Nutritional and Medicinal Properties of *Pithecellobium dulce* A review article

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Abstract

Mimosaceae family includes the tree *Pithecellobium dulce*. The plant *P. dulce* is found in South America, Asia, and North America, and is frequently applied in conventional medicine. Thus, the history of this plant, together with its physical characteristics, nutritional value, phytochemical analysis, physiological effects, pharmacological applications, and antioxidant agents, are presented in this study. It was found that this species is very significant raw materials to use as a medicinal plant and nutritional natural source due to its phytochemicals content and biochemicals properties. Therefore, it could be concluded to take care of this plant and sustain it by enlargement of cultivation areas.

Keywords: Tree, medicinal properties, Mimosoideae, Phytochemistry, antioxidant.

الخصائص الغذائية والطبية لنبات *Pithecellobium dulce*: مقالة مرجعية

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الملخص

تنتمي شجرة *Pithecellobium dulce* إلى عائلة Mimosaceae هو نبات ينتشر في أمريكا الشمالية والجنوبية وآسيا. ويستخدم عادة في الطب التقليدي. لذلك، تعرض هذه المراجعة أصل هذا النبات وخصائصه المورفولوجية، والتحليل الكيميائي النباتي، واستخداماته الغذائية والصيدلانية، وتأثيراته الفسيولوجية والعوامل المضادة للأكسدة. لقد وجد أن هذا النوع يعد من المواد الخام المهمة جدًا لاستخدامه كنبات طبي ومصدر غذائي طبيعي نظرًا لمحتواه من المواد الكيميائية النباتية وخصائصه الكيميائية الحيوية. ولذلك يمكن الاستنتاج بالاهتمام بهذا النبات واستدامته من خلال توسيع مساحات زراعته.

الكلمات المفتاحية: شجرة، خصائص طبية، العائلة المستحية، كيمياء نبات، مضادات اكسدة

Introduction

In recent decades, people have been paying medicinal plants constant and undivided attention because of their significant role in pharmaceutical industry. Because of their effectiveness, low side effects, and safety, plant products continue to be the medication of choice for novel lead identification in spite of fierce competition from contemporary synthetic equivalents created through combinatorial chemistry. (Dhanisha *et al.,* 2021). Ever from ancient times, plants had considered as one of the most important sources of medicines all throughout the world. Humanity has developed creative ideas to create medications from seeds, fruits, barks, and other natural sources, even if knowledge of using medicinal plants in production of herbal medications is the result of years of work against different diseases. The leaves and other plant body components. It's the best resource for the bioactive agents. pharmacophores and chemical phenotypes (chemotypes), in addition to the creation of novel medicinal drugs. Because of ethnological justifications, herbal therapeutic remedies were progressively reintroduced into the market as alternatives to modern medications, which were used inconsistently. (Fabricant and Farnsworth, 2001; Butler, 2008).

Medicinal plants have competitive advantages that made it a successful alternative to synthetic drugs. That was due to their immediate effects, less production costs, and time efficacy. Even while such synthetic products are becoming more and more popular, there are still substantial concerns about their safety. Over 70% of synthetic medications were proven clinically dangerous as a result of their serious side effects and poor efficacy. Because of this, developing countries have embraced alternative and complementary medicine—especially herbal medicines—as a promising new therapeutic option (Abbott, 2011). Over 70% of people worldwide still receive their medical care from conventional practitioners, according to World Health Organization. Those medicinal plants have negligible or no side effects in comparison to the synthetic drugs (Galm and Shen, 2007). As a result, bioactive components that are created naturally have drawn a lot of attention from scientists worldwide. Several medications generated from natural products are in different clinical development stages, which highlights the importance of using naturally-occurring molecules as sources of novel medicinal precursors. (Wani and Horwitz, 2014; Holmes et al., 1991). Blockbuster phytochemicals like the phenolics, alkaloids, tannins, flavonoids, saponins, terpenoids, glycosides, and provitamins were mostly derived from such plants and have garnered significant attention as potential alternative treatments for illnesses associated with oxidative stress.

From these plant *Pithecellobium dulce* is a medium-sized spiny evergreen tree with a high nutritional value. Fruits of P. dulce have been frequently utilized in Ayurvedic medicine and folk remedies. Tannin, olein, and glycosides are some of the plant's physiologically active compounds.

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There were 38 active phytocompounds found in the plant's numerous components, including quercetin, kaempferol, and dulcitol. Catechol tannins can be found in the bark of this plant. Antivenom capabilities have been revealed in the polyphenol classes of phytocompounds. Proteins and phenols were detected throughout the fruit's formation. The pH is high in the ripened stage, whereas the overall acidity is high in the pre-ripened stage. This study is aimed to highlight on some biological and pharmaceutical aspects of *Pithecellobium*. (Murugesan *et al.,* ,2019).

Origin and Morphological Features

The tree *Pithecellobium dulce* belongs to the Mimosaceae family that have been distributed in South and North America, as well as Asia, and is commonly utilized in traditional medicine (López-Angulo *et al*, 2021). It is widely present to tropical America which grew in areas like Tamaulipas, San Luis Potosi, Jalisco, and Queretaro in Mexico (López-Angulo *et al.,* 2021). This species is believed to have originated in the surrounding highlands of Central America and Mexico, or on the Pacific coast of northern South America. Since then, it has spread widely throughout Asia, including Bangladesh, India, the Caribbean, Sri Lanka, Florida, Pakistan, Thailand, and the Philippines. The Viridiplantae sub-kingdom, infra kingdom, and the Plantae kingdom are all mentioned.
Streptophyta
Division: Tracheophyta
Order: Fabales
Family: Leguminosae
Genus: *Pithecellobium* and Species: *dulce*.
A spiny, medium-sized, evergreen tree with high nutritional value is *Pithecellobium dulce*. *P. dulce* is a tree that reaches a height between 10m and 15m and has bipinnate compound leaves. One pair of apiculated, ovate-oblong, between 2 and 4 cm long leaflets are present on each pinna (phyllotaxy of leaves). Generally, each leaflet has two paired, thin spines at its base that range in length between 2 and 15 mm. It has a spiky trunk (Alrawi, 2023). Flowers are 0–1.5 cm in size, fragrant, and greenish-white or white. Every flower has a hairy corolla and a base that has a tube containing fifty thin stamens. Pods come in a variety of colors, from reddish pink to greenish brown. It is between 10 and 15cm long and 1-2cm wide. In every one, there are many kinds of seeds (Alrawi et al., 2023). The traditional usage of *P. dulce* throughout history has demonstrated its promise as a medicine for a wide range of illnesses. According to Vargas-Madriz *et al*., (2020), *P. dulce* fruits are pods that are 10–15cm long and have white or red delicious arils inside. A portion of this tree is displayed in plate 1.

Plate 1. Some *Pithecellobium dulce* parts.
A: Stem, B: leaves; B1: pinna, B2: branch, C: seeds, D: flower, E: pod.

Phytochemical Analysis nutritional Value

The edible fruits of *P. dulce* are consumed throughout India. Its fruits are highly valued for their nutritional and therapeutic qualities, drawing a lot of attention to them. The fruit pulp has long been utilized as a hemoptysis and astringent. Public health problems have long been mostly caused by malnutrition, especially in developing countries. This nutritional deficiency has highlighted the stark difference between world's population and the amount of high-quality food available. For the purpose of attaining optimal health and boosting immune system, it is evident that it is imperative to address unexpected nutritional concerns and generate highly nutritious food with the medicinal potential. The bark of *P. dulce* contained three prenylated flavonoids (Katekhaye and Laddha, 2012). *P. dulce* leaves were utilized traditionally as an emollient, for earaches and tooth, digestive problems, and to prevent miscarriages, among other ailments (Farnsworth and Soejarto, 1991). Numerous chemical components (table 1), including saponins, steroids, tannins, lipids, and phenolics, and biological activities (like antidiabetic, antioxidant, anti-inflammatory, and digestive enzyme inhibitory) have been discovered through scientific research on P. dulce, and those components are thought to be playing a significant role in disease prevention (Ponmozhiet al., 2011). Consequently, research on bio-active natural products has garnered significant global attention. The large number of medications generated from natural products that are in different clinical development stages emphasizes the significance of employing natural products as sources of new therapeutic options. (Holmes *et al*., 1991; Wani & Horwitz (2014). Essential vitamins, minerals, and amino acids are present in every section of the plant (Sneha *et al*., 2020). It has been demonstrated that the edible fruit of P. dulce represents a good source of vital minerals and vitamins. Aril has 78 calories per 100 g of food energy, along with 18.20% carbohydrates, 77.80% water, 0.40% fat, 3% protein, 1.20% fiber, and 0.60% ash. Of the 18.20% carbs, 0.96% are made out of pectin.

When compared to normal oleanolic acid, HPLC analysis demonstrated that oleanolic acid was the major triterpenoid ingredient in the extract (Sneha et al., 2020). Pithedulosides A-G, which is a group that consists of 7 saponins, had been separated from seeds of *Pithecellobium dulce*. The Echinocystic acid has been identified as their structure utilizing the spectrum analysis. 1-O-ct-L-arabinopyranosyl-3-O-ct-L-arabinopyranosyl-3-O-ct-L-arabinopyranosyl-3 Echinocystic acid, -fl-D-glucopyranoside, and oleanolic acid 3-O—L-arabinopyranosyl-(1 2)-3-O—L-arabinopyranosyl-(1 2)-3-O—L-ara. (Rao et al., 2018). ME as well as its fractions have been found more active compared to the PZQ (i.e., praziquantel), with purified chemical being identified as N-malonyl-(+)-tryptophan (NMT) Mexico (Lopez-Angulo *et al*., 2021). Some structures of phytochemicals are shown in plate 2.

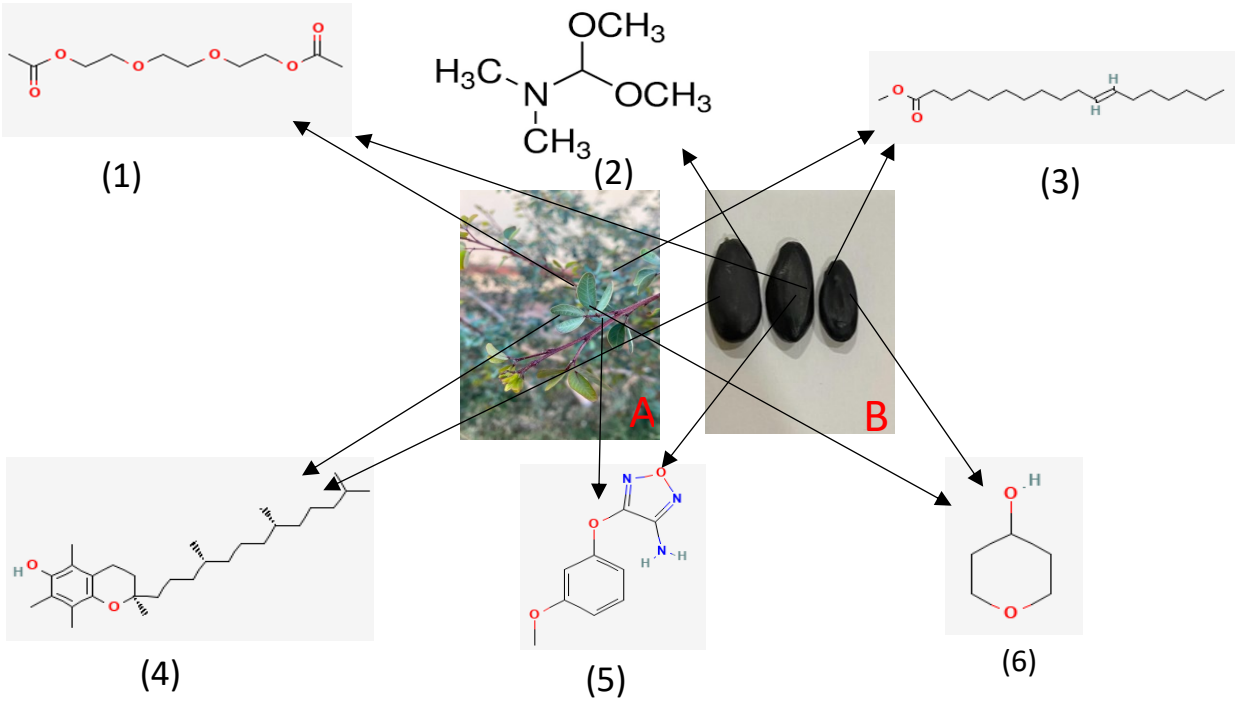

Plate 2. Some phytochemicals structures found in *P.dulce* (Alrawi et al., 2023).

1: Triethylene glycol diacetate**, 2:** N, N-Dimethylformamide trimethylene acetal, 3: Methyl vaccenate, 4: Vit E, 5: 4-(3-methoxyphenoxy)-1,2,5-oxadiazol-3-amine, 6: Tetrahydro-4-pyranol. A: leaves, B: seeds

Pharmaceutical Uses

P. dulce can be described as highly esteemed genus in the conventional medicine as a result of its broad range of the nutritional and pharmacological attributes. (Dhanisha *et al*., 2021). The positive effects of this plant on the health result mainly due to its phenolic components anti-oxidant activities. Through using various methods that could greatly differ, several authors examined phenolic components as well as antioxidant potential of the P. dulce aril, seeds, roots and leaves. (Vargas *et al.,* 2020) (table1-3). So far, natural products have shown to be one of the potential sources for novel medications (López-Angulo *et al*., 2021).

P. dulce leaves were utilized traditionally as a remedy for a wide range of illnesses, such as as gastrointestinal problems, ear and toothaches, emollients, and prevention of miscarriages. (Farnsworth and Soejarto, 1991). According to studies conducted by Ponmozhi et al. (2011), scientific investigations into *P. dulce* have identified a variety of chemical constituents (tables 1-4) such as saponins, steroids, tannins, lipids, and phenolics, and biological actions (table 1) such as antidiabetic, antioxidant, anti-inflammatory, and digestive enzyme inhibitory that are important in the prevention of disease (Ponmozhi *et al.*,2011).Consequently, research on bio-active natural products has garnered significant global attention. The large number of medications generated from natural products that are in different clinical development stages emphasizes significance of employing natural products as new therapeutic option sources. (Wani and Horwitz, 2014; Holmes et al., 1991). Amino acids, essential vitamins, and minerals are present in every section of the plant (Sneha, 2020). It has been demonstrated that the edible fruit of P. dulce is one of the good sources of vital minerals and vitamins. Aril has 78 calories per 100 g of food energy, along with 77.8% water, 18.2% carbohydrates, 3% protein, 0.4% fat, 1.2% fiber, and 0.6% ash. Of the 18.2 percent carbs, 0.96% are made out of pectin.

Table 1. phytochemical analysis in fresh leaves extracted in ethanol, methanol and petroleum ether of *P. dulce* as mentioned in past references

Type of extraction	Dominant active compound	Classification of active compound	Therapeutic/Bioactivity	Therapeutic/Bioactivity References	Reference
Ethanolic extract	Cyclohexasiloxane, dodecamethyl	Organoheterosilane	Used daily in the chemical industry	(Al Bratty *et al*., 2020)	(Gong *et al*., 2023)
	Cyclodecasiloxane, eicosamethyl	Organoheterosilane	Antimicrobial, antihelmintic, antioxidant, Hepatoprotective	(Pradeesh *et a*l., 2017)	
	13-Docosenamide, (Z)	Fatty amide	Antibacterial, antifungal activities	(Mohammed et al., 2016)	
	Hexadecanoic acid	Fatty acid	Anti-inflammatory, anti-spasmodic, anticancer and anti-viral activity	(Severyanova, *et al*, 2019)	
	L-Lysine	Amino acid	Brain functioning regulator	(Nupur et al., 2015)	
	Rhodopin	Carotenoid	Photosynthetic pigment	(Takiguchi et al., 1980)	
	Milbemycin b	Macrocyclic lactone	Antibiotic, insecticidal and acaricidal activity	(Parthipan et al., 2015)	
	1-Monolinoleoylglycero trimethylsilyl ether	Fatty acid ester	Antimicrobial Antioxidant Antiinflammatory Antiarthritic Antiasthma, Diuretic	(Bobade, 2019)	
Methanolic extract	4h-pyran-4one 3-hydroxy-2-methyl-	Pyranones	Flavoring agent	(Chen et al., 2021)	(Janani et al., 2022)
	2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4one	Dihydropyranone	Anti-inflammatory, antineoplastic, antidiabetes, antimicrobial, and antifungal actions	(Bakun et al., 2021)	
	Azulene	Allylbenzene	anti-inflammatory activity	(de Souza et al., 2021)	
	Methyleugenol	Dimethoxybenzene	insecticidal action	(Ismail et al., 2017)	
	Cedranone 5-	Heterocyclic Organic Compound.	Antimicrobial activity	(Pan et al., 2021)	
	1,2,4-Trimethoxybenzene	Anisole	As selective NLRP-3 inflammasome inhibitor	(Korsak et al., 1995)	
	1 2 4- trimethylbenzene	Aromatic hydrocarbon	Neurotoxic effect on animals	(Chen et al., 2019)	
	Tetradecanoic acid	Fatty acid	Antimicrobial activity	(Sjögren et al., 2003)	
	Dehydroxy-isocalamendiol	Sesquiterpene			
	3-methyl-3-(4-methylpent-3en-1yl)oxirane-2-carboxylic acid	Epoxide			
	Naphthalene, 1,2,3,4-tetrachloro-	Heterocyclic compound			
	3-hydroxydecanoic acid methyl ester	Fatty acid methyl ester	Anti-fungal activity	(Johnston *etal*., 1994)	
	L-Ascorbyl 6-palmitate	Fatty acid ester	An effective preservative in foods	(Takala et al., 2022)	

Petroleum ether extract	5,9,12-octadecatrienoic acid	Fatty acid	Anti-inflammatory and anti-atherogenic effects	(Kadhim, *etal*.,, 2016)	(Ganesan *et al*., 2022)
	3-Phenyl-2-propenoic acid methyl ester	Cinnamic acid ester	Anti-cancer agent	(Poongodi and Hemalatha, (2015)	
	Isoamylcinnamate	Cinnamic acid ester			
	5alpha-Cholestane-3beta,6alpha-diol, diacetate	Steroid			
	n-3-p-chlorophenyl-5p-nitrophenyl thiene-2yl 1-methylpiperidine 2-imine	Phenylpyrazole			
	9,19-Cyclolanost-7-en-3ol	Triterpenoid			
	1,16-Cyclocorynan-16 carboxylic acid, 17 (acetyloxy)-19,20 didehydro-10-methoxy-methyl ester	Alkaloid			
	Benzaldehyde,3-pentachlorophenoxymethyl-4-methoxy				
	16-Heptadecenal	Fatty aldehyde			
	Octadecanoic acid, Ethyl ester	Fatty acid ester			
	n-Hexadecanoic acid	Fatty acid	Antioxidant and antibacterial activity	(Al-Wathnani et al., 2012)	
	t-Butyl cyclopentaneperoxycarboxylate	Peroxycarboxylic acid			
	1-Hexyl-2-nitrocyclohexane	C-nitro compound	Antimicrobial activity	(Devakumar et al., 2017)	
	1,11-Dibromoundecane	Organobromide			
Ethanolic extract	1,4-benzenediol,2,5,-Bis (1,1di-methylethyl)	Phenylpropane	Dermatological drug, an analgesic	(Ismail et al., 2019)	(Premjanu and Jaynthy,2014)
	Methyl 3-bromo-1-adamantaneacetate	Heterocyclic compound			
	Cyclotrisiloxane, Hexamethyl	Organosilicon compound	Antimicrobial, antioxidant, antibacterial	(Senhaji, et al., 2020)	
	Silicic acid, Diethylbis ester	Trialkylheterosilane	Antibacterial antioxidant activity	(Ilijeva and Buchbauer,2016)	
	1,2-dimethoxy-4-(1-Methoxy propenyl) Benzene	Allylbenzene	Food flavor	(Rajarajeswari et al., 2016)	
	2-[3-(4-tert-Butyl-phenoxy)-2-hydroxy-propylsulfanyl]-4,6-di-methyl-nicotinonitrile	Phenylpropane			
	3,3-Diisopropoxy-1,1,1,5,5,5-hexamethyltrisiloxane	Siloxanes			
	cis-13-octadecenol	Fatty alcohol			
	2-octyl-cis-11-hexadecenal				
	Diethyl phthalate	Phthalate ester	antimicrobial agent	(Rufino et al., 2014)	
	Bicyclo[3.1.1]heptanes,2,6,6-trimethyl-, (1 alpha,2beta,5alpha)-	Heterocyclic compound	Potential antiosteoarthritic activity	(Campos-Ordonez and Gonzalez,2016)	
	Cyclohexane	Cycloalkane	Solvent, paint remover	(Liu and Zhang,2021)	
	2-hexadecene, 3,7,11,15-tri-methyl-, [R-[R*,R*-(E)]]-	Diterpene			
	Cyclooctane	Cycloalkane	Intermediate in organic synthesis and a chemical reagent	(Santos et al., 2013)	
Ethanolic extract	Phytol	Diterpene	Antioxidant, Anticancer, Anti-Inflammatory, Anti-microbial, Antinociceptive and Diuretic	(Canlı *et al*., 2019)	(Nagmoti and Juvekar,2013)
	Acetate camphor (+)-2-bornanone	Terpenoid	Antimicrobial activity	(Aburai et al., 2007)	
	Hexadecanoic acid	Fatty acid	Anti-inflammatory, antispasmodic, anticancer and antiviral activity	(Parthipan *etal*., 2015)	
	Linoleic acid	Fatty acid	Linoleic acid	(Lydial and Abraham,2022)	
	9,12-octadecadienoic acid ethyl ester	Ethyl ester	Anticancer, Antioxidant, Antimalarial Antimicrobial, Anti-inflammatory	(Alli and Ln,2014)	
	9,17-octadecadienal, (Z)-	Unsaturated aldehyde	Antimicrobial	(Vanitha and Manikandan, 2016)	
	Ethyl 9,12,15-octadecatrienoate	Fatty acid ester	Anti-inflammatoryand Antimicrobial activities	(Butler,2008)	

When compared to normal oleanolic acid, HPLC analysis demonstrated that oleanolic acid was the major triterpenoid ingredient in the extract (Sneha *et al.,*2013). Pithedulosides A-G, a group of seven saponins, were isolated from *P. dulce* seeds. Echinocystic acid was identified as their structure using spectrum analysis. 1-O-ct-L-arabinopyranosyl-3-O-ct-L-arabinopyranosyl-3-O-ct-L-arabinopyranosyl-3 Echinocystic acid, -fl-D-glucopyranoside, and oleanolic acid 3-O—L-arabinopyranosyl-(1 2)-3-O—L-arabinopyranosyl-(1 2)-3-O—L-ara (Rao et al.,2018). ME and its fractions have been found to be more active compared to the praziquantel (PZQ), with purified chemical being identified as N-malonyl-()-tryptophan (NMT) (López-Angulo *et al.*,2021). The phytochemicals that found in fruit of *P. dulce* are categorized in table 2. Furthermore, for seeds bioactive compounds is summarized in tables 3,4.

Table 2. phytochemical analysis in dry fruits and their peels of *P. dulce* as mentioned in past references

part	Type of extraction	Dominant active compound	Classification of active compound	Therapeutic/Bioactivity	Therapeutic/Bioactivity References	Reference
Dry Fruits	Ethanolic extract	2,5,6-trimethyl1,3-oxathiane	Monothioketal	Aroma	(Chen et al., 2012)	(Jain and Rijhwani, 2018)
		trans-3-methyl-2-n-propylthiophane	Aryl-aldehyde	Aroma	(Preethi and Mary,2014)	
		2-furancarboxaldehyde 5(hydroxymethyl)	Furan	Antibacterial	(Moreno-Marthin et al., 2021)	
		D-Pinitol	Cyclitol	Antidiabetic	(Moussa et al., 2012)	
		Heptacosanoic acid	Fatty acid	Anti-fungal	Sivakumar and Subramanian, 2009)	
		Hexadecanoic acid	Fatty acid	Antibacterial	(Zibaee et al., 2023)	
		22-Tricosenoic acid	Fatty acid			
		Tetracosanol	Fatty alcohol	Antioxidant and antimutagenic activities	(Bagale et al., 2022)	
		Methyl-2-hydroxy icosanoate	Fatty methyl ester			
		Stigmasterol	Sesquiterpenoid	Antimicrobial,anticancer,diuretic,anti-inflammatory, antioxidant	(Makhafola et al., 2017)	
Fruit peel	Ethanolic extract	2-Furancarboxaldehyde, 5-Methyl	Aryl-aldehyde			(Liu et al., 2021)
		2,4-Di-hydroxy-2,5-Di-methyl-3(2H)-Furan-3-One	Ketone	Antioxidant	(Selvakumar *etal*., 2021)	
		Alpha-Hydroxyisobutyric Acid, 2TMS derivative	A-hydroxy acid			
		1,5-Anhydro-6-Deoxyhexo-2,3-Diulose	Glycoside	Preservative	(Gopalakrishnan and Udayakumar, 2014)	
		Phloroglucinol, Trimethylsilyl ether	Phenoxy compound			
		2-Pentenedioic acid, 3-Methyl, Bis(Tri-methylsilyl) ester	Trimethylsilyl ester			
		4-Methylvaleric acid, TMS derivative	Trimethylsilyl ester			
		2-Ethylhexanol, TMS derivative	Trialkylheterosilane			

D-Erythro-Pentonic acid, 2-Deoxy-3,5Bis-O-(Tri-methylsilyl), Gamma-Lactone	Gamma butyrolactone		
2-Oxooctanoic acid, TMS derivative	Fatty acid ester		
4-Bromobutanoic acid, Tetradecyl Ester	Fatty Acyl		
Pinitol	Cyclohexanol	Antidiabetic	(Parvathi et al., 2022)
Cyclohexene, 3-Benzyl-1-(Trimethylsilyloxy)			
1-Monopalmitin, 2TMS derivative	Fatty acid ester		
n-Hexadecanoic acid	Fatty acid	Antioxidant and antibacterial activity	(Sivakumar and Subramanian, 2009)
Hexadecanoic acid, Ethyl Ester	Fatty acid ester	Antimicrobial, antioxidant, and anti-cancer activities	Ganesan *etal*., 2022)
Hexadecanoic acid, Trimethylsilyl Ester	Trimethylsilyl ester		
9,12-Octadecadienoic acid	Fatty acid	Anti-inflammatory activity	(Malar *etal*, 2018)
9-Octadecenoic acid (Z)	Fatty acid	Antiandrogenic,anti-inflammatory, Dermatitigenic, Cancer preventive, 5-Alpha reductase inhibitor, Hypocholesterolemic, Anemiagenic, Insectifuge, Flavor	(Cambiaggi *etal*., 2023)
L-Rhamnose	Deoxy sugar	Anti-aging agent	(Natarajan *etal*., 2019)
9,12-Octadecadienoic acid (Z, Z), TMS derivative	Fatty acid derivative	Anti-inflammatory, cancer preventive, antiandrogenic, dermatitigenic, irritant, anti-leukotriene—D4, 5-alpha reductase inhibitor, hypocholesterolemic, insectifuge, anemiagenic, flavor	(Shin et al., 2023)
Linoelaidic acid	Fatty acid	Anti-inflammatory activity	(Malar *et al*., 2018)
Stearic acid, TMS derivative	Trimethylsilyl ester		
3-Cyclopentylpropionic acid, 2-Di-methylaminoethyl Ester	Fatty acid ester		
L-Rhamnose, 4TMS derivative		Antimicrobial agent	(Krishnamoorthy and Subramaniam, 2014)
Octadecyl trifluoroacetate	Trimethylsilyl ester		
Heneicosane	Alkane	Antimicrobial activity	(Younis and Saleh, (2021)
1-Hexacosanol, TBDMS derivative			
Celidoniol, Deoxy	N-Alkane	Antibacterial	(Vanitha *et al*., 2020)
Stigmasta-5,22-Dien-3-Ol	Steroid	Antimicrobial, antioxidant	(Bülent Köse et al., 2016)

	Stigmasterol, TMS derivative	Stigmastane	Anti-inflammatory, inhibits tumor promotion, anti-HIV reverse transcriptase	(Naik et al., 2021)
	Cis-Valerenyl acetate	sesquiterpenoid		
	Lupeol	Pentacyclic triterpenoid	Antimicrobial, antioxidant, anticancer, anti-inflammatory	(Hsu et al., 2012)

The seeds of *P. dulce* had long been utilized as medical therapy for the gastric ulcers because it contains Flavonoids, tannins, saponins, alkaloids, as well as other bio-active phytocompounds those were discovered in a variety of plant extract regions (table 3,4). Furthermore, some fatty acids are used as Anti-inflammatory like n-hexadecanoic acid:palmitic acid (Aparna et al., 2012).

Table 3. phytochemical analysis in dry seeds extracted in hexane of *P. dulce* as mentioned in past references

Type of extraction	Dominant active compound	Classification of active compound	Therapeutic/Bioactivity	Therapeutic/Bioactivity References	Reference
Hexane extract	Butylated Hydroxytoluene	Phenolic compound	Antioxidant	(Vargas et al., 2020)	(Karim *et al*., 2016)
	Hexadecenoic acid, methyl ester, (z) -	Fatty acid methyl ester	Antibacterial & antifungal	(Chandrasekaran *et al*., 2011)	
	Hexadecanoic acid, methyl ester	Fatty acid methyl ester	Antimicrobial and antioxidant	(Davoodbasha,*et al*., 2018)	
	cis-10-Heptadecenoic acid, methyl ester	Fatty acid methyl ester			
	Heptadecanoic acid, methyl ester	Fatty acid methyl ester	Mosquito repellent	(Beschi *et al*., 2021)	
	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	Fatty acid methyl ester	Antiandrogenic, anti-inflammatory, dermatitigenic, irritant, antileukotriene—D4, hypocholesterolemic, cancer preventive, 5-alpha reductase inhibitor, anemiagenic, flavor, insectifuge,	(Krishnamoorthy & Subramaniam, 2014)	
	9-Octadecenoic acid, methyl ester, (E)-	Fatty acid methyl ester	Antimicrobial activity	(Zahara *et al*., 2022)	
	Methyl stearate	Terpenoid	GABA amino-transferase inhibitor,anti-infammatory, antihelmintic, intestinal lipid metabolism regulator, antinociceptive	(Adnan *et al*., 2019)	
	Tridecanedial	Fatty aldehyde			
	Oxiraneoctanoic acid, 3-octyl-,methyl ester	Fatty acid methyl ester			
	11-Eicosenoic acid, methyl ester	Fatty acid methyl ester			
	Methyl 18-methylnonadecanoate	Fatty acid methyl ester			
	Methyl 15-hydroxy-9,12-octadecadienoate	Fatty acid methyl ester			
	Heneicosanoic acid, methyl ester	Fatty acid methyl ester			
	Phenol, 2,2'-methylenebis[6-(1,1-dimethylethyl)-4-methyl-	Phenolic compound			

	Octadecanoic acid, 2,3-dihydroxypropyl ester	Fatty acid methyl ester		
	cis-10-Nonadecenoic acid, methyl ester	Fatty acid methyl ester		
	Methyl 20-methyl-heneicosanoate	Fatty acid methyl ester		
	Tricosanoic acid, methyl ester	Fatty acid methyl ester		
	Oxiraneoctanoic acid, 3-octyl-, methyl ester	Fatty acid methyl ester	Antibacterial activity	(Hussain *et al*., 2016)
	Tetracosanoic acid, methyl ester	Fatty acid methyl ester		

Table 4. phytochemical analysis in dry seeds extracted in ethanol of *P.dulce* as mentioned in past references

Type of extraction	Dominant active compound	Classification of active compound	Therapeutic/Bioactivity	Therapeutic/Bioactivity References	Reference
Ethanolic extract	n-Tridecanoate	Saturated Fatty acid	Inhibit Escherichia coli Persistence	(Jin *et al*., 2021)	
	n-Tetradecanoate	Saturated Fatty acid	Anti-inflammatory effect	(Malar *et al*., 2018)	
	n-Hexadecanoate	Saturated Fatty acid	Anti-inflammatory compound	(Pan *et al*., 2010)	
	n-Heptadecanoate	Saturated Fatty acid			
	n-Octadecanoate	Saturated Fatty acid	Anti-inflammatory	(Parvathi *et al*., 2022)	
	n-Hxocosanoate	Saturated Fatty acid			
	Nonacosatrienoate	Saturated Fatty acid			
	Tetratriacontanoate	Saturated Fatty acid			
	n-Heptaecenoate	Unsaturated Fatty acid			
	Tridecatrienoate	Unsaturated Fatty acid			
	Methyl-2-Tridecynote	Unsaturated Fatty acid			
	Methyl tricosenoate	Unsaturated Fatty acid			
	2,4,5-Tetradecatrienoate	Unsaturated Fatty acid			
	7-Ethyl-3-Methyl-2, 6-undecadienoate	Unsaturated Fatty acid			
	Pentadecatrienoate	Unsaturated Fatty acid			
	Hexadecadienoate	Unsaturated Fatty acid			
	Heptadectrienoate	Unsaturated Fatty acid			
	Heptadecadienoate	Unsaturated Fatty acid			
	Heptadecenoate	Unsaturated Fatty acid			
	9, 12, 15, Octadecatrienoate	Unsaturated Fatty acid	Anticancer, anti-inflammatory, antioxidant, anti-obesity, neuro-protective	(Kinoshita et al., 2014)	
	10-Octadecenoate	Unsaturated Fatty acid	Anticancer agent	(Chen *et al*., 2015)	
	Eicosatrienoate	Unsaturated Fatty acid	Anti-inflammatory effect	(Khanzada *et al*., 2013)	
	Methyl-17, 18-hexacosenate	Unsaturated Fatty acid			

Physiological Effects

Megala and Devaraju (2015) Mentioned the reviewed botanical aspects, bio-active phytocompounds and pharmacological characteristics of various *Pithecellobium dulce* parts, with special emphases on nutritional status of its fruits. The various plant extract parts had been found to have anti-inflammatory, anti-microbial, anti-diabetic, cardio protective, anti-oxidant, anti-diarrheal, anti-ulcerogenic, larvicidal and ovicidal activities. IC50 values of *P. dulce* methanolic extract against the maltase and sucrase enzymes has been found to be 10.32±1.52mg/ml and 2.84±0.96mg/ml respectively. In addition to that, IC-50 values of methanolic extract of P. dulce against pancreatic α-amylase has been found to be 16.75±1.81mg/ml, (Ponmozhi et al., 2011). Thus, the enzymatic inhabition of *P.dulce* methanolic extract could be in enhanced via present oleanolic acid triterpenoid. There have been strong anti-diarrheal effects that are found in extracts of P. dulce (Kumari, 2017). The use of a castor oil-induced diarrhea model, the anti-diarrheal characteristics of the P. dulce aqueous and ethanolic leaf extracts have been researched. Based on S. Kotb *et al*. (2020), it has shown a number of the essential biological activities for the prevention of some diseases, for example anti-diabetic, anti-oxidant, anti-inflammatory, and digestive enzyme inhibition. It has shown a number of the biological activities, like anti-oxidant, anti-inflammatory, anti-diabetic, and digestive enzyme inhibitory, which are vital in disease prevention (Ponmozhi *et al*., 2011)

Through the use of this plant's lipophilic extract, possessing linoleic acid, palmitic acid methyl ester, and no cytotoxicity, this has no cytotoxicity, Explain discovered that *P.dulc* fruit peel aqueous extract has anti-diabetic action (tables 1-4). When insulin hexokinase, protein, and levels of liver glycogen were lowered. In rats, the effects of streptozotocin were reduced. As a result, they propose that extract be utilised as a hypoglycemic component. (Nagmoti *et al*., 2015)

Antioxidant Agent

Bioactive phytochemicals including phenolics, alkaloids, tannins, flavonoids, saponins, terpenoids, glycosides, and provitamins were abundant in these plants and have all showed promise as possible therapies for disorders linked to oxidative stress. (Shad et al., 2014). Numerous plant species might be capable of scavenging radicals and acting as antioxidants. Those plants' antioxidant and radical-scavenging properties were established by *P.dulce* seed extract. The seeds' aqueous as well as methanol extracts contain antioxidant and free radical scavenging qualities, according to Nagmoti *et al,* (Ponmozhi *et al*., 2011). The high phenolic content of the extract may be responsible for this activity. Unknown anthocyanins have been related to antioxidant (AOx) and glucosidase inhibitory (IG) characteristics of red arils of the *Pithecellobium dulce* fruit, which is known often as guamuchil. *P. dulce* arils could be advantageous for the treatment and prevention of the long-term degenerative conditions such as diabetes. (Lopez-Angulo *et al*., 2021). The favorable health effects that result from this plant are mainly a result of its phenolic components and anti-oxidant activities. Many authors have utilized a variety of the approaches for investigating anti-oxidant capacity and phenolic components of leaf, seed, aril, and root of the P. dulce (Vargas-Madriz *et al.,* 2020).

As a result of *P. dulce* healing properties, it has been utilized in ancient times for treatment of many different illness kinds. Toothaches, gum diseases and bleeding are treated through using pulp bark, which are hemostatic and astringent. Chronic diarrhea, constipation, tuberculosis and dysentery are all treated using bark extracts. Leaf extract is utilized for treating both closed and open wounds, dyspepsia, gall bladder issues, and spontaneous abortion prevention. Ground seed is used as an ulcer treatment. Studies have connected it to eczema, leprosy, diabetes, panophthalmitis, inflammation, cancer, tuberculosis, venereal infections, bilious disorders, cold, fever, malaria, sore throat, acne and pimples, skin pigmentation, conjunctivitis, dark spots, irritable bowel syndrome, discomfort, and inflammation. Studies have been conducted on its anti-septic, anti-bacterial, anti-hyperlipidemic, and antioxidant properties (Vargas-Madriz *et al*., 2020).

Following a 10-day oral dosage of Fruit *Pithecellobium dulce* at 40mg/kg body weight, the protective effects of Fruit *Pithecellobium dulce* against MTX-induced oxidative stress were assessed. The existence of numerous active phytocomponents was discovered during a preliminary qualitative study of FPD (Fruit *Pithecellobium dulce*). FPD's antioxidant performance was tested in vitro, and a concentration-dependent increase in antioxidant activity was discovered. The antioxidant state of possible bioactive elements can be approximated using these data from the cell-free system (Dhanisha *et al*., 2021).

Paralysis and death periods were shorter in NMT-treated parasites (5 and 7 minutes) than in PZQ-treated parasites (15 and 30 minutes), both at 20 mg/mL. Slight-hazardousness and efficacy of measured fractions/compounds were supported by toxicity and ADMET prediction results. This is the first time both *P. dulce* ME and NMT have been shown to have antiparasitic action, indicating that they could be used for treatment of human H. nana infections (López-Angulo *et al*., 2021).

Conclusion

P. dulce is one of the active principles most frequently utilized in the traditional medicine. The plant fruits are perfect for nutritional supplements since they are high in proteins, carbohydrates, fats, important vitamins, and a range of minerals. Target prediction research suggests that bioactive phytogenic may directly mediate the plant's total pharmacological effect. Future studies are needed in order to examine the combinatorial action of the bioactive ingredients and to elucidate molecular mechanisms of the extract and its bio-active molecule.

Reference

1. Abbott, R. (2011). Treating the health care crisis: complementary and alternative medicine for PPACA. *DePaul J. Health Care L.*, *14*, 35.
2. Aburai, N., Esumi, Y., Koshino, H., Nishizawa, N., & Kimura, K. I. (2007). Inhibitory activity of linoleic acid isolated from proso and Japanese millet toward histone deacetylase. Bioscience, biotechnology, and biochemistry, 71(8), 2061-2064.
3. Adnan, M., Nazim Uddin Chy, M., Mostafa Kamal, A. T. M., Azad, M. O. K., Paul, A., Uddin, S. B., & Cho, D. H. (2019). Investigation of the biological activities and characterization of bioactive constituents of Ophiorrhiza rugosa var. prostrata (D. Don) & Mondal leaves through in vivo, in vitro, and in silico approaches. Molecules, 24(7), 1367.
4. Al Bratty, M., Makeen, H. A., Alhazmi, H. A., Syame, S. M., Abdalla, A. N., Homeida, H. E.,... & Khalid, A. (2020). Phytochemical, cytotoxic, and antimicrobial evaluation of the fruits of miswak plant, Salvadora persica L. Journal of Chemistry, 2020, 1-11.
5. Alli, K. A. V. I. T. H. A., & Ln, M. (2014). Comparative evaluation of antimicrobial activities of root, stem and leaves of Holoptelea integrifolia against pathogenic bacteria. Asian Jr. Of Microbiol. Biotech. Env. Sc, 16(1), 145-154.
6. Alrawi, M.Sh. (2023). A comparative taxonomic study for mimosoideae in Baghdad Governorate. Ph.D. Dissertation. College of Science, Universityof Anbar, Iraq.p200
7. Alrawi, M. Sh, Aldubaisi I A., Almehemdi A F. 2023. Palynological Study of Mimosoideae (Fabaceae) from Baghdad (Iraq). Phytotaxa 622 (3): 191–203. DOI: https://doi.org/10.11646/phytotaxa.622.3.2
8. Alrawi, M. Sh, Aldubaisi I A., Almehemdi A F. 2023. Chemotaxonomy of Twelve Mimosoideae Species in Iraq. IOP Conf. Ser.: Earth Environ. Sci. 1252 012085. DOI 10.1088/1755-1315/1252/1/012085
9. Al-Wathnani, H., Ara, I., Tahmaz, R. R., Al-Dayel, T. H., & Bakir, M. A. (2012). Bioactivity of natural compounds isolated from cyanobacteria and green algae against human pathogenic bacteria and yeast. Journal of Medicinal Plants Research, 6(18), 3425-3433.
10. Aparna, V., Dileep, K. V., Mandal, P. K., Karthe, P., Sadasivan, C., & Haridas, M. (2012). Anti-inflammatory property of n-hexadecanoic acid: structural evidence and kinetic assessment. Chemical biology & drug design, 80(3), 434-439. DOI: 10.1111/j.1747-0285.2012.01418.x
11. Bagale, R., Acharya, S., Gupta, A., Chaudhary, P., Chaudhary, G. P., & Pandey, J. (2022). Antibacterial and antioxidant activities of Prinsepia utilis royle leaf and seed extracts. Journal of Tropical Medicine, 2022.
12. Bakun, P., Czarczynska-Goslinska, B., Goslinski, T., & Lijewski, S. (2021). In vitro and in vivo biological activities of azulene derivatives with potential applications in medicine. Medicinal Chemistry Research, 30, 834-846.
13. Beschi, D. A., Appavoo, M. R., & Wilsy, J. I. (2021). GC-MS analysis, collected from kavalkinaru area, Tirunelveli district, Tamil nadu, India. Eur. J. Mol. Clin. Med, 7, 4287-4292.
14. Bobade, A. F. (2019). GC-MS Analysis of bioactive compound in ethanolic extract of *Pithecellobium dulce* leaves. American Society of Plastic Surgeons, 3, 8-13.
15. Bülent Köse, Y., Iscan, G., & Demirci, B. (2016). Antimicrobial activity of the essential oils obtained from flowering aerial parts of Centaurea lycopifolia Boiss. et Kotschy and Centaurea cheirolopha (Fenzl) Wagenitz from Turkey. Journal of Essential Oil-Bearing Plants, 19(3), 762-768.
16. Butler, M. S. (2008). Natural products to drugs: natural product-derived compounds in clinical trials. Natural product reports, 25(3), 475-516.
17. Cambiaggi, L., Chakravarty, A., Noureddine, N., & Hersberger, M. (2023). The Role of α-Linolenic Acid and Its Oxylipins in Human Cardiovascular Diseases. International Journal of Molecular Sciences, 24(7), 6110.
18. Campos-Ordonez, T., & Gonzalez-Perez, O. (2016). Cyclohexane, a potential drug of abuse with pernicious effects on the brain. Frontiers in Pharmacology, 6, 291.
19. Canlı, K., Yetgin, A., Benek, A., Bozyel, M. E., & Murat Altuner, E. (2019). In vitro antimicrobial activity screening of ethanol extract of Lavandula stoechas and investigation of its biochemical composition. Advances in Pharmacological and Pharmaceutical Sciences, 2019.

20. Chandrasekaran, M., Senthilkumar, A., & Venkatesalu, V. (2011). Antibacterial and antifungal efficacy of fatty acid methyl esters from the leaves of Sesuvium portulacastrum L. European Review for Medical & Pharmacological Sciences, 15(7).
21. Chen, S. J., Chuang, L. T., & Chen, S. N. (2015). Incorporation of eicosatrienoic acid exerts mild anti-inflammatory properties in murine RAW264. 7 cells. Inflammation, 38, 534-545.
22. Chen, X., Zhao, X., Deng, Y., Bu, X., Ye, H., & Guo, N. (2019). Antimicrobial potential of myristic acid against Listeria monocytogenes in milk. The Journal of Antibiotics, 72(5), 298-305.
23. Chen, Z., Dewis, M. L., & Merritt, D. (2012). Novel 1,3-oxathiane compounds and their use in flavor and fragrance compositions., United states patent publication, US20120183490A1.
24. Chen, Z., Liu, Q., Zhao, Z., Bai, B., Sun, Z., Cai, L., & Xi, G. (2021). Effect of hydroxyl on antioxidant properties of 2, 3-dihydro-3, 5-dihydroxy-6-methyl-4 H-pyran-4-one to scavenge free radicals. RSC advances, 11(55), 34456-34461.
25. Davoodbasha, M., Edachery, B., Nooruddin, T., Lee, S. Y., & Kim, J. W. (2018). An evidence of C16 fatty acid methyl esters extracted from microalga for effective antimicrobial and antioxidant property. Microbial Pathogenesis, 115, 233-238.
26. de Souza, M. A., Pereira-de-Morais, L., Silveira, Z. D. S., Macêdo, N. S., Araujo, I. M., Neto, L. J. D. L., & da Cunha, F. A. B. (2021). Toxicity of methyl eugenol against Drosophila melanogaster and its myorelaxant activity in bronchioles isolated from Sus scrofa domesticus. Biologia, 76(4), 1275-1283.
27. Devakumar, J., Keerthana, V. S. S. S., & Sudha, S. S. (2017). Identification of bioactive compounds by gas chromatography-mass spectrometry analysis of Syzygium jambos (L.) collected from Western Ghats region Coimbatore, Tamil Nadu. Asian J. Pharm. Clin. Res, 10(1), 364-369.
28. Dhanisha, S. S., Drishya, S., & Guruvayoorappan, C. (2021). Traditional knowledge to clinical trials: A review on nutritional and therapeutic potential of *Pithecellobium dulce*. Journal of Basic and Clinical Physiology and Pharmacology, 33(2), 133-142.
29. Fabricant, D. S., & Farnsworth, N. R. (2001). The value of plants used in traditional medicine for drug discovery. Environmental health perspectives, 109(suppl 1), 69-75.
30. Farnsworth, N. R., & Soejarto, D. D. (1991). Global importance of medicinal plants. The conservation of medicinal plants, 26(26), 25-51.
31. Galm, U., & Shen, B. (2007). Natural product drug discovery: The times have never been better. Chemistry & biology, 14(10), 1098-1104.
32. Ganesan, T., Subban, M., Christopher Leslee, D. B., Kuppannan, S. B., & Seedevi, P. (2022). Structural characterization of n-hexadecanoic acid from the leaves of Ipomoea eriocarpa and its antioxidant and antibacterial activities. Biomass Conversion and Biorefinery, 1-12.
33. Gong, Y., Qiu, J., Jiang, T., Li, Z., Zhang, W., Zheng, X., & Hong, Z. (2023). Maltol ameliorates intervertebral disc degeneration through inhibiting PI3K/AKT/NF-κB pathway and regulating NLRP3 inflammasome-mediated pyroptosis. Inflammopharmacology, 31(1), 369-384.
34. Gopalakrishnan, K., & Udayakumar, R. (2014). GC-MS Analysis of Phytocompounds of Leaf and Stem of Marsilea quadrifolia (L.). International Journal of Biochemistry Research & Review 4(6):517-526. DOI:10.9734/IJBCRR/2014/11350
35. Holmes, F. A., Walters, R. S., Theriault, R. L., Buzdar, A. U., Frye, D. K., Hortobagyi, G. N., & Raber, M. N. (1991). Phase II trial of taxol, an active drug in the treatment of metastatic breast cancer. JNCI: Journal of the National Cancer Institute, 83(24), 1797-1805.
36. Holmes, F. A., Walters, R. S., Theriault, R. L., Buzdar, A. U., Frye, D. K., Hortobagyi, G. N., & Raber, M. N. (1991). Phase II trial of taxol, an active drug in the treatment of metastatic breast cancer. JNCI: Journal of the National Cancer Institute, 83(24), 1797-1805.
37. Hossain, M. M., Yuan, Y., Huang, H., Wang, Z., Baki, M. A., Dai, Z., & Tu, S. (2021). Exposure to dodecamethylcyclohexasiloxane (D6) affects the antioxidant response and gene expression of Procambarus clarkii. Sustainability, 13(6), 3495.
38. Hsu, F.-L., Huang, W.-J., Wu, T.-H., Lee, M.-H., Chen, L.-C., Lu, H.-J., Hou, W.-C., & Lin, M.-H. (2012). Evaluation of Antioxidant and Free Radical Scavenging Capacities of Polyphenolics from Pods of Caesalpinia pulcherrima. Int J Mol Sci. 2012;13(5):6073-6088. doi: 10.3390/ijms13056073.
39. Hussein, H. J., Hadi, M. Y., & Hameed, I. H. (2016). Study of chemical composition of Foeniculum vulgare using Fourier transform infrared spectrophotometer and gas chromatography-mass spectrometry. Journal of Pharmacognosy and Phytotherapy, 8(3), 60-89.
40. Ilijeva, R., & Buchbauer, G. (2016). Biological properties of some volatile phenylpropanoids. Natural Product Communications, 11(10), 1934578X1601101041.
41. Ismail, G. A., Gheda, S. F., Abo-shady, A. M., & Abdel-karim, O. H. (2019). In vitro potential activity of some seaweeds as antioxidants and inhibitors of diabetic enzymes. Food Science and Technology, 40, 681-691.

42. Ismail, O. M., Abdel-Aziz, M. S., Ghareeb, M. A., & Hassan, R. Y. (2017). Exploring the biological activities of the Hylocereus polyrhizus extract. Journal of Innovations in Pharmaceutical and Biological Sciences, 4(1), 1-6.
43. Jain, P. K., & Rijhwani, S. (2018). Comparative GC-MS analysis of Cyamopsis tetragonoloba fruit extracts. International Journal of Pharmaceutical Sciences and Research, 9(10), 4236-4242.
44. Janani, A. M., Annapandian, V. M., Natarajan, P., & Mumthaj. P. (2022). Phytochemical screening, GC-MS and FTIR Analysis of Petroleum ether extract of *Pithecellobium dulce* (Roxb.) Benth.. International Journal of Novel Research and Development, 7(4), 764-772.
45. Jin, X., Zhou, J., Richey, G., Wang, M., Hong, S., & Hong, S. H. (2021). Undecanoic Acid, Lauric Acid, and N-Tridecanoic Acid Inhibit Escherichia coli Persistence and Biofilm Formation.
46. Johnston, C. S., Monte, W. C., Bolton, R. S., & Chard, M. H. (1994). A comparison of L-ascorbic acid and L-ascorbyl 6-palmitate utilization in Guinea Pigs and humans. Nutrition research, 14(10), 1465-1471.
47. Kadhim, M. J., Sosa, A. A., & Hameed, I. H. (2016). Evaluation of anti-bacterial activity and bioactive chemical analysis of Ocimum basilicum using Fourier transform infrared (FT-IR) and gas chromatography-mass spectrometry (GC-MS) techniques. Journal of pharmacognosy and phytotherapy, 8(6), 127-146.
48. Karim, A., El-Rahman, F., & Ahmed, W. (2016). GC-MS Analysis and Antimicrobial Activity of Sudanese *Pithecellobium dulce* (Roxb.) Benth Fixed Oil. International Journal of Scientific Engineering and Applied Science, 2(10), 1-9.
49. Katekhaye, D.S. and S. Laddha, K. Prenylated Flavonoids from Bark of Pithecellobium dulce. The Natural Products Journal 4(1): 43-46.
50. Khanzada, S. K., Khanzada, A. K., Shaikh, W., & Ali, S. A. (2013). Phytochemical studies on *Pithecellobium dulce* Benth. A medicinal plant of Sindh, Pakistan. Pak. J. Bot, 45(2), 557-561.
51. Kinoshita, Y., Yoshizawa, K., Hamazaki, K., Emoto, Y., Yuri, T., Yuki, M.,... & Tsubura, A. (2014). Mead acid inhibits the growth of KPL-1 human breast cancer cells in vitro and in vivo. Oncology Reports, 32(4), 1385-1394.
52. Korsak, Z. O. F. I. A., Swiercz, R., & Rydzynski, K. (1995). Toxic effects of acute inhalation exposure to 1, 2, 4-trimethylbenzene (pseudocumene) in experimental animals. International Journal of Occupational Medicine and Environmental Health, 8(4), 331-337.
53. Krishnamoorthy, K., & Subramaniam, P. (2014). Phytochemical profiling of leaf, stem, and tuber parts of Solena amplexicaulis (Lam.) Gandhi using GC-MS. International scholarly research notices, 2014.
54. Kumari, S. (2017). Evaluation of phytochemical analysis and antioxidant and antifungal activity of *Pithecellobium dulce* leaves' extract. Asian Journal of Pharmaceutical and Clinical Research, 370-375.
55. Liu, J. B., & Zhang, T. (2021). Molecular Descriptors and Topological Analysis of Cyclooctane Derivatives. Authorea Preprints. DOI:10.22541/au.163957475.58253124/v1
56. Liu, K., Zhang, X., Xie, L., Deng, M., Chen, H., Song, J.,... & Luo, J. (2021). Lupeol and its derivatives as anticancer and anti-inflammatory agents: Molecular mechanisms and therapeutic efficacy. Pharmacological research, 164, 105373.
57. López-Angulo, G., Verdugo-Gaxiola, S. E., Montes-Avila, J., Díaz-Camacho, S. P., Miranda-Soto, V., Salazar-Salas, N. Y., & Delgado-Vargas, F. (2021). Bioguided isolation of N-malonyl-(+)-tryptophan from the fruit of *Pithecellobium dulce* (Roxb.) Benth. that showed high activity against Hymenolepis nana. Natural Product Research, 35(4), 593-599.
58. Lydial, P. G. G., & Abraham, G. C. (2022). Phytochemical screening and GC-MS analysis of bioactive compounds in Caesalpinia bonduc L. from Alagarkovil Reserve Forest (ARF), Dindigul District, South India. Journal of Drug Delivery and Therapeutics, 12(4-S), 43-52.
59. Makhafola, T. J., Elgorashi, E. E., McGaw, L. J., Awouafack, M. D., Verschaeve, L., & Eloff, J. N. (2017). Isolation and characterization of the compounds responsible for the antimutagenic activity of Combretum microphyllum (Combretaceae) leaf extracts. BMC complementary and alternative medicine, 17, 1-8.
60. Malar, J., Vanmathi, J., & Chairman, K. (2018). Phytochemical Analysis of Lepidium sativum using UV-VIS and GC-MS. Int. J. Adv. Res, 6(9), 813-825.
61. Megala, J., & Devaraju, P. (2015). *Pithecellobium dulce* fruit extract exerts antiulcerogenic effect by influencing the gastric expression of H+, K+-ATPase and mucosal glycoproteins. Journal of Young pharmacists, 7(4s), 493.
62. Mohammed, G. J., Al-Jassani, M. J., & Hameed, I. H. (2016). Antibacterial, Antifungal Activity and Chemical analysis of Punica grantanum (Pomegranate peel) using GCMS and FTIR spectroscopy. International Journal of Pharmacognosy and Phytochemical Research, 8(3), 480-494.
63. Moreno-Martin, G., Sanz-Landaluze, J., León-González, M. E., & Madrid, Y. (2021). In vivo quantification of volatile organoselenium compounds released by bacteria exposed to selenium with HS-SPME-GC-MS. Effect of selenite and selenium nanoparticles. Talanta, 224, 121907.

64. Moussa, A., Noureddine, D., Saad, A., Abdelmelek, M., & Abdelkader, B. (2012). Antifungal activity of four honeys of different types from Algeria against pathogenic yeast: Candida albicans and Rhodotorula sp. Asian Pacific journal of tropical biomedicine, 2(7), 554-557.
65. Murugesan, S., Lakshmanan, D. K., Arumugam, V., & Alexander, R. A. (2019). Nutritional and therapeutic benefits of medicinal plant *Pithecellobium dulce* (Fabaceae): A review. Journal of Applied Pharmaceutical Science, 9(7), 130-139.
66. Nagmoti, D. M., & Juvekar, A. R. (2013). In vitro inhibitory effects of *Pithecellobium dulce* (Roxb.) Benth. seeds on intestinal α-glucosidase and pancreatic α-amylase. Journal of Biochemical Technology, 4(3), 616-621.
67. Nagmoti, D. M., Kothavade, P. S., Bulani, V. D., Gawali, N. B., & Juvekar, A. R. (2015). Antidiabetic and antihyperlipidemic activity of *Pithecellobium dulce* (Roxb.) Benth seeds extract in streptozotocin-induced diabetic rats. European Journal of Integrative Medicine, 7(3), 263-273.
68. Naik, B., Maurya, V. K., Kumar, V., Kumar, V., Upadhyay, S., & Gupta, S. (2021). Phytochemical analysis of Diplazium esculentum reveals the presence of medically important components. Current Nutrition & Food Science, 17(2), 210-215.
69. Natarajan, P., Singh, S., & Balamurugan, K. (2019). Gas Chromatography-Mass Spectrometry (GC-MS) Analysis of Bio Active Compounds Presents in Oeophylla smaragdina. Research Journal of Pharmacy and Technology, 12(6), 2736-2741.
70. Nupur, Tanuku, N. R. S., Shinichi, T., & Pinnaka, A. K. (2015). Phaeobacterium nitratireducens gen. nov., sp. nov., a phototrophic gammaproteobacterium isolated from a mangrove forest sediment sample. International Journal of Systematic and Evolutionary Microbiology, 65(Pt_8), 2357-2364.
71. Pan, P. H., Lin, S. Y., Ou, Y. C., Chen, W. Y., Chuang, Y. H., Yen, Y. J.,... & Chen, C. J. (2010). Stearic acid attenuates cholestasis-induced liver injury. Biochemical and biophysical research communications, 391(3), 1537-1542.
72. Pan, R. Y., Kong, X. X., Cheng, Y., Du, L., Wang, Z. C., Yuan, C.,... & Liao, Y. J. (2021). 1, 2, 4-Trimethoxybenzene selectively inhibits NLRP3 inflammasome activation and attenuates experimental autoimmune encephalomyelitis. Acta Pharmacologica Sinica, 42(11), 1769-1779.
73. Parthipan, B., Suky, M. G. T., & Mohan, V. R. (2015). GC-MS analysis of phytocomponents in *Pleiospermium alatum* (Wall. ex Wight & Arn.) Swingle, (Rutaceae). Journal of Pharmacognosy and Phytochemistry, 4(1), 216-222.
74. Parvathi, K., Kandeepan, C., Sabitha, M., Senthilkumar, N., Ramya, S., Boopathi, N. M.,... & Jayakumararaj, R. (2022). In-silico Absorption, Distribution, Metabolism, Elimination and Toxicity profile of 9, 12, 15-Octadecatrienoic acid (ODA) from Moringa oleifera. Journal of Drug Delivery and Therapeutics, 12(2-S), 142-150.
75. Ponmozhi, P., Geetha, M., Kumar, S. M., & Devi, S. P. (2011). Extraction of anthocyanin and analyzing its antioxidant properties from *Pithecellobium dulce* fruit pericarp. Asian Journal of Pharmaceutical and Clinical Research, 4(1), 41-45.
76. Ponmozhi, P., Geetha, M., Kumar, S. M., & Devi, S. P. (2011). Extraction of anthocyanin and analysing its antioxidant properties from *Pithecellobium dulce* fruit pericarp. Asian Journal of Pharmaceutical and Clinical Research, 4(1), 41-45.
77. Poongodi, T., & Hemalatha, R. (2015). In vitro cytotoxicity, phytochemistry and GC-MS analysis of *Pithecellobium dulce* leaves. World Journal of Pharmacy and Pharmaceutical Sciences (WJPPS), 4(4), 1266-1276.
78. Pradeesh, G., Suresh, J., Suresh, H., Ramani, A., & Hong, I. (2017). Antimicrobial activity and identification of potential compounds from the chloroform extract of the medicinal plant Cyathea nilgirensis Holttum. World J Pharm Pharm Sci, 6(7), 1167-1184.
79. Preethi, S., & Mary Saral, A. (2014). GC-MS Analysis of Microwave Assisted Ethanolic Extract of *Pithecellobium dulce*. Malaya Journal of Biosciences, 1(4), 242-247.
80. Premjanu, N., & Jaynthy, C. (2014). Antimicrobial activity of diethyl phthalate: An in-silico approach. Asian J Pharm Clin Res, 7(4), 141-142.
81. Rajarajeswari, B., Kumar, B. P., & Audipudi, A. V. (2016). GC-MS Analysis and Wound Healing Efficiency of Ethanolic Leaves Extract of *Cassia occidentalis* and *Pithecellobium dulce* in Wistar Albino Rats: Comparative Study. Methodology.
82. Rao, B. G., Samyuktha, P., Ramadevi, D., & Battu, H. (2018). Review of literature: phyto pharmacological studies on *Pithecellobium dulce*. J Glob Trends Pharm Sci, 9, 4797-4807.
83. Rishnamoorthy, K., & Subramaniam, P. (2014). Phytochemical profiling of leaf, stem, and tuber parts of Solena amplexicaulis (Lam.) Gandhi using GC-MS. International scholarly research notices, 2014.
84. Rufino, A. T., Ribeiro, M., Judas, F., Salgueiro, L., Lopes, M. C., Cavaleiro, C., & Mendes, A. F. (2014). Anti-inflammatory and chondroprotective activity of (+)-α-pinene: structural and enantiomeric selectivity. Journal of natural products, 77(2), 264-269.

85. Saeed Kotb, S., Ayoub, I. M., El-Moghazy, S. A., & Singab, A. N. B. (2020). Profiling the lipophilic fractions of *Pithecellobium dulce* bark and leaves using GC/MS and evaluation of their antioxidant, antimicrobial and cytotoxic activities. Chemistry & Biodiversity, 17(7), e2000048.
86. Santos, C. C. D. M. P., Salvadori, M. S., Mota, V. G., Costa, L. M., de Almeida, A. A. C., de Oliveira, G. A. L.,... & de Almeida, R. N. (2013). Antinociceptive and antioxidant activities of phytol in vivo and in vitro models. Neuroscience Journal, 2013.
87. Selvakumar, M., Palanichamy, P., Arumugam, V., Venkatesan, M., Aathmanathan, S., Krishnamoorthy, H., & Pugazhendhi, A. (2021). In silico potential of nutraceutical plant of *Pithecellobium dulce* against GRP78 target protein for breast cancer. Applied Nanoscience, 1-13.
88. Senhaji, S., Lamchouri, F., & Toufik, H. (2020). Phytochemical content, antibacterial and antioxidant potential of endemic plant Anabasis aretioïdes coss. & moq. (Chenopodiaceae). BioMed research international, 2020.
89. Severyanova, L. A., Lazarenko, V. A., Plotnikov, D. V., Dolgintsev, M. E., & Kriukov, A. A. (2019). L-lysine as the molecule influencing selective brain activity in pain-induced behavior of rats. International Journal of Molecular Sciences, 20(8), 1899.
90. Shad, A. A., Ahmad, S., Ullah, R., AbdEl-Salam, N. M., Fouad, H., Rehman, N. U.,... & Saeed, W. (2014). Phytochemical and biological activities of four wild medicinal plants. The Scientific World Journal, 2014.
91. Shin, S. H., Lee, Y. H., Rho, N. K., & Park, K. Y. (2023). Skin aging from mechanisms to interventions: focusing on dermal aging. Frontiers in Physiology, 14, 1195272.
92. Sivakumar, S., & Subramanian, S. P. (2009). Pancreatic tissue protective nature of D-Pinitol studied in streptozotocin-mediated oxidative stress in experimental diabetic rats. European Journal of Pharmacology, 622(1-3), 65-70.
93. Sivakumar, S., & Subramanian, S. P. (2009). Pancreatic tissue protective nature of D-Pinitol studied in streptozotocin-mediated oxidative stress in experimental diabetic rats. European Journal of Pharmacology, 622(1-3), 65-70.
94. Sjögren, J., Magnusson, J., Broberg, A., Schnürer, J., & Kenne, L. (2003). Antifungal 3-hydroxy fatty acids from Lactobacillus plantarum MiLAB 14. Applied and environmental microbiology, 69(12), 7554-7557.
95. Sneha, D., Prashanth, S., Kaveti, VS. (2020). Systematic Review of *Pithecellobium Dulce* (Roxb.) Benth.: A Traditional Medicinal Herb. Journal for Innovative Development in Pharmaceutical and Technical Science 3(5):1-9.
96. Takala, R., Ramji, D. P., Andrews, R., Zhou, Y., Farhat, M., Elmajee, M.,... & Choy, E. (2022). Pinolenic acid exhibits anti-inflammatory and anti-atherogenic effects in peripheral blood-derived monocytes from patients with rheumatoid arthritis. Scientific reports, 12(1), 8807.
97. Takiguchi, Y. O., Mishima, H., Okuda, M., Terao, M., Aoki, A., & Fukuda, R. (1980). Milbemycins, a new family of macrolide antibiotics: fermentation, isolation and physico-chemical properties. The Journal of antibiotics, 33(10), 1120-1127.
98. Vanitha, V., & Manikandan, K. (2016). Bio-activity guided determination of active compounds in the leaves of *Pithecellobium dulce*. Rasayan J Chem, 9, 471-477.
99. Vanitha, V., Vijayakumar, S., Nilavukkarasi, M., Punitha, V. N., Vidhya, E., & Praseetha, P. K. (2020). Heneicosane—A novel microbicidal bioactive alkane identified from Plumbago zeylanica L. Industrial Crops and Products, 154, 112748.
100. Vargas-Madriz, Á. F., Kuri-García, A., Vargas-Madriz, H., Chávez-Servín, J. L., Ferriz-Martínez, R. A., Hernández-Sandoval, L. G., & Guzmán-Maldonado, S. H. (2020). Phenolic profile and antioxidant capacity of *Pithecellobium dulce* (Roxb) Benth: a review. Journal of Food Science and Technology, 57, 4316-4336.
101. Wani, M. C., & Horwitz, S. B. (2014). Nature as a Remarkable Chemist: A personal story of the discovery and development of Taxol®. Anti-cancer drugs, 25(5), 482.
102. Younis, A., & Saleh, H. (2021). Phytochemical screening and assessment of antioxidant and antimicrobial potentialities of two Egyptian medicinal plants. Egyptian Journal of Pure and Applied Science, 59(1), 49-57.
103. Zahara, K., Bibi, Y., Arshad, M., Kaukab, G., Al Ayoubi, S., & Qayyum, A. (2022). In-vitro examination and isolation of antidiarrheal compounds using five bacterial strains from invasive species Bidens bipinnata L. Saudi Journal of Biological Sciences, 29(1), 472-479.
104. Zibaee, E., Javadi, B., Sobhani, Z., Akaberi, M., Farhadi, F., Amiri, M. S.,... & Emami, S. A. (2023). Cassia species: A review of traditional uses, phytochemistry and pharmacology. Pharmacological Research-Modern Chinese Medicine, 9(1):100325. https://doi.org/10.1016/j.prmcm.2023.100325.