygenase are two enzymes that flavonoids suppress. This treatment inhibits apoptosis and cell proliferation, promotes beta cell regeneration in pancreatic islets, increases insulin secretion, and normalizes blood glucose levels (Azeem et al., 2023)

The mode of action of flavonoids in diabetes includes reducing lipid peroxidation, increasing antioxidant enzymes activity (including SOD, GPX, and CAT), blocking insulin-dependent PI3k activation by inhibiting GLUT2, and decreasing intestinal glucose absorption. Through a method that promotes GLUT4 translocation and expression in skeletal muscle versus insulin-dependent pathways, quercetin is associated with AMPK activation, which increases GLUT4 translocation and expression in skeletal muscle (Vinayagam and Xu, 2015)

The ethanol extract of lontar fruit decrease blood sugar and lipid levels, showing effective hypoglycemic and lipid-lowering effects. Natural products have been demonstrated to inhibit α-glucosidase, one of the ways that antidiabetic medications work (Linn et al., 2021)

In vitro research by Duraipandiyan et al., (2020) the methanol extract of lontar fruit proved effective in IC50=23.98 lg/mL, inhibiting protein tyrosine phosphatase 1B (PTP1B). GC-MS analysis detected n-hexadecanoic acid (25.14%), octadecanoic acid (2.15%), and tetradecanoic acid (1.05%). This proves that the methanol extract of lontar fruit is an effective PTP1B inhibitor. PTP1B is an important regulator of insulin sensitivity that affects the regulation of glucose homeostasis and a number of physiological processes; hyperglycemia is closely correlated with its expression. Glucose homeostasis and several physiological functions, and its expression is directly related to hyperglycemia.

*Borassus flabellifer* Linn fruit has been reported to have antidiabetic effects in animal models and inhibit glucose transport in in vitro studies. A study by Rahman et al.,(2020) induced SPFP,immature endosperm (IE), and germinated endosperm (GE) in vivo and significantly reduced fasting blood glucose (FBG) levels in experimental rats. GE had the greatest antidiabetic effect, followed by IE and SPFP. GE and IE returned FBG levels to the normal range by the end of the sixth week.

In a research published in 2020, Rahman et al., produced SPFP, IE, and GE in vivo and dramatically decreased the FBG levels of the rats used in the experiment. IE and SPFP were found to have a lesser antidiabetic effect than GE. By the conclusion of the sixth week, GE and IE returned FBG levels into the normal range.

**Antihyperlipidemic**

A study by Duraipandiyan et al., (2020) according to in vitro findings, showed that when diabetic control rats were given 100 or 200 mg/kg of palm fruit, their total cholesterol and unsaturated fat levels were lower.

Antihyperlipidemic compounds contained in lontar fruit are tannins, saponins, and flavonoids. The mechanism by which tannins inhibit cholesterol biosynthesis involves reducing the absorption of dietary cholesterol, and serum cholesterol levels, and increasing bile acid secretion. The mechanism by which saponins prevent reabsorption and increase cholesterol secretion. Because saponins and cholesterol have the same receptors, receptor competition occurs and affects cholesterol biosynthesis in the liver. Conversely,, flavonoids reduce the activity of HMG-CoA reductase and cholesterol acyl-CoA acyltransferase enzymes by reducing ApoB secretion in hepatocytes, thereby inhibiting cholesterol absorption in the gastrointestinal tract (Guo et al., 2019)

Flavonoids can control dyslipidemia, and changes in fatty liver function are essential for controlling serum lipid levels, downregulating the expression of C-reactive protein and cardiovascular risk factors (Yang et al., 2020) Changes in fatty liver function are necessary for regulating blood lipid levels, downregulating the expression of C-reactive protein, and reducing cardiovascular risk factors. Flavonoids have the ability to manage dyslipidemia and f are a type of phenolic compounds that are important in the prevention and treatment of various diseases. The antioxidant properties of flavonoids can prevent and reduce fat accumulation in the body. Saponins inhibit the action of pancreatic lipase by inhibiting the conversion of triglycerides into fatty acids, which are then absorbed in the intestines and excreted in the feces. Flavonoids can fight excess free radicals generated during bile acid synthesis and increase lipoprotein lipase activity. Increased activity of lipoprotein lipase hydrolyzes triglycerides into free fatty acids and glycerol, which are stored in fats and muscle tissues (Ningsih et al., 2023)

There are two methods by which carotenoids can lower cholesterol levels. The first approach is that carotenoids, especially β-carotene, function as antioxidants, preventing lipid oxidation. Antioxidants play an important role in inhibiting fat oxidation in the arteries, thereby facilitating the passage of cholesterol through the walls in blocked arteries. Additionally, a second approach involves the inhibition of HMG-CoA reductase activity by carotenoids, particularly β-carotene, resulting in the production of mevalonate, a compound important for cholesterol synthesis. Beta-carotene has a dual function as a lipid and blood sugar regulator. The glycemic action of beta-carotene can be used to regulate triglyceride and blood sugar levels. Cell membranes in the small intestine facilitate fat absorption. Chylomicrons, formed from fat absorbed in the small intestine, are esterified and subsequently released into the bloodstream via lymphatic capillaries. Lipogenesis (lipid production) in adipose tissue is a component of its lipid metabolism. The liver and stomach provide triacylglycerol through lipoproteins, VLDL, and chylomicrons. Mevalonate is produced from acetyl-CoA and is a metabolic process involved in the synthesis of beta-carotene and cholesterol. Because the feed contains both saturated fatty acids and β-carotene, HMG-CoA reductase can work on the former to prevent saturated fatty acids from transforming into cholesterol (Alves-Bezerra and Cohen, 2018)

**Antihyperglycemic**

Compounds lower blood sugar levels are flavonoids. Flavonoids can reduce blood sugar levels by acting as antioxidants. Additionally, flavonoids can increase insulin sensitivity and prevent damage to beta cells, which are insulin-producing cells (Jin et al., 2023).

In Rahman et al (2020), FBG levels (mmol/L) were collected from 37 randomly selected patients with type 2 from rural and urban areas. The study included 30 patients with diabetes aged 25 and 50 years, 14 men and 16 women, who consumed immature palm fruit endosperm juice or IESP (100 mL) 2 times a day after a regular meal. In patients with normal BMI (18.5-24.9), mean FBG levels decreased significantly from week 1 (15.74 mmol/L) to week 4 (10.53 mmol/L). IESP is rich in fiber, minerals, and bioactive compounds such as saponins, lupeol, tannins, betulinic acid, and terpenoids. Regular consumption of IESP showed antiglycemic effects on FBG levels in patients with type 2 diabetes mellitus. Secondary plant substances in IESP have direct and indirect antiglycemic effects on diabetes. Among the phytochemicals identified, saponins and fibers inhibit glucose absorption from the gut, and lupeol, glycosides, and zinc regenerate pancreatic beta cells. Betulinic acid, stigmasterol, and betasitosterol reduce humoral glucose regeneration by inhibiting α-glucosidase and α-amylase. Anthraquinones sensitize insulin receptors, and alkaloids and tannins with antioxidant properties play roles in preventing beta cell damage, inhibiting adipogenesis, and improving glucose uptake.

Flavonoids can reduce blood sugar levels by acting as antihyperglycemic agents. Flavonoids can prevent damage to insulin-producing beta cells and increase insulin sensitivity. The capacity of flavonoids to inhibit GLUT2 in the intestinal mucosa and reduce glucose absorption is another mechanism of action of flavonoids (Widiana and Marianti, 2022)

Flavonoids can also inhibit phosphodiesterase and cause insulin secretion by pancreatic beta cells. The intestinal mucosal GLUT2 pathway, which is involved in glucose and fructose absorption, is strongly inhibited by flavonoids thereby lowering blood sugar levels by reducing glucose and fructose absorption in the intestine. This mechanism indicates that inhibition of intestinal GLUT2 could be a potential therapy to control blood glucose levels. Flavonoids inhibit phosphodiesterase and increase cAMP levels in pancreatic beta cells, stimulating insulin secretion through the Ca pathway. The beta cell plasma membrane's K+-ATP channels close as because of the increase in cAMP levels. Ca ions enter the cell more quickly because of membrane depolarization and voltage-gated Ca channel opening. Pancreatic beta cells secrete insulin because of an increase in Ca ions in the cytoplasm of the cells (El et al., 2023)

**Antioxidants**

Antioxidants bind free radicals to target molecules to prevent or delay oxidative damage. Many natural substances, including flavonoids, phenolic acids, and polyphenols, are considered superior free radical scavengers. Human disorders and diseases are linked to reactive oxygen species (ROS) and other oxidants (Mizutani et al.,2021)

Antioxidant systems in humans prevent free radicals from attacking biological targets and combat ROS and certain other oxidants. The enhanced capacity of natural antioxidants to combat reactive oxygen species and free radicals has garnered significant attention in recent years Polyphenols are thought to be antioxidants, and palm fruits are known to contain them, pharmacological research has connected polyphenols to the antioxidant qualities of palm fruit extracts (Ediriweera et al.,2017)

The fruit extract of *Borassus flabellifer* Linn shows good scavenging activity against 2, 2-diphenyl-1-picrylhydrazyl (DPPH). The methanol extract of the fruit showed maximum activity against DPPH and ABTS at concentrations of 1,000 μg/mL, 87.63% and 70.11% (Mahendiran et al.,2021).

Free radicals are created during the oxidation process, which harms living cells in living things. Antioxidants are substances that prevent oxidation and combat free radicals. Flavonoids are substances with antioxidant properties. Antioxidants are essential for maintaining food and preserving human health because they shield the body's lipids and DNA from oxidation. The mechanism by which flavonoids act as antioxidants is to directly counteract free radicals and prevent their proliferation which can damage body tissues. (Lankalapalli, 2017)

The body produces free radicals during metabolism, which are one of the reasons for numerous illnesses, including genetic abnormalities and cell membrane damage. Free radicals also accelerate aging and contribute to several illnesses, including diabetes, liver damage, heart disease, and others (Qi et al., 2022)

The body's antioxidant capacity is directly correlated with overall health. Diabetes, cancer, inflammation, and other illnesses can be directly caused by a decreased antioxidant capacity. Antioxidant qualities are possessed by metabolic substances like ellagic acid, tannins, flavonoids, and saponins. Malondialdehyde, a harmful byproduct of lipid peroxidation, can induce crosslink polymerization in proteins, nucleic acids, and other macromolecules. Overindulgence in nutrients, such as elevated blood sugar and cholesterol levels, can trigger the production of α,β-unsaturated 4-hydroxyalkenes by lipid peroxidation (Luo et al., 2019)

In the in vitro study (Idayati et al., 2014) using the DPPH (1,1-diphenyl-2-picrylhydrazyl) method, the ethanol extract of lontar fruit mesocarp as an antioxidant is approximately 87%, suggesting its potential as an antioxidant compound. In similar research, the in vitro research Sudiono, (2021) demonstrated the antioxidant activity of the ethanol extract of lontar fruit seed coat using the DPPH (1,1-diphenyl-2-picrylhydrazyl) method with gallic acid comparison solution with average IC50 of 12.29 and 0.96 ppm, respectively. The ethanol extract of the *Borassus flabellifer* Linn seed coat and gallic acid exhibited strong antioxidant properties. The basic principle of antioxidant test using the DPPH method is the chemical reaction between antioxidant compounds and DPPH free radicals through the mechanism of donation reactions or giving hydrogen atoms by antioxidant compounds to DPPH free radicals which results in a change in the color of the solution from purple to yellow or from concentrated purple to faded purple. The color change decreased the absorbance value of the sample.

The presence of phytochemicals such flavonoids, saponins, tannins, and phenolic compounds is responsible for the antioxidant activity of the methanol and ethanol extracts of palm fruit, according to the authors' conclusion. Therefore, the fruit of *Borassus flabellifer* Linn may be useful as "nutraceuticals" in the cooking of functional foods. Strong antioxidant effects were observed in the methanol and ethanol extracts of *Borassus flabellifer* Linn fruit, which may be attributable to the presence of phenolic chemicals. The scientists also concluded that this antioxidant activity might be applied to the creation production of natural antioxidants for pharmaceutical and agroproduct industries. (Le et al., 2021). It is commonly known that bioactive substances like flavonoids and phenolic acids are advantageous antioxidants that can scavenge hazardous active oxygen species including superoxide radical (O2-), hydrogen peroxide (H2O2) , hydroxyl radical (-HO) (Reshma et al., 2017). Numerous detrimental diseases, such as cancer, diabetes, cardiovascular disease, and aging, are linked to the involvement of oxygen radicals (Guo et al., 2017)

**Anticancer**

An illness known as cancer is characterized by an uncontrolled and rapidly growing cell population that defies normal cell division principles. Normal cells become cancerous when the body's defense mechanisms against disease fail. This is how cancer arises. A substance's ability to prevent cancer is known as its anticancer activity. Chemical, synthetic, or natural compounds with the ability to stop, or reverse the development of cancer can be used as active components. The anticancer properties of natural products can be assessed using various in vitro and in vivo techniques. Currently on the market, appromaximately 80% of anticancer medications are produced from plants (Durr-e-Samin et al., 2018)

Flavonoids are compounds that act as anticancer agents. The flavonoid mechanism for inhibiting cancer cells functions as an antioxidant by inactivating oxygen radicals, inhibiting cell proliferation, DNA oxidation, angiogenesis, and lipid peroxidation. (Isyraqi et al., 2020)

Quercetin, a flavonoid, is a phenolic compound that has anticancer properties against breast and prostate cancers. Flavonoids in particular have a long history of use as chemopreventive agents in cancer therapy. Quercetin can to stimulate miR-200b-3p, which controls the self-division mechanism of pancreatic cancer (Tungmunnithum et al., 2018)

Quercetin exerts its antitumor effects through various mechanisms. Quercetin can induce tumor cell death by altering the apoptotic pathway of cancer cells. It can also upregulate the expression of pro-apoptotic proteins and downregulate that of anti-apoptotic proteins. The PEL PI3K/AKT/mTOR and STAT3 signaling pathways are inhibited by quercetin, which also suppresses the production of cell survival proteins such c-FLIP, cyclin D1, and cMyc. induces apoptosis in MCF-7 cells, and induces MCF-7 to inhibit proliferation. Breast cancer cells increase in concentration over time, thereby suppressing breast cancer cells. Additionally,in a human PA-1 cell line model of metastatic ovarian cancer, quercetin functions by inducing mitochondria-mediated apoptosis, which impedes the growth of metastatic ovarian cancer cells (Yang et al., 2020)

Research conducted by Vandarkuzhali et al.,(2021) in vitro using the MTT (3-(4,5-dimethylthiazol-2-yl)-2,5- diphenyltetrazolium bromide) colorimetric method, showed that the ethanol extract of palm fruit improved the cytotoxic effect of AgNPs.

Cytotoxic activity was determined using the potency of gold nanoparticles (AuNPs) or their anticancer potential on the investigated microorganisms and human breast cancer cells (MCF-7) was assessed by live cell reflectance using surface plasmon resonance absorption bands at 410 and 534 nm. Cellular oxidoreductase enzymes dependent on nicotinamide adenine dinucleotide hydrogen phosphate were measured in live cells. Both the antigen and the AuNPs exhibited selectivity toward cancer cells, with AuNPs demonstrating marginally greater activity than AgNPs.This activity is mainly due to the small size of the nanoparticles, which can lead to the nanoscale migration and localization of targeted cancer cells. The harmful effects of AgNPs and AuNPs can be linked to oxidative stress-induced elevations in ROS levels. The interaction between nanoparticles hand proteins and functional groups on DNA inhibits cancer cells and can result in cell death (Enea et al., 2020).

## CONCLUSIONS

On the basis of literature review, it can be concluded that: chemical compounds found in palm fruits include tannins, saponins, glycosides, terpenoids, alkaloids, gums, lupeol, phlobotanin, phenols, quercetin, anthracene, betulinic acid, carotenoids, flavonoids, free anthraquinones, glucomannan, albuminoids, phytosterols, triterpenoids, quinones, cardiac glycosides, steroids, coumarins, and betacyanin and the pharmacological effects found in lontar fruit are antibacterial, antidiabetic, antihyperlipidemic, antihyperglycemic, antioxidant and anticancer activities.

## CONFLICTS OF INTEREST

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