International Journal of Agriculture and Biosciences 2026, 15(1): 1-10.
https://doi.org/10.47278/journal.ijab/2025.163

RESEARCH ARTICLE
eISSN: 2306-3599; pISSN: 2305-6622

Evaluation on Bioactive Compounds, Antioxidant, Anti-α-Glucosidase and Anti-Acetylcholinesterase in Different Parts of *B. flabellifer* L.

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ABSTRACT

Borassus flabellifer L. is a highly valuable medicinal plant, with all parts of the tree possessing potential therapeutic properties and diverse applications. This study seeks to comprehensively assess the phytochemical composition and bioactive potential of various parts of *B. flabellifer* L., including the endosperm, haustorium, leaves, male flowers, mesocarp, ripe pulp, exocarp, and sap. Specifically, this research investigates the phenolics, flavonoids, anthocyanins, carotenoids, tannins, antioxidant activities, and inhibitory effects on α-glucosidase and acetylcholinesterase enzymes across various plant parts. The male flowers had the highest value of phenolic acids, flavonoids, anthocyanins, and tannins in the samples of all the different parts, while ripe pulp showed the highest value of carotenoids in all parts of *B. flabellifer* L. All sample parts of *B. flabellifer* L. possessed strong antioxidant capacity, with the male flowers demonstrating the highest DPPH, ABTS, and FRAP radical scavenging activity (IC_{50} at 1.10mg/mL, IC_{50} at 0.44mg/mL, 147.09mg of TE/100g sample). The male flowers of *B. flabellifer* L. also had the most activity for α-glucosidase inhibitory with IC_{50} at 0.75mg/mL, more than the positive control, acarbose, with IC_{50} at 3.20mg/mL. The exocarp of *B. flabellifer* L. showed the highest acetylcholinesterase inhibitory activity with IC_{50} at 157.82mg/mL. Seven phenolic acids (gallic acid, protocatechuic acid, vanillic acid, caffeic acid, coumaric acid, ferulic acid, and sinapic acid) and 3 flavonoids (catechin, rutin, and quercetin) were identified and quantified using HPLC. According to this study, *B. flabellifer* L. has the potential to be developed into dietary and pharmaceutical treatments for diabetes and Alzheimer's disease.

Keywords: Bioactive compounds, Antioxidant, Anti-α-glucosidase, Anti-acetylcholinesterase, *B. flabellifer* L.

Article History
Article # 25-114
Received: 12-Mar-25
Revised: 05-Apr-25
Accepted: 26-Apr-25
Online First: 01-Oct-25

INTRODUCTION

Plants are a source of natural product compounds, which contain a large number of bioactive compounds with therapeutic potential to treat various diseases and health conditions. Recently, there has been an increased interest in exploring native plants as a source of phytochemicals with antioxidant, antidiabetic, and neuroprotective activities (Anitha et al., 2023; Moise et al., 2024). Among these plants, *Borassus flabellifer Linn.*, a type of palm tree and important economic crop, has gained attention as one of Thailand's local plants widely distributed throughout the country, especially in the southern region, due to its various benefits and medicinal properties. *B. flabellifer* L., also known as palmyra palm in English and Ton Taan in Thai, is a medicinally important plant that is generally distributed and cultivated in tropical regions of Asian nations, including Bangladesh, India, Myanmar, Sri Lanka, Malaysia, and Thailand, and various regions of East Africa (Jamkhande et al., 2016; Kurian et al., 2017). It belongs to the family Arecaceae, usually grows to a height of 30-35 meters with a stem diameter of 1.5-3.0m, has a life span of more than 120 years, and can be used for a variety of benefits including food, beverages, fiber, animal feed, medicine, and wood (Basava Prasad et al., 2023; Subramanian et al., 2024). Because of the presence of various bioactive compounds, *B. flabellifer* L. tree is used in traditional medicine as remedies for treating a myriad

Cite this Article as: Sukhonthara S and Thipnate P, 2026. Evaluation on bioactive compounds, antioxidant, anti-α-glucosidase and anti-acetylcholinesterase in different parts of *B. flabellifer* L.. International Journal of Agriculture and Biosciences 15(1): 1-10. https://doi.org/10.47278/journal.ijab/2025.163

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array of diseases, in which different parts of *B. flabellifer* L. tree, such as roots, stem, flower, fruit, sprout, leaves, and seed embryo, exhibit unique medicinal value (Basava Prasad et al., 2023; Abu et al., 2024). There have been studies on the nutritional and medicinal properties of various parts of the *B. flabellifer* L., such as the endosperm, which was reported as a beneficial source of carbohydrate, fiber, sodium, potassium, zinc, and phytochemical content (Rahman et al., 2021). The haustorium is a great source of macronutrients such as carbohydrates, protein, and fiber and micronutrients such as potassium and phosphorus, calcium, iron, and sodium (Basava Prasad et al., 2022). The sap is rich in nutrients and bioactive components such as polyphenols, antioxidants, flavonoids, and volatile compounds and has potential as an antidiabetic (Sarkar et al., 2023). The mesocarp and exocarp provide nutrients such as insoluble fiber, protein, ash, saponin, tannins, and phenolic compounds, and simple sugars (fructose, mannose, galactose, and glucose) and have antioxidant properties, with the exocarp demonstrating superior radical scavenging activity and reducing power than those of the mesocarp (Rodiah et al., 2019). Palm jaggery and palm honey have antidiabetic, antioxidant, anti-hyperglycemic, and insulinogenic characteristics (Manivannan et al., 2024). Palm syrup contains protein, phenolic content, and various vitamins, with vitamin E being the most abundant (Le et al., 2021). The male flowers have antioxidant, anti-inflammatory, and antibacterial effects (Tunit et al., 2022). The roots comprise dietary elements, phytochemicals, and bioactive compounds (carbohydrates, terpenoids, flavonoids, coumarins, alkaloids, tannins, saponins, cardiac glycosides, and proteins) (Arirudran et al., 2022). The antioxidant activity of several plant species is interesting due to their preventive properties against oxidative stress in the development of many chronic diseases, such as cancer, hepatitis, cardiovascular disorders, neurodegenerative conditions, and ageing (Sultana et al., 2023; Zongo et al., 2024). Oxidative stress is caused by an imbalance between the accumulation of reactive oxygen species (ROS) and the body's antioxidant defenses, resulting in cellular damage and tissue malfunction (Caturano et al., 2023). Natural antioxidants, including phenolic compounds, carotenoids, vitamins, and trace elements, would help prevent oxidation reactions (Kashtiban et al., 2024). Type 2 diabetes mellitus (T2DM) is becoming more prevalent worldwide. One treatment approach to manage type 2 diabetes is controlling carbohydrate digestibility by inhibiting α-glucosidase, an essential enzyme that catalyses the final stage of carbohydrate digestion in the small intestine (Li et al., 2022; Kashtoh and Baek, 2022). Since plants all contain phytochemicals that can inhibit glucosidase enzymes and control blood sugar levels, many plants have been studied for their antioxidant and antidiabetic activities, and blood sugar-lowering effects (Niaz et al., 2021). Plant-based bioactive compounds, including polyphenols, alkaloids, flavonoids, coumarins, and terpenoids, exhibit superior antidiabetic efficacy compared to non-plant-based hypoglycemic agents (Tresina et al., 2022). Alzheimer's disease (AD), the predominant form of dementia accounting for 70% of all dementia cases, is a progressive neurodegenerative disorder and a major health concern among the aging population worldwide (Rawat et al., 2024). Inhibition of acetylcholinesterase, a key enzyme involved in the breakdown of the neurotransmitter acetylcholine, is considered a promising treatment for Alzheimer's disease (Gajendra et al., 2024). Plants are currently gaining attention, since plants contain phytochemicals with a lot of potential to mitigate the risk of Alzheimer's disease, and phytochemicals from plants are safe to consume. Several plants from different families have been documented to have a range of bioactive chemicals such as galantamine, curcumin, and silymarin which are used for the treatment of Alzheimer's disease (Koul et al., 2023). The phytochemicals well-known for their cardiotonic properties and antimicrobial properties, such as alkaloids, flavonoids, glycosides, phenolic compounds, tannins, terpenes, saponins, steroids, and sterols, are present in *B. flabellifer* L. (Alam et al., 2022; Behera, 2022). Phenolic compounds present in various parts of the *B. flabellifer* L. plant, such as flavonoids and tannins, act as primary (chain breaking) antioxidants and have biological activities and pharmacological functions, including antimicrobial, anti-inflammatory, antiallergic, anticancer, and antineoplastic activity (Jamkhande et al., 2016; Behera, 2022). Different portions of *B. flabellifer* L., such as leaves, roots, pulp, flowers, sap, and fruit fibers, have been shown to be effective in treating diabetes (Kavatagimath et al., 2016; Akter et al., 2020; Leida et al., 2020) and possess anthelmintic, antioxidant, antiarthritic, antibacterial, anticancer, antidiabetic, antifungal, anti-inflammatory, anti-acetylcholinesterase, antipyretic, diuretic, hypersensitivity, immunomodulatory, and wound healing properties (Shanmugalingami et al., 2021; Abraham et al., 2021). Nonetheless, no research has examined the efficacy of antioxidants, acetylcholinesterase, and α-glucosidase inhibitory in various parts of *B. flabellifer* L. Therefore, the aim of this study was to evaluate the bioactive compounds, antioxidant activities, α-glucosidase inhibitory activities, and acetylcholinesterase inhibitory activities in each part of Thai *B. flabellifer* L., including endosperm, haustorium, leaves, male flowers, mesocarp, ripe pulp, exocarp, and sap.

MATERIALS & METHODS

Plant Material and Extraction Methodology

In the study, *B. flabellifer* L. samples (endosperm, haustorium, leaves, male flowers, young mesocarp, ripe pulp, exocarp, and sap) (Fig. 1) were collected from Phetchaburi province, Thailand, air-dried at 50°C, and ground into fine powder. The ethanolic extracts (70% ethanol) were performed following the procedure described by Nefzi et al. (2022) with minor modifications. One gram of dried powder was suspended with 10mL 70% ethanol, stirred with a magnetic stirrer, and kept at 4°C in the dark for 24h. The extracts were then filtered and placed at 4°C in the dark for future utilization.

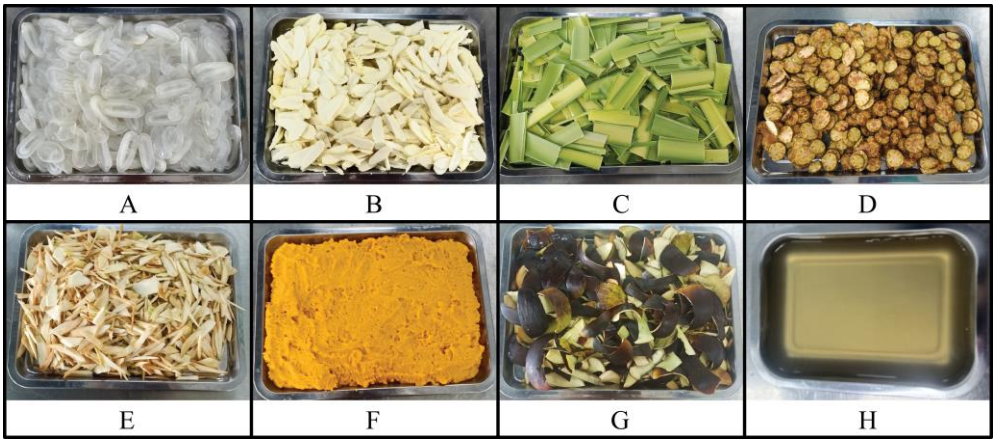

Fig. 1: *B. flabellifer* L. (A) endosperm, (B) haustorium, (C) leaves (D) male flowers, (E) mesocarp, (F) ripe pulp, (G) exocarp, and (H) sap

Bioactive Compounds

Total Phenolics

Total phenolic content in each *B. flabellifer* L. extract was determined using Folin-Chiocalteu reagent following the methodology of Kupina et al. (2019) and Sansenya et al. (2021) with a minor modification. One milliliter of each extract was combined with 5mL of Folin-Ciocalteu reagent and then incubated in the dark for 5min at room temperature (30±2°C). After that, the mixture was added with 4mL of 7.5% sodium bicarbonate (Na_2CO_3) solution, further incubated for 30min, and measured at 765nm using a UV-visible spectrophotometer. The result was expressed in µg equivalents of gallic acid per 1g of dried sample (µg GAE/g).

Flavonoids

The total flavonoid content of all *B. flabellifer* L. samples was quantified based on the aluminum chloride colorimetric technique as described by El Atki et al. (2020) with some modifications. 0.6mL of each extract of *B. flabellifer* L. was combined with 2.4mL of distilled water and 0.3mL of 5% $NaNO_2$. After incubating for 5min, the mixture was added with 0.3mL of 10% $AlCl_3$, and incubated again for 5min. Furthermore, the mixture was added with 1mL of 1M NaOH and 1.4mL of distilled water, incubated once again for 15min, and then measured at a wavelength of 415nm with a UV-Vis spectrophotometer. The outcome was quantified in µg equivalents of quercetin per 1g of dried sample (mg QE/g).

Anthocyanins

The total Anthocyanin content was analyzed using the pH differential method as described by Anggraini et al. (2019), with minor changes. Each extract was diluted with 0.025M potassium chloride buffer (pH 1.0) and 0.4M sodium acetate buffer (pH 4.5). After 15min at ambient temperature, the absorbance of each dilution at 510 and 700nm was assessed utilizing distilled water as the blank. The anthocyanin content of each dilution was calculated and reported as milligrams of cyanidin-3-glucoside (C3G) per gram of dry weight (DW).

Tannins

The total concentration of tannins content in *B. flabellifer* L. samples was quantified using a spectrophotometric method using Folin-Ciocalteu (FC) reagent according to Chandran & Indira (2016). 0.1mL of each sample extract was combined with 7.5mL of distilled water, 0.5mL of Folin-Ciocalteu reagent, and 1mL of 35% sodium carbonate solution and allowed to incubate at room temperature for 30min. The absorbance of each sample at 450nm was determined as tannic acid equivalents (mg TA/g extract) using a standard curve of tannic acid.

Total Carotenoids

The total carotenoid concentration in each segment of *B. flabellifer* L. was analyzed using a spectrophotometer (Suwanaruang, 2022) with absorbance at wavelengths of 470, 645, and 663nm. The quantification of carotenoids in each sample was calculated based on the equation described by Suwanaruang (2022).

Estimation of Radical Scavenging Activities

DPPH Radical Scavenging Ability

The DPPH (1,1-Diphenyl-2-picrylhydrazyl) assay was conducted as detailed by Zhou et al. (2018) with slight modifications. Specifically, each sample extract (10µL) was combined with 0.1mM DPPH (195µL) and incubated in a well of a 96-well microtiter plate at room temperature for 30min in the dark, and the absorbance was measured at 517nm. The DPPH scavenging capacity of each extract was represented as IC_{50} (mg/mL) utilizing GraphPad Prism V5.0 software (GraphPad Software, San Diego, CA, USA).

ABTS Radical Scavenging Ability

The ABTS assay was determined based on the methodology of Zhou et al. (2018) and carried out in a 96-well microtiter plate. Each extract (10µL) was combined with ABTS radical solution (195µL), mixed well, and incubated at room temperature for 30min in the dark, and the absorbance was measured at 734nm. IC_{50} values for the ABTS scavenging capacity of each extract were evaluated using GraphPad Prism V5.0 software.

FRAP Radical Scavenging Assay

The FRAP assay was conducted as detailed by Liao & Banbury (2015) with slight modifications. The FRAP solution was prepared by mixing 1mL of TPTZ (10mmol/L), 1mL of $FeCl_3$ (20mmol/L), and 10mL acetate buffer (pH 3.6), with the mixture held at 37°C. 50µL of each sample was combined with 250µL of the FRAP

solution in a well of a 96-well microtiter plate, incubated for 10min in the dark at 30°C, and then measured at 593nm. Trolox served as a positive control, and results were expressed as milligrams of Trolox equivalents/g of extract (mg TE/g extract)

Enzyme Inhibitory Activities

Inhibition Assay for α-glucosidase Activity

The α-glucosidase inhibitory activity was assessed following the method of Telagari & Hullatti (2015) with minor changes. 40µL of each sample extract was mixed with 10µL of α-Glucosidase (1UN/mL) and 40µL of 3mM p-nitrophenyl-α-D-glucopyranoside in phosphate buffer (pH 6.9). The mixture was thereafter incubated at 37°C for 30min and added with 100µL of 1M Na_2CO_3. The absorbance of the mixture was subsequently assessed at a wavelength of 405nm. The α-glucosidase inhibition of the extracts was estimated by IC_{50} values (mg/mL) using GraphPad Prism V5.0 software.

Inhibition Assay for Acetylcholinesterase Activity

The anticholinesterase activity of the samples was conducted following the method of Ghribia et al. (2014) with slight modification with the dopachrome technique with a 96-well microplate reader. In a well of a 96-well microtiter plate, 5µL of each sample was combined with 45µL of acetylcholinesterase, incubated at 37°C for 15min, and subsequently added with reactive mix solution (1µL of acetylthiocholine iodide (ATCI), 0.5µL of DTNB, and 154µL of Tris-HCl buffer). The absorbance of the combination was recorded at a wavelength of 405nm at 10min. The inhibition of α-acetylcholinesterase of each sample was calculated and determined as IC_{50} (mg/mL) using GraphPad Prism V5.0 software.

Determination of Phenolic Acids and Flavonoids by HPLC

Determination of phenolic acids (gallic acid, protocatechuic acid, vanillic acid, caffeic acid, coumaric acid, ferulic acid, and sinapic acid) and flavonoids (catechin, rutin, and quercetin) was carried out using HPLC by the method of Butsat & Siriamornpun (2010) and Zhang et al. (2015), respectively. The reversed-phase Phenomenex C18 column (4.6mm×250mm) packed with 5µm diameter particles was utilized. The mobile phase of phenolics was Acetic acid 1% (phase A) and Acetonitrile (phase B), while flavonoids utilized a formic acid solution (pH 2.5, phase A) and methanol (phase B). A sample injection value of 10µL was set at a flow rate of 1mL, with absorbance measured at a wavelength of 280nm.

Statistical Analysis

Each sample of *B. flabellifer* L. was analyzed in triplicate, and the results were provided as mean±standard deviation (SD). The data were subjected to one-way analysis of variance (ANOVA), specifically Duncan's New Multiple Range Test (DMRT), for comparing mean differences test at a significant level of 5% ($P<0.05$).

RESULTS & DISCUSSION

Bioactive Compounds

The quantity of each bioactive compound (phenolic compounds, flavonoids, anthocyanins, carotenoids, and tannins) from the endosperm, haustorium, leaves, male flowers, mesocarp, ripe pulp, exocarp, and sap of *B. flabellifer* L. are showed in Table 1. The phenolic compounds, flavonoids, anthocyanins, carotenoids, and tannins of *B. flabellifer* L. samples ranged from 7.49-64.89mgQE/g sample, 22.85-338.92mg of catechin/g sample, 0.98-47.04mg/100g, 0.01-10.54mg/100g, and 1.26-136.63mgTA/100g, respectively. The male flowers showed a significantly high bioactive compound content value and the highest amount of phenolic acids, flavonoids, anthocyanins, and tannins among all the parts, whereas the ripe pulp showed the highest amount of carotenoid content with a significant value ($P<0.05$). The phenolic content found in the different parts of *B. flabellifer* L. was in the following order: male flowers > exocarp > endosperm > leaves > ripe pulp > mesocarp > sap > haustorium. Phenolic compounds are secondary metabolites of plants characterized by the presence of various phenol groups and possess high antioxidant activities, which means any plant extracts with a high polyphenol content will have a high antioxidant effect as well (Yun & Seo, 2023). Nevertheless, the amount of phenolic content in the plants depends on numerous environmental factors such as genetics, age, vegetation period, etc. (Hofmann et al., 2020). Rodiah et al., (2019) reported that the mesocarp and exocarp of *B. flabellifer* L. have low total phenolic content, while the exocarp has a higher total phenolic content than the mesocarp. Our experiments show corresponding results, with the exocarp having significantly ($P<0.05$) higher phenolic content (33.82mgQE/g sample) compared to the mesocarp (13.16mg QE/g sample). Flavonoids, a group of polyphenolic compounds, are plant-derived secondary metabolites, found in all plant parts, including leaves, fruits, seeds, roots, and bark (Saberi et al., 2022). Among the parts of *B. flabellifer* L., male flowers had the highest total flavonoid content (338.92mg catechin/g sample). The

Table 1: Bioactive compounds from different parts of *B. flabellifer* L.

	Total phenolics (mg QE/g sample)	Total flavonoids (mg of catechin /g sample)	Anthocyanins (mg/100g)	Carotenoids (mg/100g)	Tannins (mg TA/100 g)
Endosperm	22.49±1.35c	101.06±0.74c	2.24±1.44d	0.06±0.01f	3.30±0.31c
Haustorium	7.49±0.19g	47.96±0.94f	2.15±0.45d	0.20±0.05e	1.26±0.02c
Leaves	21.49±0.51c	76.65±1.61e	19.76±2.82b	7.72±0.10b	5.56±0.10c
Male Flowers	64.89±1.20a	338.92±1.09a	47.04±1.99a	1.11±0.02d	136.63±5.73a
Mesocarp	13.16±0.38e	26.89±1.56g	3.41±0.61d	0.19±0.02e	2.57±0.29c
Ripe Pulp	15.16±0.51d	22.85±1.49h	0.98±0.45d	10.54±0.08a	3.12±0.15c
Exocarp	33.82±0.84b	126.89±1.64b	7.90±0.18c	1.71±0.00c	19.35±1.69b
Sap	9.49±0.38f	90.70±0.90d	2.54±0.17d	0.01±0.00f	3.17±0.10c

Values (mean±SD) with different letters in a column indicate a significant difference ($P<0.05$).

total flavonoid content in various parts had a positive correlation to total phenolic content in the following descending order: male flowers > exocarp > endosperm > sap > leaves > haustorium > mesocarp > ripe pulp. Anthocyanins are one of the polar compounds of flavonoids that provide red, purple, and blue color in fruits and vegetables (Warnasih & Hasanah, 2018). Anthocyanins in the male flower were the highest (47.04mg/100g) followed by the leaves (19.76mg/100g) and the exocarp (7.90mg/100g), respectively. Carotenoids are a large group of hydrocarbons and xantofiles that contribute to the red, orange, or yellow color of plants (Warnasih & Hasanah, 2018). The highest content of carotenoids was present in ripe pulp (10.54mg/100g), followed by leaves (7.72mg/100g) and exocarp (1.71mg/100g), respectively. Tannins is a polar polyphenol compound found naturally in vegetables exhibiting antioxidant activities. Tannins were found to be in very high concentrations in the male flowers (136.63mg TA/100 g). Lou et al. (2018) reported that tannins exhibited more reducing power, DPPH, and ABTS radical scavenging activities than TBHQ, showed higher cellular antioxidant activity than gallic acid in the PBS wash protocol, and had the α-amylase inhibitory activity beyond that of acarbose.

Antioxidant Activity

The DPPH, ABTS, and FRAP radical scavenging activities of the *B. flabellifer* L. sample are given in Table 2. The male flower of *B. flabellifer* L. exhibited the highest DPPH, ABTS, and FRAP radical scavenging activity (IC_{50} at 1.10mg/mL, IC_{50} at 0.44mg/mL, 147.09mg of TE/100g sample), followed by exocarp (IC_{50} at 17.09mg/mL, IC_{50} at 2.57mg/mL, 17.33mg of TE/100g sample) and leaves (IC_{50} at 40.43mg/mL, IC_{50} at 5.61mg/mL, 6.89mg of TE/100g sample), respectively. The result indicates that the male flower of *B. flabellifer* L. has the greatest antioxidant activity, proportional to the amount of polyphenol. Generally, plant parts with higher antioxidant effects have higher polyphenol content as well. Barbosa and Nueva (2019) reported a positive correlation between antioxidant activity and total phenolic content in the plant parts of *H. conoidea*, attributing the high total antioxidant activity predominantly to the phenolic compounds found in the leaves of *H. conoidea*.

Enzyme Inhibition Studies

The α-glucosidase inhibitory and anticholinesterase activity from different parts of *B. flabellifer* L. are shown in Table 3. The male flower of *B. flabellifer* L. exhibited the most significant α-glucosidase inhibitory activity (IC_{50} at 0.75mg/mL), followed by exocarp (IC_{50} at 55.24mg/mL) and leaves (IC_{50} at 62.37mg/mL), respectively. In addition, the inhibitory effect of the male flowers was greater than that of the positive control, acarbose, which expressed the IC_{50} at 3.20mg/mL. α-Glucosidase is an enzyme required for hydrolyzing starches and disaccharides to glucose for intestinal absorption, and has been used as a target for the treatment of type 2 diabetes (Assefa et al., 2019; Kittiwisut et al., 2021). Inhibition of this enzyme function delays carbohydrate absorption after a meal, leading to a reduction of postprandial blood sugar (Assefa et al., 2019). Various parts of the Palmyra tree have shown potent α-glucosidase inhibitory activity and antidiabetic activity in animal models due to the presence of the components that exhibited α-glucosidase inhibition and various bioactive chemicals such as flavonoids and phenolic acids (Dej-adisai et al., 2017; Abu et al., 2024). The male flowers have demonstrated antidiabetic potential in alloxan-induced diabetic rats, in which the antioxidant potential may be attributed to the presence of flavonoids and triterpenoids (Kavatagimath et al., 2016). Palm sugar, fruit pulp, immature endosperm, germinated endosperm, sap, palm jaggery, and palm honey had an antidiabetic effect on alloxan-induced diabetic rats (Leida et al., 2020; Rahman et al., 2021; Manivannan et al., 2024). Fresh sugar palm fruits were also found to have inhibitory activity

Table 2: DPPH, ABTS, and FRAP radical scavenging activities from different parts of *B. flabellifer* L.

	DPPH radical scavenging activity (IC_{50} mg/mL)	ABTS radical scavenging activity (IC_{50} mg/mL)	FRAP radical scavenging activity (mg of TE/ 100g sample)
Endosperm	175.78±0.94a	33.91±1.19c	2.04±0.20de
Haustorium	165.20±1.90b	163.80±2.30a	0.26±0.05f
Leaves	40.43±1.43f	5.61±0.12f	6.89±0.31c
Male Flowers	1.10±0.10h	0.44±0.04h	147.09±2.55a
Mesocarp	119.40±1.04c	25.59±0.69e	2.24±0.15d
Ripe Pulp	116.80±1.10d	31.41±1.11d	2.79±0.24d
Exocarp	17.09±0.20g	2.57±0.12g	17.33±0.53b
Sap	80.31±0.99e	48.72±1.02b	0.53±0.08ef
Trolox	0.164±0.01h	0.107±0.02h	-

Values (mean±SD) with different letters in a column indicate a significant difference ($P<0.05$).

Table 3: α-Glucosidase inhibitory and anticholinesterase activity from different parts of *B. flabellifer* L.

	α-glucosidase inhibitory IC_{50} (mg/mL)	anticholinesterase activity IC_{50} (mg/mL)
Endosperm	909.05±5.01b	>1,000a
Haustorium	>1,000a	561.88±3.48c
Leaves	62.37±0.92d	356.14±2.82d
Male Flowers	0.75±0.01g	918.52±6.76b
Mesocarp	>1,000a	>1,000a
Ripe Pulp	>1,000a	>1,000a
Exocarp	55.24±1.17e	157.82±2.03e
Sap	368.99±2.27c	>1,000a
Acarbose	3.20±0.08f	
Physostigmine		0.02±0.00e

Values (mean±SD) with different letters in a column indicate significant difference ($P<0.05$).

Table 4: Phenolic contents from different parts of *B. flabellifer* L.

	Gallic acid (µg/g)	Proto-catechuic acid (µg/g)	Vanillic acid (µg/g)	Caffeic acid (µg/g)	Coumaric acid (µg/g)	Ferulic acid (µg/g)	Sinapic acid (µg/g)
Endosperm	31.49±0.16c	9.55±0.83d	4.96±0.00d	7.37±0.51d	3.19±0.04e	5.97±0.06c	6.18±0.37e
Haustorium	ND	6.07±0.05f	5.60±0.15cd	5.29±0.07e	3.39±0.03de	5.11±0.01c	8.30±0.05de
Leaves	ND	12.17±0.40b	8.85±1.28a	8.92±0.41c	21.92±0.34a	14.76±2.69b	60.68±2.64a
Male Flowers	224.89±0.74a	10.33±0.26c	5.32±0.36cd	38.27±0.65a	19.23±0.75b	28.07±6.50a	36.92±1.08b
Mesocarp	8.32±0.13d	7.39±0.25e	5.67±0.16cd	11.81±0.14b	3.82±0.12de	5.35±0.06c	6.48±0.20e
Ripe Pulp	2.07±0.02e	12.49±0.12b	8.31±0.02a	7.66±0.06d	3.62±0.12cd	5.59±0.06c	17.80±0.13c
Exocarp	63.14±0.75b	7.81±0.05e	6.20±0.10bc	8.85±0.09c	4.87±0.07c	5.80±0.02c	8.26±0.30de
Sap	2.04±0.04e	16.43±0.24a	6.89±0.20b	11.73±0.26b	4.89±0.05c	6.08±0.45c	10.25±1.58d

Values (mean±SD) with different letters in a column indicate significant difference (P<0.05).

against α-glucosidase, whereas two isolated substances, tyrosol and glucosyl-(6-1)-glycerol, shown moderate and weak α-glucosidase inhibition, respectively (Dej-adisai et al., 2017). Acetylcholinesterase (AChE) is a key enzyme that catalyzes the hydrolysis of acetylcholine to acetate and choline, serving as an important target of most of the clinically used drugs for Alzheimer's disease treatment (Basnet et al., 2020). The exocarp of *B. flabellifer* L. showed the highest α- acetylcholinesterase inhibitory activity (IC_{50} at 157.82mg/ml), followed by leaves (IC_{50} at 356.14mg/mL) and haustorium (IC_{50} at 561.88mg/mL) respectively. Some reports regarding the acetylcholinesterase inhibitory activity of *B. flabellifer* L. Abraham et al. (2022) reported haustoria of *B. flabellifer* L. contained the compounds docking affinities against acetylcholinesterase and β-secretase, demonstrating superior binding scores and ADME properties, suggesting their potential as therapeutic agents for Alzheimer's disease. The results showed that the *B. flabellifer* L. possessed α-glucosidase inhibitory and anticholinesterase activity. In addition, male flowers showed considerable α-glucosidase inhibitory activities with IC_{50} at 0.75mg/mL, higher than acarbose (IC_{50} at 3.0mg/mL).

Phenolic and Flavonoid Profile

Using the HPLC technique, 7 phenolic compounds were investigated in different parts of *B. flabellifer* L., and the result is shown in Table 4. Protocatechuic acid, vanillic acid, caffeic acid, coumaric acid, ferulic acid, and sinapic acid were identified in differing concentrations across all eight portions of *B. flabellifer* L. However, gallic acid was present only in 6 parts out of 8: endosperm, male flowers, mesocarp, ripe pulp, exocarp, and sap. The most abundant phenolic components were gallic acid, sinapic acid, and caffeic acid, respectively. The male flowers contained the highest amount of gallic acid (224.89µg/g), caffeic acid (38.27µg/g), sinapic acid (36.92µg/g), and ferulic acid (28.07µg/g), while the leaves and sap contained the highest amount of coumaric acid (21.92µg/g) and protocatechuic acid (16.43µg/g), respectively. Vanillic acid was abundant in leaves (8.85µg/g) and ripe pulp (8.31µg/g). The 3 flavonoids, catechin, rutin, and quercetin were determined and shown in Table 5. The most abundant flavonoid compounds were catechin, rutin, and quercetin, respectively. Catechin, rutin, and quercetin were present in all parts of *B. flabellifer* L., in which the male flowers contain the highest amount of catechin (189.26µg/g) and quercetin (134.82µg/g), while the sap contains the highest amount of rutin (239.76µg/g). Our results correspond with previous research, in which

Table 5: Flavonoid contents from different parts of *B. flabellifer* L.

	Catechin (µg/g)	Rutin (µg/g)	Quercetin (µg/g)
Endosperm	113.90±1.30c	41.90±0.55e	5.75±0.13g
Haustorium	165.95±2.23b	23.46±0.62f	5.85±0.10g
Leaves	48.30±0.38f	77.38±2.76d	94.13±0.64b
Male Flowers	189.26±8.12a	113.33±1.15c	134.82±1.62a
Mesocarp	64.07±1.83e	4.29±0.49g	13.79±0.25d
Ripe Pulp	121.67±2.63c	0.63±0.06h	9.16±0.22e
Exocarp	36.51±0.96g	121.70±9.96b	62.80±2.78c
Sap	86.38±2.38d	239.76±4.31a	8.39±0.14f

Values (mean±SD) with different letters in a column indicate significant difference (P<0.05).

catechin has been identified as the only phytochemical compound detected in water and ethanol extracts of young and mature male flowers of *B. flabellifer* L. (Fongsuk et al., 2023). Numerous researchers have indicated that medicinal plants and their phenolic and flavonoid content have therapeutic benefits, such as antioxidants and the potential to inhibit both enzymes. (α-glucosidase and acetylcholinesterase). Tamfu et al. (2021) reported that *T. diversifolia, P. Biglobosa* and *C. Febrifuga*, medicinal plants from Chad, exhibited good inhibition against acetylcholinesterase and butyrylcholinesterase, making them potential candidates for the management of oxidative-stress-linked illnesses, such as Alzheimer's disease and diabetes, attributed to the presence of rutin, gallic acid, and protocatechuic acid within their phenolic compounds. Mollaei et al. (2021) reported that the ethyl acetate fractions of *Salsola vermiculata* leaves and the aqueous-acid fraction of its roots had the most significant inhibitory activity against acetylcholinesterase (IC_{50} at 17.24µg/mL) and α-glucosidase (IC_{50} at 62.37µg/mL), respectively, furthermore, vanillic acid, rutin, salsoline, salsoline A, palmitic acid, oleic acid, linoleic acid, cumin aldehyde, and carvone were reported as major components in the roots, while gallic acid, vanillic acid, caffeic acid, rosmaric acid, rutin, quercetin, limonene, and carvone were identified as major components in the leaves. Eruygur et al. (2022) reported that *Glaucosciadium cordifolium* demonstrated strong antioxidant potential and anti-acetylcholinesterase activity due to the caffeic acid and 1,2-dihydroxy benzene found in the aqueous extract of the roots. Koudoro et al. (2023) reported that *Pteleopsis suberosa* (Combretaceae) leaves possess the potential to mitigate Alzheimer's disease by inhibiting acetylcholinesterase and butyrylcholinesterase, as well as exhibiting antidiabetic activity, attributable the abundant of gallic acid among the fourteen identified phenolic compounds. Saad et al. (2024) reported that the *C. spinosum* L. leaf extracts possessed anti-acetylcholinesterase, antioxidant, and anti-inflammatory

activity, attributed to the significant levels of caffeic acid and coumaric acid in the extracts. According to the referenced research, our findings show that *B. flabellifer* L. has extraordinary potential in the treatment of diabetes and Alzheimer's disease, as it is a substantial source of strong potent antioxidants, anti-α-glucosidase, and anti-acetylcholinesterase compounds.

Conclusion

This study reported the evaluation of phenolic contents, flavonoids, anthocyanins, carotenoids, antioxidant activities, α-glucosidase inhibitory activities, and anti-acetylcholinesterase inhibitory activities of the endosperm, haustorium, leaves, male flowers, mesocarp, ripe fruit pulp, exocarp, and sap of *B. flabellifer* L. The male flower exhibited the highest concentrations of phenolic acids, flavonoids, anthocyanins, and tannins among all the different parts, while the ripe pulp showed the highest value of carotenoids among all parts of *B. flabellifer* L. The male flowers exhibited significantly elevated antioxidant activity and α-glucosidase inhibitory activity, with α-glucosidase inhibition even greater than that of the positive control, acarbose, a commonly used antidiabetic drug. Moreover, the exocarp of *B. flabellifer* L. showed the highest acetylcholinesterase inhibitory activity, followed by leaves and haustorium, respectively. The results indicate that *B. flabellifer* L. shows antioxidant, anti-α-glucosidase, and anti-acetylcholinesterase activity, making it highly effective for the treatment of diabetes and Alzheimer's disease.

Acknowledgements: The authors would like to thank the Phetchaburi Rajabhat University (Fundamental Fund: the fiscal year 2023 by National Science Research and Innovation Fund, NSRF), Thailand for financial support with grant number FF004-2566.

Conflicts of Interest: The author declares no conflict of interest.

Data Availability: All the data is available in the article.

Author's Contribution: S.S. initiated, designed, and conducted the experiments, analyzed and interpreted the data, drafted and edited the manuscript. P.T. participated in sample collection, conducted experiments, and revised the manuscript.

Generative AI statement: The authors declare that no Gen AI/DeepSeek was used in the writing/creation of this manuscript.

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REFERENCES

Abraham, J.T., Maharifa, H.N.S., & Hemalatha, S. (2022). In silico molecular docking approach against enzymes causing Alzheimer's disease using *Borassus flabellifer* Linn. *Applied Biochemistry and Biotechnology*, 194, 1804-1813. https://doi.org/10.21203/rs.3.rs-774037/v1

Abu, M.L., Mohammed, H., Abubakar, H., Mayaki, F.G., Ndatsu, Y., Olalekan, A.A., Suleiman, R., Isuwa, A.E. & Musah, M. (2024). The potency of *B. flabellifer* L. in Type 2 diabetes: A review. *Lapai Journal of Science and Technology*, 10(1), 93-109.

Akter, M., Islam, K., Sarkar, U.R., Hossien, M.M., Akter, S., Tondra, S.F.S., Hossen, M.I., & Hasan, M.N. (2020). Investigation of antidiabetic properties of *Borassus flabellifer* L. (roots) on type-2 diabetic rats. *Pharmacology online*, 11,105-112.

Alam, S., Dhar, A., Hasan, M.M., Richi, F.T., Emon, N.U., Aziz, A., Mamun, A.A., Chowdhury, M.N.R., Hossain, M.J., Kim, J.K., Kim, B., Hasib, M., Zihad, S.M.N.K., Haque, E., Mohamed, I.N., & Rashid, M.A. (2022). Antidiabetic potential of commonly available fruit plants in Bangladesh: Updates on prospective phytochemicals and their reported MoAs. *Molecules*, 27(24), 8709. https://doi.org/10.3390/molecules27248709

Anitha, P., Nargis Begum, T., & Senthil Kumar, R. (2023). In vitro antidiabetic and antioxidant potential of the sprout of *Borassus flabellifer* L. *Extract. Oriental Journal of Chemistry*, 39(1), 202-211. https://doi.org/10.13005/ojc/390125

Anggraini, T., Syafni, W., Syukri, D., & Azima, F. (2019). Total phenolic, anthocyanin, catechins, DPPH radical scavenging activity, and toxicity of *Lepisanthes alata* (Blume) Leenh. *International Journal of Food Science*, 2019(1), 9703176. https://doi.org/10.1155/2019/9703176

Arirudran, B., Shalini, E., & Anbarasu, K. (2022). Phytochemcial analysis and isolation, identification of bioactive compounds present in root of *Borassus flabellifer* Linn. using GC/MS. *Journal of Natural Remedies*, 22(4), 705-716. https://doi.org/10.18311/jnr/2022/28696

Assefa, S.T., Yang, E.Y., Chae, S.Y., Song, M., Lee, J., Cho, M.C., & Jang, S. (2019). Alpha glucosidase inhibitory activities of plants with focus on common vegetables. *Plants*, 9(1), 2. https://doi.org/10.3390/plants9010002

Barbosa, G.B., & Nueva, M.C.Y. (2019). Antioxidant activity and phenolic content of *Hornstedtia conoidea* (Zingiberaceae). *Asian Journal of Biological and Life Sciences*, 8(1), 1-7. https://doi.org/10.5530/ajbls.2019.8.1

Basava Prasad, A.R., Arunkumar, A, Vignesh, S, Chidanand, D.V., & Baskaran, N. (2022). Exploring the nutritional profiling and health benefits of Palmyra palm haustorium. *South African Journal of Botany*, 151, 228-237. https://doi.org/10.1016/B978-0-323-91250-1.00004-5

Basava Prasad, A.R., Vignesh, S., Elumalai, A., Anandharaj, A., Chidanand, D. V., & Baskaran, N. (2023). Nutritional and pharmacological properties of *B. flabellifer* L. *Food and Humanity*, 1, 817-825. https://doi.org/10.1016/j.foohum.2023.07.030

Basnet, R., Khadka, S., Basnet, B.B., & Gupta, R. (2020). Perspective on acetylcholinesterase: a potential target for Alzheimer's disease intervention. *Current Enzyme Inhibition*, 16(3), 181-188. https://doi.org/10.2174/1573408016999200801021329

Behera, S. (2022). Phytochemical constituents and nutritional potential of *B. flabellifer* L.: A review. *The Review of Contemporary Scientific and Academic Studies*, 2(12), 101-107. https://doi.org/10.55454/rcsas.2.12.2022.003

Butsat, S., & Siriamornpun, S. (2010). Phenolic acids and antioxidant activities in husk of different Thai rice varieties. *Food Science and Technology International*, 16(4), 329-336. https://doi.org/10.1177/1082013210366966

Caturano, A., D'Angelo, M., Mormone, A., Russo, V., Mollica, M.P., Salvatore, T., Galiero, R., Rinaldi, L., Vetrano, E., Marfella, R, Monda, M., Giordano, A., & Sasso, F.C. (2023). Oxidative stress in type 2 diabetes: impacts from pathogenesis to lifestyle modifications. *Current Issues in Molecular Biology*, 45(8), 6651-6666. https://doi.org/10.3390/cimb45080420

Chandran, K.C., & Indira, G. (2016). Quantitative estimation of total phenolic, flavonoids, tannins and chlorophyll content of leaves of *Strobilanthes Kunthiana* (Neelakurinji). *Journal of Medicinal Plants Studies*, 4(4), 282-286.

Dej-adisai, S., Pitakbut, T., & Wattanapiromsakul, C. (2017). Alpha-glucosidase inhibitory activity and phytochemical investigation of *Borassus flabellifer* Linn. *African Journal of Pharmacy and Pharmacology*, 11(3), 45-52. https://doi.org/10.5897/ajpp2016.4706

El Atki, Y., Aouam, I., El kamari, F., zejli, H., Taroq, A., Lyoussi, B., Taleb, M., & Abdellaoui, A. (2020). Antioxidant activities, total phenol and flavonoid contents of two *Teucrium polium* subspecies extracts. *Moroccan*

Journal of Chemistry, 8(2), 446-455.

Eruygur, N., Ayaz, F., Bağcı, Y., Ayyıldız, H.F., Çağıl, E.M., Malik, P., & Ali, A. (2022). Investigation of phenolic compounds, in vitro antioxidant and enzyme inhibition activities of methanol and aqueous extracts of different parts of *Glaucosciadium cordifolium*. *Botanica Serbica*, 46 (2), 239-252. https://doi.org/10.2298/botserb2202239e

Fongsuk, C., Wongmanit, P., & Pansuksan, K. (2023). Effect of plant stage and solvent extraction on catechin contents in *Borrasus flabellifer* L. male flower. *Pharmacognosy Journal*, 15(6), 1036-1041. https://doi.org/1036-1041. 10.5530/pj.2023.15.190

Gajendra, K., Pratap, G.K., Poornima, D.V., Shantaram, M., & Ranjita, G. (2024). Natural acetylcholinesterase inhibitors: A multi-targeted therapeutic potential in Alzheimer's disease. *European Journal of Medicinal Chemistry Reports*, 11, 100154. https://doi.org/10.1016/j.ejmcr.2024.100154

Ghribia, L., Ghouilaa, H., Omrib, A., Besbesb, M., Janneta, H.B. (2014). Antioxidant and anti-acetylcholinesterase activities of extracts and secondary metabolites from *Acacia cyanophylla. Asian Pacific Journal of Tropical Biomedicine*, 4(1), S417-S423. https://doi.org/10.12980/APJTB.4.2014C1064

Hofmann, T., Visi-Rajczi, E., & Albert, L. (2020). Antioxidant properties assessment of the cones of conifers through the combined evaluation of multiple antioxidant assays. *Industrial Crops and Products*, 145, 111935. https://doi.org/10.1016/j.indcrop.2019.111935

Jamkhande, P.G., Suryawanshi, V.A., Kaylankar, T.M., & Patwekar, S.L. (2016). Biological activities of leaves of ethnomedicinal plant, *Borassus flabellifer* Linn. (*B. flabellifer* L.): An antibacterial, antifungal and antioxidant evaluation. *Bulletin of Faculty of Pharmacy, Cairo University*, 54(1), 45-49. https://doi.org/10.1016/j.bfopcu.2016.01.002

Kashtiban, A. E., Okpala, C. O. R., Karimidastjerd, A., & Zahedinia, S. (2024). Recent advances in nano-related natural antioxidants, their extraction methods and applications in the food industry. *Exploration of Foods and Foodomics*, 2, 125-154. https://doi.org/10.37349/eff.2024.00030

Kashtoh, H & Baek, K.H. (2022). Recent updates on phytoconstituent alpha-glucosidase inhibitors: an approach towards the treatment of type two diabetes. *Plants (Basel)*, 11(20), 2722. https://doi.org/10.3390/plants11202722

Kavatagimath, S.A., Jalalpure, S.S., & Hiremath, R.D. (2016). Screening of ethanolic extract of *Borassus flabellifer* flowers for its antidiabetic and antioxidant potential. *Journal of Natural Remedies*, 16 (1), 22-32, https://doi.org/10.18311/jnr/2016/654

Kittiwisut, S., Amnuoypol, S., Pathompak, P., & Setharaksa, S. (2021). α-Glucosidase and α-amylase inhibitory effects with anti-oxidative activity of *Tetracera loureiri* (Finet & Gagnep.) Pierre ex Craib leaf extracts. *Pharmaceutical Sciences Asia*, 48 (2), 175-184. https://doi.org/10.29090/psa.2021.02.19.125

Koudoro, A.Y., Tamfu, A.N., Munvera, A.M., Küçükaydın, S., Cokou, P.A.D., Avlessi, F., Koko, D.S.C., & Ceylan, Ö. (2023). Phenolic composition, anti-biofilm, anti-quorum sensing, antioxidant and enzyme inhibitory activities of *Pteleopsis suberosa* (Combretaceae) leaves. *Pharmacophore, 14*(3), 89–99. https://doi.org/10.51847/uflidelfqf

Koul, B., Farooq, U., Yadav, D., & Song, M. (2023). Phytochemicals: A promising alternative for the prevention of Alzheimer's disease. *Life (Basel)*, 13(4), 999. https://doi.org/10.3390/life13040999

Kupina, S., Fields, C., Roman, M.C., & Brunelle, S.L. (2019). Determination of total phenolic content using the Folin-C assay: Single-laboratory validation, First Action 2017.13. *Journal of AOAC International, 102*(1), 320–321. https://doi.org/10.5740/jaoacint.18-0031

Kurian, A., Thiripuranathar, G., & Paranagama, P. (2017). Determination of total phenolic content and antioxidant activity of *Borassus flabeliffer* Linn. fruit pulp collected from several parts of Sri Lanka. *International Journal of Pharmaceutical Sciences and Research*, 8(6), 2701-2705. https://doi.org/10.13040/IJPSR.0975-8232.8(6).2701-05

Le, D.H.T., Chiu, C.S., Chan, Y.J., Wang, C.C.R., Liang, Z.C., Hsieh, C.W., Lu, W. C., Mulio, A.T., Wang, Y.J. & Li, P.H. (2021). Bioactive and physicochemical characteristics of natural food: Palmyra palm (*Borassus flabellifer* Linn.) syrup. *Biology,* 10(10), 1028. https://doi.org/10.3390/biology10101028

Leida, I., Thaha, R.M., Yusnitasari, A.S., & Afsahyana, A. (2020). Effect of sap palm (*Borassus flabellifer*) on blood glucose level in pre-diabetic patients. *International Journal of Current Research and Review*, 24(12), 96-100. https://doi.org/10.31782/ijcrr.2020.122419

Li, X., Bai, Y., Jin, Z., Svensson, B. (2022). Food-derived non-phenolic α-amylase and α-glucosidase inhibitors for controlling starch digestion rate and guiding diabetes-friendly recipes. *LWT*, 153, 112455. https://doi.org/10.1016/j.lwt.2021.112455

Liao, H., & Banbury, L. (2015). Different proportions of Huangqi (Radix Astragali Mongolici) and Honghua (Flos Carthami) injection on α-glucosidase and α-amylase activities. *Evidence-Based Complementary and Alternative Medicine*, 2015(1), 785193. https://doi.org/10.1155/2015/785193

Lou, W., Chen, Y., Ma, H., Liang, G. & Liu, B. (2018). Antioxidant and α-amylase inhibitory activities of tannic acid. *Journal of Food Science and Technology*, 55, 640-3646. https://doi.org/10.1007/s13197-018-3292-x

Manivannan, M.I., Allwin, L., Richard, K.N., Premalakshmi, V., Nandhini, M., & Manikandan, K. (2024). Evaluation of antidiabetic activity of palmyrah (palm jaggery and palm honey) (*Borassus flabellifer* L.) against streptozotocin-nicotinamide induced diabetic wistar rats. *Plant Science Today*, 11(4), 01-08. https://doi.org/10.14719/pst.5936

Moise, G., Jîjie, A.R., Moacă, E.A., Predescu, I.A., Dehelean, C.A., Heghes, A., Vlad, D.C., Popescu, R., & Vlad, C.S. (2024). Plants' impact on the human brain-exploring the neuroprotective and neurotoxic potential of plants. *Pharmaceuticals*, 17(10), 1339. https://doi.org/10.3390/ph17101339

Mollaei, S., Farnia, P., & Ghanavi, J. (2021). Metabolic profiling and inhibitory properties of different parts of *Salsola vermiculata* towards acetylcholinesterase and α-glucosidase. *Journal of Plant Molecular Breeding*, 9(1), 25-34. https://doi.org/10.21203/rs.3.rs-923017/v1

Nefzi, K., Jemaa, B.M., Baraket, M., Dakhlaoui, S., Msaâda, K., & Nasr, Z. (2022). In vitro antioxidant, antibacterial and mechanisms of action of ethanolic extracts of five Tunisian plants against bacteria. *Applied Sciences*, 12(10), 5038. https://doi.org/10.3390/app12105038

Niaz, A., Adnan, A., Bashir, R., Mumtaz, M.W., Raza, S.A., Rashid, U., Tan, C.P., & Tan, T.B. (2021). The in vitro α-glucosidase inhibition activity of various solvent fractions of *Tamarix Dioica* and 1H-NMR based metabolite identification and molecular docking analysis. *Plants (Basel)*, 10(6), 1128. https://doi:10.3390/plants10061128

Rahman, S.S., Chowdhury, S.N., Salauddin, M., Hosen, Z., Karim, M.R., & Rouf, S.M. (2021). Comparative studies on nutrient content and antidiabetic effects of sugar palm (*Borassus flabellifer*) fruit pulp & endosperm on rats. *Endocrine and Metabolic Science,* 5, 100113. https://doi.org/10.1016/j.endmts.2021.100113

Rawat, K., Tewari, D., Bisht, A., Chandra, S., Tiruneh, Y.K., Hassan, H.M., Al-Emam, A., Sindi, E.R., & Al-Dies, A.M. (2024). Identification of AChE targeted therapeutic compounds for Alzheimer's disease: an in-silico study with DFT integration. *Scientific Reports*, 14(1), 30356. https://doi:10.1038/s41598-024-81285-2

Rodiah, M.H., Jamilah, B., Kharidah, S.M.S., & Russly, A.R. (2019). Physico-chemical and antioxidant properties of mesocarp and exocarp from *Borassus flabellifer*. *International Food Research Journal,* 26(5), 1469-1476

Saad, S.A., Abd-Alla, H.I., Aly, H.F., Shalaby, N.M.M., Afify, A.M.R., Ali, H.F.M., & Abdel-Moein, N.M. (2024). Citharexylum spinosum promotes antioxidant, anti-inflammatory, and anti-acetylcholinesterase activities. *Egyptian Journal of Chemistry*, 67(5), 63-75. https://doi.org/10.21608/ejchem.2023.235755.8594

Saberi, M., Kamali, N., Tarnian, F., Sadeghipour, A. (2022). Investigation phenol, flavonoids and antioxidant activity content of *Capparis spinosa* in three natural habitats of Sistan and Baluchestan province, Iran. *Journal of Rangeland Science,* 12(2), 191-204. https://doi.org/10.30495/rs.2022.682941

Sansenya, S., Payaka, A., Wannasut, W., Hua, Y., & Chumanee, S. (2021). Biological activity of rice extract and the inhibition potential of rice extract, rice volatile compounds and their combination against α-glucosidase, α-amylase and tyrosinase. *International Journal of Food Science & Technology*, 56(4), 1865-1876. https://doi.org/10.1111/ijfs.14816

Sarkar, T., Mukherjee, M., Roy, S., & Chakraborty, R. (2023). Palm sap sugar an unconventional source of sugar exploration for bioactive compounds and its role on functional food development. *Heliyon*, 9(4), e14788. https://doi.org/10.1016/j.heliyon.2023.e14788

Shanmugalingami, V, Sathasivampillai, S.V., & Srithayalan, S. (2021). Pharmacological activities of *Borassus flabellifer* L. extracts and isolated compounds. *International Journal of Innovative Research and Reviews*, 5(2), 23-31.

Subramanian, S.P., Renuka, K., & Pillai, S.I. (2024). *B. flabellifer* L. (*Borassus Flabellifer* Linn) - A Celestial Tree. *Journal of Chemical Health Risks*, 14(4), 1720-1734. https://doi.org/10.22034/jchr.2023.380495.1363

Sultana, N., Saini, P.K., Kiran, Rout, S., & Kanaka, S. (2023). Exploring the antioxidant potential of medicinal plant species: A comprehensive. Review. *Journal of Plant Biota*, 2(2), 1-13. https://doi.org/10.51470/JPB.2023.02.02.09

Suwanaruang, T. (2022). Determining total carotenoid content in different colours fruits. *Agricultural and Biological Research*, 38(1), 232-234.

Tamfu, A.N., Roland, N., Mfifen, A.M., Kucukaydin, S., Gaye, M., Botezatu, A. V., Duru, M.E., & Dinica, R.M. (2021). Phenolic composition,

antioxidant and enzyme inhibitory activities of *Parkia biglobosa* (Jacq.) Benth. *Tithonia diversifolia* (Hemsl) A. Gray, and *Crossopteryx febrifuga* (Afzel.) Benth. *Arabian Journal of Chemistry*, 15, 103675. https://doi.org/10.1016/j.arabjc.2021.103675

Telagari, M., & Hullatti, K. (2015). In-vitro α-amylase and α-glucosidase inhibitory activity of *Adiantum caudatum* Linn. and *Celosia argentea* Linn. extracts and fractions. *Indian Journal of Pharmacology*, 47(4), 425-429. https://doi.org/10.4103/0253-7613.161270

Tresina, P.S., Santhiya Selvam, M., Doss, A. & Mohan, V.R. (2022). Antidiabetic bioactive natural products from medicinal plants. *Studies in Natural Products Chemistry*, 75, 75-118. https://doi.org/10.1016/B978-0-323-91250-1.00004-5

Tunit, P., Thammarat, P., Okonogi, S., & Chittasupho, C. (2022). Hydrogel containing *Borassus flabellifer* L. male flower extract for antioxidant, antimicrobial, and anti-inflammatory activity. *Gels*, 8(2), 126. https://doi.org/10.3390/gels8020126

Yun, K., & Seo, K. (2023). Comparison of in vitro antioxidant capacities of *Phragmites communis* Trin. and *Phragmites japonica* Steud. *Korean Journal of Food Preservation*, 30(6), 960-969. https://doi.org/10.11002/kjfp.2023.30.6.960

Warnasih, S., & Hasanah, U. (2018). Phytochemical characterization and tannins stability test from kluwek (*Pangium edule Reinw*). *Journal of Science Innovare*, 1(2), 44-49. https://doi.org/10.33751/jsi.v1i02.1000

Zhang, X., Wu, Z., Weng, P., & Yang, Y. (2015). Analysis of tea catechins in vegetable oils by high-performance liquid chromatography combined with liquid–liquid extraction. *International Journal of Food Science & Technology*, 50(12), 885-891. https://doi.org/10.1111/ijfs.12726

Zhou, J., Diao, X., Wang, T., Chen, G., Lin, Q., Yang, X., & Xu, J. (2018). Phylogenetic diversity and antioxidant activities of culturable fungal endophytes associated with the mangrove species *Rhizophora stylosa* and *R. mucronata* in the South China Sea. *Plos One*, 13(6), e0197359. https://doi.org/10.1371/journal.pone.0197359

Zongo, P.F.I., Bayala, B., Zongo, L., Yonli, A., Compaore, J.M., & Simpore, J. (2024). Evaluation of antioxidant and anti-inflammatory activities of a medicinal plant recipe from Burkina Faso. *Biochemistry and Molecular Biology*, 9(3), 53-62. https://doi.org/10.11648/j.bmb.20240903.12