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Fieldwork and literature review to identify fruits with antidiabetic properties in the Jaffna District, Sri Lanka

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ABSTRACT

Introduction: Antidiabetic medications are often associated with side effects such as mood changes, dizziness, and breathing difficulties. Studies have suggested that fruit consumption may contribute to the prevention and management of diabetes. This study aimed to document the fruits sold in the Jaffna District, Sri Lanka, through fieldwork conducted at markets, fruit kiosks, shops, superstores, and street vendors and, to determine the antidiabetic potential of the identified fruits.

Methods: To conduct this study, researchers visited key markets and local kiosks at least three times to document the presence of fruits, identify different species, and observe how they are used in local diets. The antidiabetic potential of the identified fruits was assessed by reviewing scientific evidence from published studies in electronic databases, including Web of Science, PubMed, Scopus, and ScienceDirect, up to September 2023.

Results: A total of 103 fruit species belonging to 43 families were identified, 9% of which are utilized in antidiabetic preparations in Sri Lankan Siddha Medicine. Among the identified fruits, 52% demonstrated in vivo evidence, 22% were supported by in vitro studies, and 20% had clinical evidence. Additionally, 22 active compounds were isolated from these fruits.

Conclusion: This study serves as a valuable resource for future research on the antidiabetic potential of fruits in the Jaffna District. Further investigations are needed to fully explore their therapeutic applications in diabetes management.

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Intorduction

In 2021, roughly 537 million people between the ages of 20 and 79 were living with diabetes. This number is expected to rise to 700 million by 2045. The majority (90%) of the people have type 2 diabetes, while 10% have type 1 diabetes (International Diabetes Federation, 2023). Furthermore, approximately 79% have diabetes reside in low-income and middle-income nations. One in five adults (above 65 years) have diabetes in the world. Unfortunately, around 232 million people (half of those with diabetes) are undiagnosed. This can lead to serious complications, such as cardiovascular diseases, nerve damage, and kidney failure (World Health Organization, 2023). So far, 4.2 million people have died from diabetes, and diabetes causes 1.6 million deaths each year. In addition, at the minimum of 760 billion US dollars spent for diabetes in 2019. It was nearly 10% of the total adult healthcare expenditure (International Diabetes Federation, 2023). Approximately 1.1 million children are diagnosed with type 1 diabetes in the world. In addition, one in six live births (20 million) is affected by gestational diabetes. Interestingly, 374 million people are at risk of getting type 2 diabetes (World Health Organization, 2023).

Increased blood glucose concentration in the body is called diabetes, and it is a metabolic and chronic illness. Diabetes leads to complications of kidney failure, stroke, blindness, heart attack, amputation, etc. (World Health Organization, 2023). Also, the three types of diabetes are type 1 diabetes, type 2 diabetes, and gestational diabetes. Risk factors for diabetes include obesity, physical inactivity, poor diet, and a family history of the disease (European Association for the Study of Diabetes, 2023). Some behaviors like obesity, overweight, unhealthy food, and physical inactivity can increase the risk factors. Anyhow, taking key actions such as healthy eating, avoiding unnecessary weight gain, being physically dynamic, monitoring glucose concentrations, and following medical advice could reduce the risks of getting diabetes (Mayo Foundation for Medical Education and Research, 2023). Type 1 diabetes is managed by injecting insulin into the body. Type 2 diabetes is managed by taking the medications like Metformin and Sulfonylureas (Glibenclamide, Gliclazide, Glimepiride, Glipizide, and Tolbutamide) (International Diabetes Federation, 2023). These medications cause common side effects including a metallic taste, constipation, dark urine, diarrhea, easy bleeding, fever, headache, sore throat, itching, swelling, loss of appetite, mood changes, nausea, rash, yellowing eyes, seizures, weakness, severe dizziness, stomach pain, stomach upset, hands swelling, feet swelling, trouble breathing, unusual tiredness, weight gain, vomiting, weight gain, and yellowing skin (American Diabetes Association, 2023; WebMD LLC, 2023).

Given these concerning global statistics, it is critical to explore alternative, low-cost, and accessible treatments. One promising area of research is the potential role of fruits, which have shown promise in managing blood sugar levels. Fruit consumption showed prevention and management of diabetes in researches (Feskens et al., 1995; Van Dam et al., 2002). Several research articles were published regarding the antidiabetic activities of various fruits. For example, Intake of fruit juice and incidence of type 2 diabetes: A systematic review and meta-analysis, Potential health benefits of fruits and vegetables: Epic inspite glycemia Food groups in dietary prevention of type 2 diabetes, Fruit and vegetable intake and incidence of type 2 diabetes mellitus: Systematic review and meta-analysis, Prevention of metabolic disorders: Fruits (including fruit sugars) vs. vegetables (Carter et al., 2010; Kuzma et al., 2017; Xi et al., 2014). Polyphenols found in fruits are antioxidants that have defensive properties (Anderson et al., 2004). Fruits such as berries, apples, and citrus are rich in polyphenols and fiber, which have been shown to improve insulin sensitivity and reduce blood sugar levels. Fruits have insulin-like and enhancing insulin secretion effects (Survay et al., 2010; Wedick et al., 2012). Polyphenols in fruits may help manage diabetes by improving insulin sensitivity, inhibiting carbohydrate-digesting enzymes like α-amylase and α-glucosidase, and reducing oxidative stress. These compounds have shown promise in regulating postprandial blood sugar levels, making them key targets for future diabetes treatments.

As mentioned before, biomedicine medications and treatments cause adverse side effects, and they are expensive. Therefore, it is essential to identify natural and cost-effective treatments that can be used to manage diabetes. Hence, this research is crucial because, while numerous studies have explored the antidiabetic potential of fruits globally, few have focused on the fruits widely available in Sri Lanka, particularly in the Jaffna District. Understanding these local fruits could offer an affordable and accessible solution for diabetes management. It assesses the levels of scientific antidiabetic evidence available for the documented fruits. This work benefits the public to manage or prevent diabetes naturally and economically by consuming fruits with antidiabetic properties. Moreover, it is useful for the researchers to study the possible fruits to identify potential antidiabetic active extracts and compounds. These compounds may serve as potential candidates for the development of future antidiabetic drugs.

Materials and methods

The Study Region

This study was performed in the Jaffna District in the Northern Province of Sri Lanka (Figure 1). Jaffna District has a 1,025 km² area and had a population of 624,179 in 2017. The majority of the population is Sri Lankan Tamil, and the Tamil language is mostly spoken in the study region (Annual Performance and Accounts Report - Jaffna District, 2017).

Data Collection

This study was conducted from January 2019 to June 2023. Field visits were conducted at least three times to key markets and local kiosks to document the availability of fruits, identify species, and observe their use in local diets. This process helped ensure that only widely available fruits were included in the study. The authors spent at least two hours in each visit to each market and the surrounding areas.

The Jaffna District, located in the northern part of Sri Lanka, is characterized by its tropical climate and diverse agricultural practices. This area is home to a variety of fruits that may possess untapped potential for managing diabetes, making it an ideal location for this study. The main markets in the Jaffna district visited and the latitudes and longitudes of each location are given below:

1. Jaffna Town Market (09°39’55.53” N, 80°00’31.12” E)
2. Thirunelveli Market (09°41’19” N, 80°01’40.8” E)
3. Chavakachcheri Market (09°39’32.32” N, 80°09’44.11” E)
4. Kodikamam Market (09°40’57.04” N, 80°13’15.79” E)
5. Point Pedro Market (09°49’29.75” N, 80°14’10.68” E)
6. Nelliyadi Market (09°48’00.75” N, 80°11’59.96” E)
7. Pandatharippu Market (09°46’23.89” N, 79°58’16.45” E)
8. Maruthanarmadam Market (09°43’46.37” N, 80°01’22.41” E)
9. Velanai Market (09°37’52.25” N, 79°53’46.73” E)
10. Sankanai Market (09°44’55.52” N, 79°58’13.03” E)

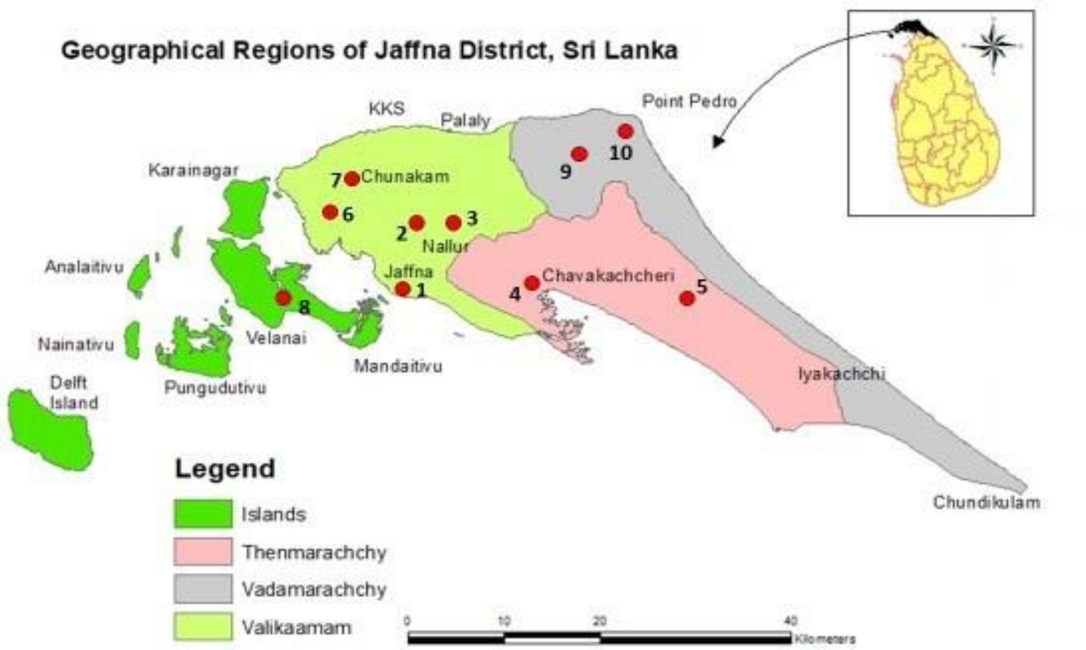

Figure 1: The study region and the fieldworks carried out main markets based on Survey Department of Sri Lanka (2014).

Fruit Identification

All the fruits available for sale at each location were identified and confirmed by Dr. Pholtan Rajamanoharan (Provincial Herbal Garden Management Center, Trincomalee 31000, Sri Lanka).

Voucher Specimens

Voucher specimens of the identified fruit species locally available were collected in the Jaffna District from January 2019 to June 2023. Dr. Fultaan Rajamanoharan, a botanist with over 20 years of experience in plant taxonomy, confirmed the botanical identification of each species. This ensured that the species included in the study were accurately classified. Plant specimens were carefully preserved in the herbarium, with each sample stored in silica gel to prevent degradation. These samples are available for further study and verification at the Provincial Herbal Garden in Trincomalee. All the scientific names and families of the identified fruit plant species were validated using Kew Science (2024) and Global Biodiversity Information Facility (2024).

Data Analysis

Data were analyzed using a combination of qualitative and quantitative methods, comparing the identified species with existing databases such as the Kew Science database and published literature. Statistical analyses were conducted to identify significant patterns in the occurrence and medicinal properties of the plants. A record that includes the scientific name, family, Tamil name, and herbarium voucher specimen number (if applicable) of all the identified and confirmed fruit species in the fieldwork was created. Then they were compared with the fruits used to treat diabetes in Sri Lankan Siddha Medicine using previously published articles. For example, (Vivekanandarajah and Jeyaseelan 2020; Vivekanandarajah and Rajamanoharan 2021; Vivekanandarajah et al., 2015, 2016, 2017, 2018; Vivekanandarajah, 2021, 2021a, 2021b (Part 1, 2, 3), 2021c), and Rajamanoharan (2014; 2016). Other ethnobotanical uses analysis was performed using the published works in Sri Lanka. For example, Jayaweera (1980; 1981; 1982). In addition, the electronic databases namely, Web of Science, PubMed, Scopus, SpringerLink, ScienceDirect, Wiley Online Library, Taylor & Francis Online, Mary Ann Liebert Inc. Publishers, Wolters Kluwer Medknow Publications, Thieme Medical Publishers, Hindawi Limited, Directory of Open Access Journals (DOAJ), Multidisciplinary Digital Publishing Institute (MDPI), Walter de Gruyter GmbH, BioMed Central Ltd., SAGE Publishing, JSTOR, Public Library of Science (PLOS), and Frontiers Media S.A. were used to identify the published relevant articles until September 2023. Plant species mentioned in American Herbal Pharmacopoeia-Verified Botanical Reference Materials (2023), American Herbal Pharmacopoeia: Botanical Pharmacognosy-Microscopic Characterization of Botanical Medicines (2016), European Medicines Agency's Committee on Herbal Medicinal Products (2023), World Health Organization (WHO) Monographs on Selected Medicinal Plants - Volumes 1 to 4 (1999; 2004; 2007; 2009), and African Herbal Pharmacopoeia (2010) was very well studied for global plant species. Hence, these plant species were excluded from identifying the antidiabetic activities-related articles. The scientific name of each plant species was used as a search term. Only identified fruit species showed antidiabetic activities were considered in this work. Then, the available levels of scientific evidence of antidiabetic activity of each species were assessed.

Results

Most of the fruits were identified in Jaffna Town and Thirunelveli markets, followed by, Kodikamam, Chavakachcheri, Point Pedro, and Nelliyadi markets. On one hand, *Aegle marmelos, Anacardium occidentale, Ananas comosus, Annona cherimola, A. muricata, A. reticulata, A. squamosa, Artocarpus heterophyllus, Averrhoa bilimbi, A. carambola, Borassus flabellifer, Carica papaya, Carissa carandas, Citrullus lanatus, Citrus × aurantium, C. maxima, C. medica, Cocos nucifera, Cordia dichotoma, Cucumis melo, Donella lanceolata, Ficus racemosa, Fragaria × ananassa, Garcinia mangostana, G. quaesita, G. zeylanica, Lansium domesticum, Limonia acidissima, Malus domestica, Mangifera indica, Manilkara hexandra, Musa × paradisiaca, Nephelium lappaceum, Passiflora edulis, Phoenix dactylifera, P. pusilla, Phyllanthus acidus, P. emblica, Psidium cattleyanum, P. guajava, Punica granatum, Schleichera oleosa, Selenicereus undatus, Syzygium cumini, S. malaccense,* and *Vitis vinifera* fruits were widely identified and available in all visited markets. On the other hand, fruit species namely, *Actinidia chinensis, Antidesma bunius, Atalantia ceylanica*, *Baccaurea motleyana*, *Bridelia retusa, Calophyllum calaba, Canthium coromandelicum*, *Careya arborea, Carissa spinarum, Citrus japonica, Dillenia retusa, Dimocarpus longan, Diospyros malabarica, Elaeocarpus serratus, Erythroxylum moonii, Flacourtia indica, F. jangomas, Gmelina arborea, Grewia tiliifolia, Huberantha korinti, Lantana camara*, *Mangifera zeylanica*, *Memecylon intermedium*, *Mimusops elengi, Morus alba, Opuntia stricta, Passiflora foetida, Phyllanthus reticulatus, Pouteria campechiana, Pyrus communis, P. pyrifolia, Salacia chinensis*, *Sandoricum koetjape*, *Sonneratia caseolaris, Synsepalum dulcificum, Syzygium aqueum, S. caryophyllatum, S. nervosum, Syzygium samarangense, Tarenna asiatica, Vateria copallifera, Ziziphus linnaei,* and *Z. oenopolia* were rarely identified and available.

A total of 103 fruit species from 43 families were identified and documented in this work (Table 1). Most of the fruits belong to *Syzygium*, followed by *Citrus, Annona*, and *Ziziphus* species. Most of the fruits were from *the Myrtaceae* family, followed by *Rutaceae*, *Sapotaceae*, *Phyllanthaceae*, and *Annonaceae.*

Discussion

Many of the identified fruits were from food plants. Nine fruit species including *A. marmelos*, *A. occidentale*, *A. carambola*, *B. flabellifer*, *L. acidissima*, *M. paradisiaca*, *P. dactylifera*, *P. emblica*, and *P. granatum* are used in Sri Lankan Siddha Medicine antidiabetic preparations (Vivekanandarajah and Jeyaseelan 2020; Vivekanandarajah and Rajamanoharan 2021; Vivekanandarajah et al., 2015, 2016, 2017, 2018; Vivekanandarajah, 2021, 2021a, 2021b, 2021c).

Levels of Scientific Evidence of Identified Fruit Species

A sum of 26 (25%) fruit species was very well studied and globally distributed. Hence, a literature review of 77 fruit species revealed that 25 fruit species (32%) have antidiabetic scientific evidence. Most numbers of the fruit species with antidiabetic properties were from the *Annonaceae* family, followed by *Rutaceae* and *Sapotaceae*.

Fruit Species Had in vitro Antidiabetic Scientific Evidence

A total of seven fruits (28%) had *in vitro* antidiabetic scientific evidence as to the highest level (Table 2). *A. cherimola* and *S. dulcis* had the majority of evidence (Vasarri et al., 2020; Galarce-Bustos et al., 2019; Hossain et al., 2008; Mohamed Yunus et al., 2021). No antidiabetic compound was isolated from these fruit species.

Table 1: Fruit species sold in markets in jaffna district

Scientific name	Family	Tamil	Herbarium voucher specimen identification
Actinidia chinensis Planch.	*Actinidiaceae*	Kiwi	NA
Aegle marmelos (L.) Corrêa	*Rutaceae*	Vilvai	PR-1
Anacardium occidentale L.	*Anacardiaceae*	Munthirihai	PR-10
Ananas comosus (L.) Merr.	*Bromeliaceae*	Annaasi	NA
Annona cherimola Mill.	*Annonaceae*	Parangi Annamunnaa	PR-26
Annona muricata L.	*Annonaceae*	Seeththaa	PR-37
Annona reticulata L.	*Annonaceae*	Iraama Seeththaa	NA
Annona squamosa L.	*Annonaceae*	Annamunnaa	PR-52
Antidesma bunius (L.) Spreng.	*Phyllanthaceae*	Naalaithali	NA
Artocarpus heterophyllus Lam.	*Moraceae*	Palaa	PR-55
Atalantia ceylanica (Arn.) Oliv.	*Rutaceae*	Kurunthu	PR-56
Averrhoa bilimbi L.	*Oxalidaceae*	Vilimbi	PR-2
Averrhoa carambola L.	*Oxalidaceae*	Thamarath

thai | PR-3 |
Baccaurea motleyana (Müll.Arg.) Müll.Arg.	*Phyllanthaceae*	Moottipuli	NA
Borassus flabellifer L.	*Arecaceae*	Panai	PR-4
Bridelia retusa (L.) A.Juss.	*Phyllanthaceae*	Mulvengai	NA
Calophyllum calaba L.	*Calophyllaceae*	Manjatpunnai	PR-5
Canthium coromandelicum (Burm.f.) Alston	*Rubiaceae*	Kaarai	PR-6
Careya arborea Roxb.	*Lecythidaceae*	Aayimaa	NA
Carica papaya L.	*Caricaceae*	Pappaasi	PR-7
Carissa carandas L.	*Apocynaceae*	Perungkalaa	PR-8
Carissa spinarum L.	*Apocynaceae*	Kalaa	PR-9
Chrysophyllum cainito L.	*Sapotaceae*	Seemai Laavul	NA
Citrullus lanatus (Thunb.) Matsum. & Nakai	*Cucurbitaceae*	Thatpoosani	NA
Citrus × aurantium L.	*Rutaceae*	Then Thodai	PR-11
Citrus × limon (L.) Osbeck	*Rutaceae*	Malaielumichchai	NA
Citrus japonica Thunb.	*Rutaceae*	Kaattuth Thodai	PR-12
Citrus maxima (Burm.) Merr.	*Rutaceae*	Naaraththai	NA
Citrus medica L.	*Rutaceae*	Elumichchai	PR-13
Cocos nucifera L.	*Arecaceae*	Thennai	PR-14
Cordia dichotoma G.Forst.	*Boraginaceae*	Naruvili	PR-15
Cucumis melo L.	*Cucurbitaceae*	Waththhai	PR-16
Cynometra cauliflora L.	*Fabaceae*	Naminam	NA

Dialium ovoideum Thwaites	*Fabaceae*	Kaattuppuli	NA
Dillenia retusa Thunb.	*Dilleniaceae*	Naaiththekku	NA
Dimocarpus longan Lour.	*Sapindaceae*	Nurai	NA
Diospyros malabarica (Desr.) Kostel.	*Ebenaceae*	Panichchai	PR-17
Donella lanceolata (Blume) Aubrév.	*Sapotaceae*	Ilaavul	PR-18
Drypetes sepiaria (Wight & Arn.) Pax & K.Hoffm.	*Putranjivaceae*	Weerai	PR-19
Durio zibethinus L.	*Malvaceae*	Mulnaari	NA
Elaeocarpus serratus L.	*Elaeocarpaceae*	Weralu	NA
Erythroxylum moonii Hochr.	*Erythroxylaceae*	Sirusemmanaththai	NA
Ficus racemosa L.	*Moraceae*	Aththi	PR-20
Flacourtia indica (Burm.f.) Merr.	*Salicaceae*	Kaattukkalai	PR-21
Flacourtia inermis Roxb.	*Salicaceae*	Lovi	NA
Flacourtia jangomas (Lour.) Raeusch.	*Salicaceae*	Vaiyangkaarai	NA
Fragaria × *ananassa* (Duchesne ex Weston) Duchesne ex Rozier	*Rosaceae*	Strawberry	NA
Garcinia mangostana L.	*Clusiaceae*	Mangusththaan	NA
Garcinia quaesita Pierre	*Clusiaceae*	Korakkaappuli	NA
Garcinia zeylanica Roxb.	*Clusiaceae*	Kattuk Korakkaappuli	NA
Gmelina arborea Roxb. ex Sm.	*Lamiaceae*	Kumil	PR-22
Grewia tiliifolia Vahl	*Malvaceae*	Thavittai	PR-23
Huberantha korinti (Dunal) Chaowasku	*Annonaceae*	Karuvalli	NA
Lansium domesticum Corrêa	*Meliaceae*	Kadukuda	NA
Lantana camara L.	*Verbenaceae*	Arisimalar	PR-24
Limonia acidissima L.	*Rutaceae*	Vilaa	PR-25
Malus domestica (Suckow) Borkh.	*Rosaceae*	Apple	NA
Mangifera indica L.	*Anacardiaceae*	Maa	PR-27
Mangifera zeylanica (Blume) Hook.f.	*Anacardiaceae*	Kaattu Maa	NA
Manilkara hexandra (Roxb.) Dubard	*Sapotaceae*	Paalai	PR-28
Manilkara zapota (L.) P.Royen	*Sapotaceae*	Seemayilupai	PR-29
Memecylon intermedium Blume	*Melastomataceae*	Kaayaa	PR-30
Mimusops elengi L.	*Sapotaceae*	Mahilam	PR-31
Morus alba L.	*Moraceae*	Mayirkkottichchedi	PR-32
Musa × *paradisiaca* L.	*Musaceae*	Vaalai	PR-33
Nephelium lappaceum L.	*Sapindaceae*	Irambuttaan	NA
Opuntia stricta (Haw.) Haw.	*Cactaceae*	Naahathaali	PR-34
Passiflora edulis Sims	*Passifloraceae*	Kodiththodai	PR-35
Passiflora foetida L.	*Passifloraceae*	Sirupoonaikkaali	PR-36
Persea americana Mill.	*Lauraceae*	Vennai Maram	NA
Phoenix dactylifera L.	*Arecaceae*	Pereechchai	NA
Phoenix pusilla Gaertn.	*Arecaceae*	Eechchai	PR-38
Phyllanthus acidus (L.) Skeels	*Phyllanthaceae*	Arunelli	PR-39
Phyllanthus emblica L.	*Phyllanthaceae*	Nelli	PR-40
Phyllanthus reticulatus Poir.	*Phyllanthaceae*	Sempoolaa	PR-41

Pouteria campechiana (Kunth) Baehni	*Sapotaceae*	Kaattilaavul	PR-42
Psidium cattleyanum Sabine	*Myrtaceae*	Kilokkoyyaa	NA
Psidium guajava L.	*Myrtaceae*	Koyyaa	PR-43
Psidium guineense Sw.	*Myrtaceae*	Pulikkoyyaa	NA
Punica granatum L.	*Lythraceae*	Maathulai	PR-44
Pyrus communis L.	*Rosaceae*	Salvaagu	NA
Pyrus pyrifolia (Burm.f.) Nakai	*Rosaceae*	Seenach Chalvaahu	NA
Salacia chinensis L.	*Celastraceae*	Mallivembu	NA
Sandoricum koetjape (Burm.f.) Merr.	*Meliaceae*	Sevvai	NA
Schleichera oleosa (Lour.) Oken	*Sapindaceae*	Kumbaththiri	NA
Selenicereus undatus (Haw.) D.R.Hunt	*Cactaceae*	Dragon	NA
Sonneratia caseolaris (L.) Engl.	*Lythraceae*	Kinnai	PR-45
Spondias dulcis Parkinson	*Anacardiaceae*	Ambiralaa	PR-46
Synsepalum dulcificum (Schumach. & Thonn.) Daniell	*Sapotaceae*	Atputham	NA
Syzygium aqueum (Burm.f.) Alston	*Myrtaceae*	Neerchchambanaaval	NA
Syzygium caryophyllatum (L.) Alston	*Myrtaceae*	Sirunaaval	PR-47
Syzygium cumini (L.) Skeels	*Myrtaceae*	Naaval	PR-48
Syzygium jambos (L.) Alston	*Myrtaceae*	Sambanaaval	PR-49
Syzygium malaccense (L.) Merr. & L.M.Perry	*Myrtaceae*	Periya Sambanaaval	NA
Syzygium nervosum A.Cunn. ex DC.	*Myrtaceae*	Naahai	NA
Syzygium samarangense (Blume) Merr. & L.M.Perry	*Myrtaceae*	Neerkkumali	NA
Tarenna asiatica (L.) Kuntze ex K.Schum.	*Rubiaceae*	Tharani	NA
Vateria copallifera (Retz.) Alston	*Dipterocarpaceae*	Kungiliyampinai	NA
Vitis vinifera L.	*Vitaceae*	Thiraatchai	NA
Ziziphus jujuba Mill.	*Rhamnaceae*	Ilanthai	PR-50
Ziziphus linnaei M.A.Lawson	*Rhamnaceae*	Soorai	PR-51
Ziziphus mauritiana Lam.	*Rhamnaceae*	Perilanthai	PR-53
Ziziphus oenopolia (L.) Mill.	*Rhamnaceae*	Soorayilanthai	PR-54

Table 2: Fruits have *in vitro* scientific evidence

Scientific names	**Extract / compound**	**Assay / model / human subject**	**Citation**
Annona cherimola	Ethanol	Non-enzymatic glycation of human serum albumin inhibitory; α-Glucosidase inhibitory	(Vasarri et al., 2020)
Annona cherimola	NA	α-Glucosidase inhibitory	(Galarce-Bustos et al., 2019)
Annona muricata	Aqueous	α-Amylase inhibitory; α-Glucosidase inhibitory	(Adefegha et al., 2015)
Chrysophyllum cainito	Ethanol	α-Glucosidase inhibitory	(Ningsih et al., 2020)
Phoenix pusilla	Ethanol	α-Amylase inhibitory; α-Glucosidase inhibitory	(Sankar and Shoba, 2015)
Phyllanthus acidus	NA	α-Glucosidase inhibitory	(Suliaman and Ooi, 2014)
Phyllanthus acidus	Ethanol	α-Glucosidase inhibitory	(Zulaikha et al., 2018)
Spondias dulcis	Ethanol	α-Amylase inhibitory; α-Glucosidase inhibitory	(Hossain et al., 2008)
Spondias dulcis	Ethanol	α-Glucosidase inhibitory	(Yunus et al., 2021)
Syzygium caryophyllatum	Ethanol	α-Amylase inhibitory	(Wathsara et al., 2020)

Table 3: Fruits have in vivo scientific evidence

Scientific names	Extract/ compounds	Assay / model / human subject	Reference
Annona squamosa	NA	Alloxan-induced diabetic	(Gupta et al., 2005)
Averrhoa bilimbi	Aqueous	Streptozotocin-induced diabetic	(Kurup and Mini, 2016), (Kurup and Mini, 2017)
Carissa carandas	Methanol	Alloxan-induced diabetic	(Itankar et al., 2011)
Citrus maxima	Ethanol	Alloxan-induced diabetic	(Sci et al., 2020)
Citrus medica	NA	NS	(Peng et al., 2009)
Ficus racemosa	Ethanol	Type 1 diabetic; Type 2 diabetic	(Trinh et al., 2017)
Ficus racemosa	α-Amyrin acetate	Streptozotocin-induced diabetic	(Narender et al., 2009)
Gmelina arborea	Butanol, Ethanol, Ethyl acetate, Petroleum ether	Alloxan-induced diabetic	(Nayak et al., 2012)
Limonia acidissima	NA	Fluoride-induced diabetic	(Vasant and Narasimhacharya, 2013)
Manilkara zapota	Aqueous	Normal	(Barbalho et al., 2015)
Synsepalum dulcificum	Ethanol	Alloxan-induced diabetic	(Haddad et al., 2020)
Synsepalum dulcificum	NA	Fructose-rich chow-fed-induced insulin resistant	(Jang et al., 2008)
Syzygium samarangense	Vescalagin	High-fructose diet-induced diabetic	(Shen and Chang, 2013), (Huang et al., 2016)

Table 4: Fruits have clinical scientific evidence

Scientific names	Extract / compound	Human subject	Reference
Borassus flabellifer	NA	Type 2 diabetic	(Rahman et al., 2020)
Garcinia mangostana	α-Mangostin, γ-Mangostin	Obese female	(Watanabe et al., 2018)
Mangifera indica	NA	Obese	(Evans et al., 2014)
Passiflora edulis	NS	Type 2 diabetic	(De Queiroz et al., 2012)

Conclusion

Fruits are one of the most important parts of daily food. The primary goal of this study is to evaluate the scientific evidence for the antidiabetic properties of fruits commonly found in the Jaffna District. As mentioned above, many of the fruits have no antidiabetic scientific evidence. Hence, more studies should be conducted to identify the antidiabetic potentials of these fruits. Furthermore, priority should be provided to the widely available fruits in these future studies. Thus, these fruits will be useful to manage diabetes with fewer side effects in an economical way. Widely available fruits also have easier access, and they are affordable. The identified fruits in the study contain several antidiabetic active compounds. Therefore, further researches should be carried out to study these compounds in more advanced models to create more scientific evidence. This study identified, documented, and assessed the antidiabetic activities of fruits currently sold in the Jaffna District in Sri Lanka. This research provides a foundation for future studies on locally available fruits and their potential role in diabetes management.

Declarations

Conflict of interest

The authors declare that there is no conflict of interest.

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Consent for publications

All authors have read and approved the manuscript for publication.

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Authors' contributions

SV conceptualized and designed the the study. PR and VS coppellaborated in theon data curation and carried out the study. All authors had the same role in carring outstudy implementation. All authors contributed equally to conducting the literature search and wridrafting the first draft of theinitial manuscript. All authors reaviewed and approved the final manuscript for publication.

Ethical Considerations

Ethical issues (including plagiarism, data fabrication, double publication and submission, redundancy) have been completely looked into by the author.

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