Medicinal plants have been used since ancient times for human healthcare as drugs, spices, and food additives. The progress in technology and medicine observed in the last decades has improved the quality of life and healthcare but with worrisome drawbacks. Side effects caused by synthetic drugs for instance originate sometimes irreversible health disorders. Natural substances, in contrast, are biologically and environmentally friendly. *Syzygium jambos* L. (Alston) also known as rose apple conveys a long history as essential traditional medicine with a broad spectrum of application in various cultures. The plant discloses a diverse group of secondary metabolites and extracts that displayed major susceptibilities towards various health concerns especially stress-related and inflammatory diseases. Despite a rich literature about the plant, the chemistry and biology of *S. jambos* have not been comprehensively reviewed yet. Accordingly, we present herein a literature survey of rose apple which aims to draw the chemical identity of the plant and establish a consistent discussion on the respective biological application of plant extracts and their corresponding traditional uses. The present work could provide a scientific basis for future studies and necessary information for further investigations of new drug discovery.

**Keywords:** *Syzygium jambos*, medicinal plants, pharmacological activities, antioxidant, antiinflammatory

**INTRODUCTION**

The renown of alternative medicines nowadays is appealing although progress in technology and medicine encountered the last decades has improved the quality of life and healthcare around the world. Corresponding drawbacks are quite worrisome. Side effects caused by synthetic drugs for instance hurt human health system, sometimes with irreversible impacts (van Wyk and Wink 2015). Natural substances, in contrast, are biologically and environmentally friendly as they are recognized...
by other organisms which facilitate their metabolisms. These substances are provided from plants, microorganisms, or animals with a pronounced interest since they constitute the main sources of foods and thus, our first resort in case of pain (van Wyk and Wink 2015).

Plants contain chemicals not essential for their metabolism rather for the fight against attacks and stress due to the plant habitats. These phytochemicals have shown distinct biological properties against numbers of illnesses (Iwu, 1993; van Wyk and Wink 2015). Both plants and compounds are of great interest in drug development to face new medical challenges.

Accordingly, numerous of research works have been conducted on plants from the genus Syzygium to elucidate its chemistry and pharmacology. Species of this genus, including S. jambos, offer edible fruits found under various formulation including juices, jellies, and jams (Sun et al., 2020). The decoction of these fruits serves to alleviate gastrointestinal disorders, wounds, syphilis, leprosy, as well as toothache (Chua et al., 2019). Reports have highlighted the occurrence of polyphenols, flavonoids, tannins, and sterols from various organs of S. jambos species. Meanwhile, plant extracts and compounds also claimed a broad spectrum of activities from antibacterial to anti-inflammatory activities through analgesic, antiviral, anti-dermatophyte, anticancer, and hepatoprotective properties (Sobeh et al., 2018). Two recent reviews very briefly highlighted the chemical composition, traditional uses and biological activities of the plant (Harsha et al., 2021; Subbulakshmi et al., 2021).

The present research survey tends to summarize the traditional uses, chemical constituents, and pharmacological properties of extracts and compounds from S. jambos in one document as much information as possible about this plant, which has many biological properties. This work could provide a scientific basis for future study and necessary information for further investigations of new drug discovery.

TAXONOMY AND BOTANICAL DESCRIPTION

The genus Syzygium contains approximately 1,200–1800 species, the majority of which are flowering plants (Khalaf et al., 2021). Its taxonomy has been disputed for long with that of the genus Eugenia (Mabberley, 2017). As a result, species of the latter have been ranged in the genus Syzygium. Amongst them, S. malaccense, S. subbirculare, S. paniculatum, S. aquem, samarangense, and S. jambos (Sobeh et al., 2016; Cocks and Cheesman, 2018). S. jambos L. Alston, synonym of Eugenia jambos, is native to Reunion Island, Central America (Guatemala), and South-East of Asia, especially in Nepal, Indonesia, Philippines, and Malaysia. It has been naturalized in India and claims various vernacular names in different cultures including malabar plum, plum rose, rose apple, and water apple (Maskey and Shah, 1982; Morton, 1987; Avila-Peña et al., 2007).

S. jambos belonging to the family Myrtaceae, is a medium sized tree reaching 7.5–12 m in height, Figure 1 (Morton, 1987). Due to its physical characteristics and the aroma of the fruits, the plant is often known as rose apple. It has a dense crown of slender with wide spreading branches. Leaves are opposite, lanceolate, and glabrous with 2.5–6.25 cm wide and 10–22 cm length. They are glossy and dark-green when mature while vibrant red when young. Flowers are in small terminal clusters, white or greenish white with a diameter of 5–10 cm. Usually, there are 4–5 flowers together in terminal clusters (Nawwar et al., 2016). The berries have a fleshy pericarp with 10–15 mm thick on the tree. They are sub-globose and whitish-to pinkish-yellow color. Every fruiting season, a mature rose apple tree produces about 35.57 g of fruit, with 7.16 cm length and 5.15 cm width. The epicarp of the fruit is thin, smooth, and reddish, while the mesocarp and endocarp are whitish and succulent, Figure 1 (Daly et al., 2016; Mangini et al., 2020).

PHYTOCHEMICAL COMPOSITION

Phenolic compounds are mainly present in the leaves of S. jambos. They are represented by flavonoids, ellagitannins, phloroglucinols, and phenolic acids, Table 1; Figure 2 (Rocchetti et al., 2019; Slowing et al., 1994; Slowing et al., 1996; Sobeh et al., 2018). Flavanoids are the most abundant group of compounds while quercetin sounds to be the most abundant monomer in every organ of the plant, except the stem bark. It is found in both aglycone and saponin forms. Only flavone and chalcone-types of flavonoids occur in S. jambos (Reynerton et al., 2008). Some anthocyanidins have also been detected in the plant mainly, petunidin 3-O-glucoside, pelargonidin 3-O-(6″-malonyl-glucoside) and delphinidin 3-O-galactoside (Rocchetti et al., 2019). Catechin has been identified from the leaves of the plant suggesting a tentative occurrence of non-hydrolysable tannins in the plant. As part of tannins, only ellagitannins (hydrolysable tannins) have been found in some plant extracts to date. Likewise, ellagic acid monomer derivatives have also been reported in the leaves and stem bark of the plant. Moreover, phenolic acids, listed as intermediates in the metabolism of flavonoids and ellagic acids like gallic acid and cinnamic acid, have also been alarmed in the leaves and fruit of S. jambos. Gallic acid is the most abundant and distributed phenolic acid in the plant. The other phenolic acids were either glycosylated benzoic acid or derivatives of phenylpropanoids. Phloroglucinols also occur in S. jambos leaves. Though only one report highlighted their presence in S. jambos, phloroglucinols are well distributed in Myrtaceae family. The seven compounds of this class were isolated from a Chinese species and no trace of one of this group of compounds was mentioned in the Egyptian or Brazilian varieties, Table 1; Figure 2 (Li et al., 2015).

Pentacyclic triterpenoids are also abundant in the plant especially in the leaves and stem bark. They belong to oleanean, ursane, lupane and friedaleane subclasses. The major ones were betulinic acid and friedelin. Saponins of triterpenes have not yet been isolated except the readily available β-sitosterol glucoside, Table 1 (Kuiate et al., 2007; Li et al., 2015). Roots and flowers of the plant have not been investigated yet.

The essential oil of the plant leaves contain mostly volatile sesquiterpenes including δ-cadinene, cumaldehyde, β-
himachalene, isocaryophyllene, and β-cedrene, Table 1 (Khalaf et al., 2021). Linalool is one of the essential oil markers in the identification of the plant fruit. Indeed, linalool, cinnamyl alcohol, and geraniol are the main volatile terpenes in the extracts. Differences were observed in the volatile aromatic composition of fruits from the Brazilian, Malaysian, and Egyptian species. Linalool was found as the main compound in the Brazilian fruits while 3-phenylpropyl alcohol (Z)-3-hexen-1-ol and (Z)-cinnamaldehydes were identified as major compounds in the Malaysian and Egyptian ecospecies (Vernin et al., 1991; Wong and Lai, 1996; Guedes et al., 2004; Ghareeb et al., 2017).

TRADITIONAL USES

Rose apple carries a long history as essential traditional medicine with a broad spectrum of application in various cultures. In India, the fruit tonic helps to improve brain and liver health while fruit infusions convey diuretic property (Morton, 1987). Moreover, the juices from macerated leaves in water were used as a febrifuge (Maskey and Shah, 1982). Dysentery is also alleviated by the seeds together with diarrhea, and catarrh. Furthermore, the flowers are assumed to relieve fever (Baliga et al., 2017). The infusion of the powdered leaves is beneficial to diabetes (Maskey and Shah, 1982). In South American cultures, the seeds have an anesthetic property whereas leaf decoction is applied to sore eyes, and used as diuretic, expectorant and to treat rheumatism (Maskey and Shah, 1982). The decoction of the bark is administered to treat asthma, bronchitis, and hoarseness (Maskey and Shah, 1982). The plant is also used to treat hemorrhages, syphilis, leprosy, wounds, ulcers, and lung diseases due to its potency to relieve fever and pains. In China, each plant organ is used to treat digestive tract and tooth pains (Mahmoud et al., 2021; Reis et al., 2021).

BIOLOGICAL ACTIVITIES

The biological applications of S. jambos are rich and diverse. Isolates were screened in accordance with the traditional uses of the plant encountered worldwide. Mainly, plant extracts and compounds have presented antifungal, antibacterial, hepatoprotective, analgesic, antioxidant, anti-inflammatory, antidiabetic, anticancer, anti-pyretic activities, Figure 3. The main pharmacological characteristics of S. jambos are listed in Tables 2–4.

Toxicity Studies

To date, only few literatures have reported the toxicity of the plant. The leaf extract of S. jambos is safe at a dose up to 5 g/kg b.wt. assessed by the acute toxicity test (Dhanabal and Devakumar, 2014). The toxicity of the methanol extract of S. jambos and its fraction were evaluated by shrimp lethality bioassay. Methanolic extract and carbon tetrachloride fraction displayed significant lethality with LC50 = 6.97 and 13.61 µg/ml,
| Class of compounds | Compound names | Plant organs | Characterization methods | References |
|--------------------|----------------|--------------|--------------------------|------------|
| Flavonoids         | Quercetin      | Fruit, whole plant | HPLC, ES-MS, EIMS, IR, 1D and 2D NMR | Slowing et al., (1994), Reynertson et al., (2008), Bonfanti et al., (2013), Hossain et al., (2016), Reynertson et al. (2008), Ghareeb et al. (2017) |
|                    | Quercitrin     | Fruit        |                          |            |
|                    | Ruftin         | Whole plant  |                          |            |
|                    | 5,4'-dihydroxy, 7-methoxy, 6-methyl-flavone |                      |                          |            |
|                    | Isoetin-7-O-β-D-glucopyranoside |                      |                          |            |
|                    | Myricitin-3-O-beta-d-xylopyranosyl(1→2)α-l-rhamnopyranosides | Leaves |                          |            |
|                    | Kaempferol     | Whole plant  |                          |            |
|                    | Quercetin-3-O-xylosyl (1→2) xyloside | Leaves |                          |            |
|                    | Quercetin-3-O-glucuronide |                      |                          |            |
|                    | Myricitin-3-O-glucoside |                      |                          |            |
|                    | Myricitin-7-methylketo-3-O-xylosyl (1→2)rhamnose |                      |                          |            |
|                    | Myricitin-3'-5'-dimethyl ether 3-O-xylosyl (1→2)rhamnose |                      |                          |            |
|                    | Myrigalone B   | Leaves       |                          |            |
|                    | Phloretin-4-O-methyl |                      |                          |            |
|                    | Myrigalone G   |                      |                          |            |
| Triterpenoids      | Oleanolic acid | Leaves       |                          | Li et al. (2015) |
|                    | Betulinic acid |                      |                          |            |
|                    | Friedelin      | Stem bark, leaves |                          |            |
|                    | 3-nor-2,3-Secofriedelan | Stem bark |                          |            |
|                    | B-Sitosterol   |                      |                          |            |
|                    | B-Amyrin acetate |                      |                          |            |
|                    | Ursolic acid   |                      |                          | Lin et al. (2014) |
|                    | 3-Acetyl-ursolic acid |                      |                          |            |
|                    | Asiatic acid   |                      |                          |            |
|                    | Arjunic acid   |                      |                          |            |
|                    | Monoric acid 3-O-cafsate |                      |                          |            |
| Phenolic acid      | Gallic acid    | Leaves, fruit | HPLC-PDA-MS/MS and GC-MS | Bonfanti et al., (2013), Nawwar et al., (2016) |
|                    | Cinnamic acid  |                      |                          | Ghareeb et al. (2017) |
|                    | 3,4,5-Trimethoxybenzoic acid |                      |                          |            |
|                    | Prenylenzoic acid 4-O-β-D-glucoside |  |                          |            |
|                    | 4'-hydroxy-3'-methoxysphenol-β-D-β-(6-O-(4'-hydroxy-3',5'-dimethoxylbenzoxyl)glucopyranoside |  |                          |            |
|                    | Caffeic acid   |                      |                          |            |
|                    | Chlorogenic acid |                      |                          |            |
|                    | Rosmarinic acid |                      |                          |            |
|                    | Rosmarinic acid rhamnoside |                      |                          |            |
| Organic acides     | Citric acid    | Leaves | GC-MS |            |
|                    | Malic acid     |                      |                          |            |
| Volatile compounds | Phenylacetic acid |                      |                          | Khalaf et al. (2021) |
|                    | Hexanal        |                      |                          |            |
|                    | Geranial       |                      |                          | Mushafha et al. (2017) , Ries et al. (2021) |
|                    | Citronellol    |                      |                          |            |
|                    | Hotrienol      |                      |                          |            |
|                    | (E)-cinnamyl alcohol |                      |                          |            |

(Continued on following page)
respectively. Whereas the chloroform and hexane fractions showed moderate to low lethality with LC_{50} = 64.94 µg/ml and 257.6 µg/ml, respectively (Haque, 2015). In the same line, Ghareeb et al. (2016) tested different extracts and fraction obtained from the leaves and flowers against the brine shrimp Artemia salina, a useful tool to determine the toxicity of natural products. As a result, the n-butanol fraction of the leaves showed a strong toxicity with LC_{50} = 50.11 µg/ml while the dichloromethane and petroleum ether fractions were less toxic (LC_{50} = 446.65 µg/ml) (Ghareeb et al., 2016).

Toxicology safety evaluation is essential for plants applications and new drug development. However, the toxicological studies of extracts and compounds isolated from S. Jambos have not been fully explored yet. Therefore, further research in toxicity is needed to determine the suitability of the plant extracts and related compounds composition.

### TABLE 1 | (Continued) Phytoconstituents from S. jambos.

| Class of compounds | Compound names | Plant organs | Characterization methods | References |
|--------------------|---------------|--------------|--------------------------|------------|
| **Phytoconstituents** |  |  |  |  |
| B-phenylethyl alcohol | | | | |
| (E)-2-methyl-2-buten-1-ol | | | | |
| Linalool | | | | |
| (2)-3-hexan-1-ol | | | | |
| 3-phenylpropanol | | | | |
| (2)-3-hexan-1-ol | | | | |
| B-carophyllane | | | | |
| A-humulane | | | | |
| B-isobolene | | | | |
| (E)-a-farnesene | | | | |
| Caryophyllenyl alcohol | | | | |
| Caryolan-8-ol | | | | |
| N-heneicosane | | | | |
| Limonene | | | | |
| Leadil | | | | |
| Humulene epoxide | | | | |
| 1 | | | | |
| 
| Epi-cadinen | | | | |
| Epi-a-murolol | | | | |
| Trans-(lpp vc oh) sesquisabinene hydrate | | | | |
| 4,8-a-Epoxy-caryophyllane | | | | |
| Trans-caryophyllane | | | | |
| 2-Cadinen | | | | |
| 1-Murolol | | | | |
| Neophytadiene | | | | |
| 2-propan-1-one, 1-(2,6-dihydroxy-4-methoxyphenyl)-3-phenyl, (6)- | | | | |
| 4h-1-Benzopyran-4-one, 2,3-dihydro-5,7-dihydroxy-6,8-dimethyl-2- | | | | |
| phynyl, 6i- | | | | |
| 1h-Benzimidazo, 5-ethoxy-2-phenylsulfanyl | | | | |
| 2,3-Dihydro-2,4-diphenyl-1h-1,5-benzodiazepine | | | | |
| = Toxophenol | | | | |
| [3-Deuterium]-a - tocoophenyl methyl ether | | | | |
| **Fatty acid** |  |  |  |  |
| Lauric acid | | | | |
| Capric acid | | | | |
| Hentriacontane | | | | |
| 3-Pentadecylpheno (3-n-pentadecylpheno) | | | | |
| (a, b)-1,4,4-trimethyl-8-methylene-1,5-cycloundecadiene | | | | |
| Methyl (p)-5,11,14,17-eicosatetraenolate | | | | |
| 4h-1-Benzopyran-4-one, 2,3-dihydro-5,7-dihydroxy-2-phenyl-(9) | | | | |
| 3,7,11,15-tetramethyl-2-hexadecan-1-ol | | | | |
| Hexadecanoic acid, methyl ester | | | | |
| Hexadecanoic acid | | | | |
| Hexadecanoic acid, ethyl ester | | | | |
| 9,12-Octadecdienoic acid, methyl ester | | | | |
| 9,12,15-Octadecatrienoic acid, methyl ester, (2,2,2) | | | | |
| 9,12-Octadecatrienoic acid, (2,2)- | | | | |
| 8,11,14-Octadecatrienoic acid, (2,2,2)- | | | | |
| Ethyl linoleate | | | | |
| Octadecanoic acid, ethyl ester | | | | |
| Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester | | | | |
| Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester | | | | |
| 2,6,10,14,18,22-Tetracosahexaene, 2,6,10,15,19,23-hexamethyl | | | | |

### Antimicrobial Activity

Diverse antimicrobial activity of crude extracts and isolated compounds from the plant were described in previous reports. Disc diffusion assays, agar well diffusion, and broth microdilution procedures were employed to assess the antibacterial activity of plant extracts. As shown in Table 2. Microbial growth inhibition zones and percentages, as well as minimum inhibitory concentrations (MICs), demonstrated that S. jambos has potential as a significant antibacterial agent.

Wamba et al. (2018) reported the capacity of S. jambos extracts to increase the potency of chloramphenicol antibiotic towards bacteria strains expressing MDR phenotype (Wamba et al., 2018). Leaf and bark extracts of the plant expressed up to 70% of antibiotic-modulating activity against S. aureus strains at MIC/2. Similar results were obtained in association with tetracycline, ciprofloxacin, and erythromycin against Gram-negative bacteria.
including strains of *Escherichia coli* (AG100ATet, AG102), *Enterobacter aerogenes* (EA27, EA289), *Klebsiella pneumoniae* (KP55, KP63), *Providencia stuartii* (PS299645, NEA16) and *Pseudomonas aeruginosa* (PA01, PA124) (Wamba et al., 2018). Likewise, *S. jambos* leaf extracts demonstrated potent antiviral effects on the virus involved in vesicular stomatitis and against different types of herpes simplex virus (Abad et al., 1997; Athikomkulchai et al., 2008).

Isolated compounds friedelin, β-amyrin acetate, betulinic acid, and lupeol, from the bark extract, were tested for their antidermatophytic activity against three commonly dermatophytes species found in Cameroon namely *Microsporum audouinii*, *Trichophyton mentagrophytes* and *T. soudanense*. Betulinic acid and friedelolactone were the most active compounds with MIC ranging from 12.5 to 100 µg/ml and the most sensitive fungi were *Trichophyton soudanense* (MIC ≥ 25 µg/ml) and *Trichophyton mentagrophytes* (12.5 µg/ml) (Kuiate et al., 2007). The phenolic compounds, quercetin, rutin, prenylbenzoic acid 4-O-β-D-glucopyranoside, morolic acid 3-O-caffeate, 5,4'-dihydroxy-7-methoxy-6-methylflavone, 3,4,5-trihydroxybenzoic acid, isoezin-7-O-β-D-glucopyranoside, and (4'-hydroxy-3'-methoxyphenol-β-D-[6-O-(4″-hydroxy-3″,5″-dimethoxybenzoate)] glucopyranoside) also exhibited both antibacterial and antifungal potentials with a diameter of inhibition zones ranging from 9–19 mm (Ghareeb et al., 2017). Accordingly, the antimicrobial activity of *S. jambos* crude extracts have been related to the presence of an increased level of tannins in the preparation (Baliga et al., 2017).

Moreover, silver nanoparticles synthetized from leaves and bark extracts of *S. jambos* showed higher antiplasmodial activity against chloroquine sensitive and resistant strains of *Plasmodium falciparum* (Dutta et al., 2017). The fatty compounds, ethyl linoleate, methyl linolenate and phytol, inhibited the QS-dependent pigment production in *C. violaceum* and lowered pyoverdine production in *P. aeruginosa* as well. Results were also confirmed by docking
analysis (Musthafa et al., 2017). The above research confirmed the antimicrobial activity of *S. jambos*. However, it is worthy to note that the above studies focused on the *in vitro* evaluations. Consequently, these studies only give preliminary information about the activity of *S. jambos*. Therefore, further studies combining *in vivo* and *in vitro* need to be conducted to provide reliable basis for exploring new potentially and low toxic antimicrobial agents from the studied plant.

**Antioxidant Activity**

Several studies, both *in vitro* and *in vivo*, reported the antioxidant activity of *S. jambos* extracts and its phytochemicals. Bonfanti et al. (2013) demonstrated the potency of the leaf aqueous extract of *S. jambos* to inhibit the nitric oxide radical, the lipid peroxidation and the mitigation sodium-nitroprusside-induced oxidative stress in rats. The extract also showed a capacity to increase the GSH levels in rats (Sobeh et al., 2018). Furthermore, the bark extract inhibited lipid peroxidation and increased reduced glutathione (GSH) in pancreatic tissues of STZ-diabetic rats (Mahmoud et al., 2021). *S. jambos* leaf extract abolished ROS production by endothelin-1 in human polymorphonuclear and mononuclear cell migration (Inostroza-Nieves et al., 2021). On the other hand, *S. jambos* rich phenolic and flavonoid fractions demonstrated good antioxidant activities as shown in Table 3. The chalcones phloretin 4′-O-methyl ether, myrigalones B and G were assessed for their antioxidant activity using DPPH radical. As a result, myrigalone B showed a significant capacity of scavenging radicals with an IC\(_{50}\) of 3.8 µg/ml while the other compounds showed low to moderate activity (IC\(_{50}\) > 30 µg/ml) (Jayasinghe et al., 2007). Moreover, 2,6-dihydroxy-4-methoxy-3,5-dimethylindolychalcone showed anti-DPPH activity with an IC\(_{50}\) value of 10.6 µg/ml while, the flavones, 4′-methoxysideroxylin and 6-demethylsideroxylin, and phloroglucinols, jambones A-B, presented weak antioxidant activities in FRAP and DPPH radical scavenging activities (Li et al., 2015).

**Neurological Activity**

There are relatively few studies on neuroprotective effect of *S. jambos*. Bonfanti et al. (2013) investigated the effects of *S. jambos* in the inhibition of both AChE and BuCE, the two main enzymes in the occurrence of Alzheimer. As a result, the aqueous leaves extract of *S. jambos* showed significant AChE (IC\(_{50}\) = 16.5 µg/ml) and BuCE (IC\(_{50}\) = 15.2 µg/ml) inhibition potentials in support with the uses of the plant to alleviate Alzheimer disorders. Considering these findings, further investigations may improve the neuroprotective effect of *S. jambos*.

**Anticancer Activity**

*In vitro* anticancer activity of isolates from *S. jambos* was determined towards various cancer cell lines, providing data on the bioactivity of both extract and single compounds, Table 3. Methanolic extract of *S. jambos* leaves showed cytotoxic effects against liver cancer cell line, Hep G2 cells, by inducing apoptotic pathways (Thamizh Selvam et al., 2016). Moreover, another study evaluated the anticancer effects of the leaves along with other extracts on human melanoma (A431), epidermoid carcinoma (A431), cervical epithelial carcinoma (HeLa) and human embryonic kidney cells (HEK-293). They found that the extract showed low toxicity against HEK-293 cells but better effects against A431 and HeLa cells (IC\(_{50}\) = 34.90–56.20 µg/ml) (Twilley et al., 2017). The hydrolysable tannins, 1-O-galloyl castalagin and casuarinin, exhibited significant cytotoxic activity against the human promyelocytic leukemia cell line HL-60 with IC\(_{50}\) of 10.8–12.5 µM and showed moderate to low cytotoxicity on the human adenocarcinoma SK-HEP-1, normal cell lines of human lymphocytes and liver cell lines. Results were confirmed by DNA fragmentation assay and microscopic investigation of cells (Yang et al., 2000). The cytotoxic effects of the phenolic compounds, cis-3-
| Extract       | Tested strains                                                                 | Key results                                                                 | Reference                          |
|---------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------|
| Methanol      | Alcaligens faealis, A. Hydrophila, Bacillus cereus, S. aureus, Aeromonas hydrophila, Citobacter freundii, E. coli, Klebsiella pneumoniae, Proteus mirabilis, P. fluorescens, Salmonella Newport, Serratia marcescens, Shigella sonnei, S. epidermidis and Streptococcus pyogenes | These bacteria were not susceptible by S. jambos leaf extract                   |                                    |
| Ethanolic     | Chromobacter violaceum DMST 21761                                               | At 500 µg/ml, a highest inhibition in QS-dependent violacein pigment production was observed up to 90% | Mustafa et al. (2017)              |
| Ethanolic     | P. aeruginosa ATCC 27853                                                        | At sub-MIC (500 µg/ml), the extract showed significant reduction in QS-regulated virulence determinants | Rakumari et al. (2018a)            |
| Ethanolic     | P. aeruginosa                                                                    |                                                                                |                                    |
| Ethanolic     | P. aeruginosa                                                                    |                                                                                |                                    |
| Ethanolic     | P. acnes, E. coli, A. niger, C. albicans                                        | No activity against E. coli, A. niger and C. albicans at 1,000 and 2000 µg/ml | Sharma et al. (2013)               |
| Decoction     | P. vulgaris (ATCC 6896)                                                          | MIC = 31 µg/ml and MBC = 1.0 mg/ml                                            | Luciano-Montalvo et al. (2013)      |
| Aqueous and   | Epidermophyton floccosum (ATCC 26072)                                            |                                                                                |                                    |
| Ethanolic     | C. albicans (ATCC10231)                                                          |                                                                                | Noé et al. (2019)                  |
| Aqueous and   | Trichophyton mentagrophytes BSL2 (ATCC 13996)                                    |                                                                                |                                    |
| Ethanolic     | Trichophyton rubrum (ATCC 22402)                                                |                                                                                |                                    |
| Ethanolic     | S. aureus, E. coli                                                              |                                                                                |                                    |
| Ethanolic     | S. aureus                                                                        |                                                                                |                                    |
| Acetone       | Staphylococcus aureus                                                            |                                                                                |                                    |
| 85% MeOH      | S. aureus, Methicillin-resistant, S. aureus, P. aeruginosa, C. albicans, and A. niger | Phi = 13.5, 11.0, 13.5, and 11.5 mm, respectively                                |                                    |
| Defatted 85% MeOH |                                                                                   |                                                                                |                                    |
| Petroleum ether |                                                                                   |                                                                                |                                    |
| Dichloromethane |                                                                                   |                                                                                |                                    |
| Ethyl acetate |                                                                                   |                                                                                |                                    |
| n-Butanol     |                                                                                   |                                                                                |                                    |
| Aqueous       |                                                                                   |                                                                                |                                    |
| Methanolic    | 26 strains of S. aureus                                                          | MIC ranging between 32 and 512 µg/ml                                          | Wambat al. (2018)                  |
|               | Enterobacter aerogenes EA294                                                       |                                                                                |                                    |
|               | Enterobacter cloacae (ECC689)                                                     |                                                                                |                                    |
|               | Pseudomonas aeruginosa (PA01, PA124)                                             |                                                                                |                                    |
| MeOH          | Providencia stuartii (NEA16, PS2638)                                             |                                                                                |                                    |
| Petroleum ether |                                                                                   |                                                                                |                                    |
| Aqueous       |                                                                                   |                                                                                |                                    |
| Acetone       | Staphylococcus aureus                                                            |                                                                                |                                    |
| Aqueous       | Bacillus subtilis                                                                |                                                                                |                                    |
| Aqueous       | Escherichia coli                                                                |                                                                                |                                    |
| Bark, leaves and seeds |                                                                                   |                                                                                |                                    |
| Aqueous       | Klebsiella pneumoniae                                                            |                                                                                |                                    |
| Aqueous       | Proteus vulgaris                                                                 |                                                                                |                                    |
| Aqueous       | Pseudomonas aeruginosa                                                            |                                                                                |                                    |
| Aqueous       | Salmonella typhi                                                                 |                                                                                |                                    |
| Aqueous       | Vibrio cholera                                                                   |                                                                                |                                    |
| Bark          | S. aureus                                                                        | MIC ranged between 500 and 1,000 µg/ml                                        | Djipa et al. (2000)                |
| Bark          | Y. enterocollicita                                                                | MIC ranged between 250 and 750 µg/ml                                          |                                    |

(Continued on following page)
-p-coumaroylfлавилетичная кислота и 4′-метоксифенилпропионовая кислота, на меланома SK-MEL-28 и SK-MEL-110 клеточном уровне были оценены как также, как и нормальной Вero клетки, следуя MTT-тест. Используя комплаунд, были оценены потенциальные эффекты на два меланома клетки с IC50, сбрасывающийся от 18,3–81,5 μM (Li et al., 2015). Лейкотриеническая роль меркаптен-3-О-β-D-xилофуранозил-(1 → 2)-α-L-рhamnopyranoside and myricetin-3-О-β-D-xyloluranosyl-(1 → 2)-α-L-rhamnopyranoside изолированных из CH2Cl2/MеOH фракции растения было оценивано против RW 264.7 клеточном уровне. Обе флавоноиды демонстрировали умеренный активность (IC50 = 1.68 и 1.11 μM, соответственно) (Ticina et al., 2021). Лейкотриенический эффект наночастиц синтезированных из листьев S. jambos был оценен против HeLa и L6 клеток используя MTT-тест. Как результат, наночастицы были найдены быть нетоксичные против HeLa и L6 клеточном уровне (Dutta et al., 2017). Эти исследования исследовали антираковый потенциал S. jambos, что включает in vivo, токсикологические, и клинические исследования необходимы в будущем для гарантии эффективности и безопасности.

**Anti-Inflammatory Effect**

Инфляция и специфически низко- GRA inflammation play a vital role in many diseases. Natural products with -inflammatory activities are promising targets for drug discovery. In vitro and in vivo models were applied to determine the anti-inflammatory effects of crude extracts and pure compounds from S. jambos. In vitro studies showed that the ethanol leaf extract of S. jambos and the commercially available chemicals урсольный кислота and myricitrin dramatically reduced the release of inflammatory cytokines IL-8 and TNF-α by 74–99% indicating anti acne effects (Sharma et al., 2013). A more recent study on two isolated glycosylated flavonoids, the quercetin-3-O-β-D-xyloluranosyl-(1 → 2)-α-L-rhamnopyranoside and myricetin-3-O-β-D-xyloluranosyl-(1 → 2)-α-L-rhamnopyranoside, isolated from the chloroform/methanol fraction of S. jambos showed that they reduced the production of TNF-α, with IC50 values of 1.68 and 1.11 M, respectively, in the RAW 264.7 cell line. In addition, at a dose of 5 mg/kg, the flavonoids reduced the levels of TNF-α, C-reactive protein, and fibrinogen in murine models (Apaza Ticina et al., 2021). In vivo studies showed that the ethanol extract of the leaves also exerted potent anti-inflammatory effects at a dose of 400 mg/kg in carrageenan and histamine edema rat models (Hossain et al., 2016). The soluble fraction of polysaccharide fraction of the plant also expressed a capacity to increase the secretion of TNF-α, IL-1β and IL-10 in a concentration-dependent manner (10–100 μg/ml). The aqueous extract of the plant attenuated the inflammatory response induced by LPS at a concentration of 100 μg/ml (Tamiello et al., 2018b). Furthermore, the extract inhibited pancreatic inflammation in STZ diabetic rat model where it dose-dependently suppressed the pro-inflammatory, TNF-α and increased the anti-inflammatory IL-10 levels (Mahmoud et al., 2021).

**Hepatoprotective Activities**

Liver is one of the largest and important organs in human body and performs numerous interrelated vital functions, such as metabolism, biotransformation, and detoxification of toxins. Consequently, liver diseases resulting from liver damage is a global problem. Herbal medicine has been used traditionally for the prevention of liver diseases (Islam et al., 2012). Preclinical studies have shown that extracts from different parts of S. jambos possess beneficial effect in liver related diseases, Table 4. The methanol extract of the leaves of the plant significantly modulated the levels of liver biochemical parameters ALT, AST, MDA, TB, TC, TG, GSH and SOD) in comparison with the positive control, silymarin, Table 4 (Sobeh et al., 2018). Isolation of the compounds of the extract may lead to the discovery of promising active constituents.

**Antidiabetic Activity**

Diabetes and diabetic complications are global health problem. Although many medicinal plants were investigated for their possible antidiabetic activities, there are relatively few studies on antidiabetic effect of S. jambos extracts. An in vitro study compared the inhibitory effects of ethanol extract of different organs of S. jambos on α-glucosidase and α-amylase activities, enzymes related to diabetes, and showed that the inhibitory effects against yeast and mice intestinal α-glucosidase activity was on the following order: seed > stem > leaf > root > flower > flesh > acarbose, while the inhibitory effect on α-amylase activity was

---

**TABLE 2 (Continued) Antimicrobial activity of S. jambos extracts.**

| Extract | Tested strains | Key results | Reference |
|---------|----------------|-------------|-----------|
| **Leaves** | | | |
| S. hominis | MIC ranged between 15 and 250 μg/ml | Ghareeb et al. (2016) |
| S. cohnii | MIC = 250 μg/ml, in both extracts | | |
| S. warneri | MIC ranged between 15 and 750 μg/ml | | |
| **Flower** | | | |
| 85% MeOH | S. aureus, Methicillin-resistant, P. aeruginosa, C. albicans, A. niger | Δmm between 8.5 and 10.5 mm | | |
| **Seeds** | | | |
| Aqueous extract | Microsporum gypseum, Microsporum canis, Candida albicans | IZ = 28.75 mm, IZ = 30.25 mm, IZ = 16 mm | Sakander, et al. (2015) |
| Extract                        | Activity               | Used method                              | Country | Effects                                                                 | Reference                                      |
|-------------------------------|------------------------|------------------------------------------|---------|-------------------------------------------------------------------------|-----------------------------------------------|
| Whole plant                   |                        |                                          |         |                                                                         |                                               |
| Ethanol extract               | Antioxidant            | DPPH and NO scavenging assay             | South Africa | DPPH (IC<sub>50</sub> = 14.10 µg/ml) NO scavenging assay (Low activity) | Twilley et al. (2017)                         |
|                               |                        | COX-2                                    |         | IC<sub>50</sub> of 3.79 µg/ml                                           |                                               |
|                               | Anti-inflammatory      |                                          |         |                                                                         |                                               |
|                               | Cytotoxic              | A375, A431, HeLa and HEK-293 cell lines  |         | IC<sub>50</sub> ranged between 56 and 198 µg/ml                         |                                               |
|                               | Antiviral              | Anti-herpes simplex virus type-1 assay   |         | The extract exhibited potential anti-viral activity at 50.00 µg/ml     |                                               |
|                               |                        |                                          |         | 100% viral inhibition when tested at the highest viral dose             |                                               |
| Leaves                        |                        |                                          |         |                                                                         |                                               |
| Hydroethanol                  | Antioxidant            | DPPH                                      | Brazil  | EC<sub>50</sub> = 5.68 µg/ml                                          | Donatini et al. (2009)                        |
| Methanolic extract            | Anti-inflammatory      | MDA                                       | India   | IC<sub>50</sub> = 0.17 µg/ml                                          | Reddy et al. (2014)                           |
|                               | Antioxidant            | Hyaluronidase inhibition assay           |         | IC<sub>50</sub> = 60.80% inhibition at 1 µg/ml                         |                                               |
|                               |                        | Nitric oxide assay                       |         | IC<sub>50</sub> = 41 ± 1.8 µg/ml                                      |                                               |
|                               |                        | Lipid peroxidation                       |         | IC<sub>50</sub> = 63 ± 1.6 µg/ml                                      |                                               |
|                               |                        |                                          |         | IC<sub>50</sub> = 48 ± 20 µg/ml                                       |                                               |
| Ethanol extract               | Antioxidant            | ABTS                                      | Bangladesh | IC<sub>50</sub> = 57.80 µg/ml                                       | Hossain et al. (2016)                         |
| Methanolic extract            | Antioxidant            | DPPH                                      | Egypt   | IC<sub>50</sub> = 5.7 ± 0.45 µg/ml                                     | Sobhe et al. (2018)                           |
| Ethanol extract               | Antioxidant            | FRAP                                       |         | IC<sub>50</sub> = 19.77 ± 0.79 mM                                     |                                               |
| Methanolic extract            | Anticancer             | XTT                                       | South Africa | IC<sub>50</sub> < 60 µg/ml against the HeLa and A431 cell line       | Twilley et al. (2017)                         |
|                               | Antiviral              | Cytotoxic effect (CPE) inhibition assay   |         | Potential antiviral activity with 100% viral inhibition for both (10 and 100 TCID<sub>50</sub>) viral doses against HSV-1 |                                               |
| Methanolic, hexane and dichloromethane extract | Antioxidant | DPPH                                      | Thailand | IC<sub>50</sub> = 1.17 ± 0.30 µg/ml At 100 µg/ml, extracts of hexane and dichloromethane exhibited HSV-1/HSV-2 inhibitory activity greater than 50% inhibition | Athikomkulchaisi et al. (2003) |
| 70% aqueous acetone extract   | Cytotoxicity           | MTT assay                                 | Taiwan  | IC<sub>50</sub> = 10.2 µg/ml strongest cytotoxic effect on human promyelocytic leukemia cells (HL-60) | Yang et al. (2000) |
| Methanol extract              | Cytotoxicity           | SRB assay                                 | Egypt   | At 100 µg/ml, the extract exhibited an increase of MCF-7 cell proliferation | Rocchetti et al. (2019) |
| 85% MeOH Delfatted 85% MeOH   | Antioxidant            | Phosphomolybdenum assay                   | Egypt   | 538.20 mg AAE/g extract 619.51 mg AAE/g extract 147.96 mg AAE/g extract 222.76 mg AAE/g extract 460.15 mg AAE/g extract 643.90 mg AAE/g extract 315.44 mg AAE/g extract | Gnareebo et al. (2016) |
| Petroleum ether               |                        |                                          |         |                                                                         |                                               |
| Dichloromethane               |                        |                                          |         |                                                                         |                                               |
| Ethyl acetate                 |                        |                                          |         |                                                                         |                                               |
| n-Butanol                     |                        |                                          |         |                                                                         |                                               |
| Aqueous extract               | Antioxidant            | DPPH                                      | Bangladesh | IC<sub>50</sub> = 14.10 µg/ml                                         | Islam et al. (2012) |
| Ethanol extract               | Antioxidant            | DPPH                                      | India   | PI = 19.63–30.56% of inhibition at 2% of extract                       | Deka et al. (2021) |
| Methanolic extract            | Antioxidant            | DPPH                                      | Egypt   | IC<sub>50</sub> = 48.13 µg/ml                                         | Khalaf et al. (2021) |
| Ethanol extract               | Antioxidant            | DPPH                                      | India   | IC<sub>50</sub> = 38.73 µg/ml                                         | Rajkumari et al. (2018b) |
| Aqueous ethanolic extract     | Antioxidant            | DPPH                                      | Egypt   | IC<sub>50</sub> = 48.13 ± 0.69 µg/ml                                   | Nawwar et al. (2016) |
|                               | Cytotoxicity           | ORAC assay                                |         | EC<sub>50</sub> = 13.52 ± 2.67 µg/ml                                   |                                               |
|                               |                        | Neutral red uptake assay                  |         | EC<sub>50</sub> = 34.35 ± 12.45 µg/ml                                  |                                               |
|                               |                        |                                          |         | HaCaT (IC<sub>50</sub> = 106.74 ± 10.89 µg/ml) Brain carcinoma cells (IC<sub>50</sub> = 55.24 ± 2.67 µg/ml) |                                               |
| Fruit                         |                        |                                          |         |                                                                         |                                               |
| Methanolic extract            | Antioxidant            | DPPH                                      | United States | IC<sub>50</sub> = 92.0 ± 8.24 µg/ml                                  | Reynertson et al. (2008) |
| Hydroalcoholic extract        | Antioxidant            | DPPH                                      | Pahang   | IC<sub>50</sub> = 24.44 µg/ml                                         | Yunus et al. (2021) |
| Ethanol extract               | Antioxidant            | DPPH                                      | Malaysia | Lower activity, IC<sub>50</sub> = 24.44 µg/ml                        |                                               |

(Continued on following page)
acarbose ’ seed ’ stem ’ root ’ leaf ’ flesh ’ flower (Wen et al., 2019). In vivo studies showed that the infusion of the combined leaves of S. jambos and S. cumini had no significant effect on blood glucose levels in a randomized double-blind clinical trial in non-diabetic and diabetic subjects (Teixeira et al., 1990). However, a more recent study showed that the ethanol extract of leaves at two dose levels (374.5 mg/kg and 749 mg/kg, Po) lowered blood glucose levels in alloxan induced diabetic rabbits (Prastiwi et al., 2019). Moreover, an aqueous leaf extract from the plant showed better blood modulation of insulin resistance and organic extracts have shown significant capabilities in reducing radicals and heavy metal ions. In vivo anti-inflammatory activity of plant extracts has also been demonstrated with considerable endpoints. These biological characteristics of the plant could be related to their main chemical constituents. Flavonoids and ellagitannins are excellent free radical scavengers (Koagne et al., 2020). For this reason, they protect cells from aging and stress, and exerted anti-inflammatory activity of plant extracts has also been shown for some models. Indeed, S. jambos plant extracts have shown considerable anti-inflammatory activity towards some models. The analgesic potential has been ascribed to two glycosylate flavonoids occurring in rose apple namely, myricetin-3-O-β-D-xyloluranosyl-(1→2)-α-L-rhamnopyranoside and quercetin-3-O-β-D-xylopyranosyl-(1→2)-α-L-rhamnopyranoside. However, no mechanism of action of the recorded biological activity was proposed yet. Nevertheless, both antioxidant and anti-inflammatory activities encountered for S. jambos extracts and compounds are closely related. The anti-inflammatory potency of rose apple extracts is a key point in the uses of plant extracts to alleviate different illnesses. More importantly, the major constituents of S. jambos extracts, flavonoids and ellagitannins, are mostly glycosylated. They can then be found in large extent in the blood because of their water solubility. This parameter is quite important in drug development as it improves the therapeutic action of a drug. Accordingly, S. jambos constitutes a potential candidate to the development of potent traditional drugs against ROS and inflammation-induced illness.

CONCLUSION AND PERSPECTIVES

This review provides an up-to-date summary of S. jambos from the perspectives of its phytochemistry, pharmacology, traditional uses as well as toxicology. Phytochemical investigations have been focused on different organs of the plant, prepared with various organic and water solvents. These studies revealed the presence of flavonoids (flavones, chalcones, anthocyanins and
### TABLE 4 |  In vivo effects of *S. jambos* extracts.

| Extract       | Doses    | Route               | Model                                      | Activity            | Country  | Effects                                                                                                           | Reference                  |
|---------------|----------|---------------------|--------------------------------------------|---------------------|----------|-------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Aerial parts  |          |                     |                                            |                     |          |                                                                                                                                                                           |                            |
| Hydro-alcoholic | 100-300 mg/kg | Intraperitoneal injection | Male Sprague-Dawley rats | Anti-inflammatory | Venezuela | Analgesic effect on inflammatory cutaneous and deep muscle pain                                              | Ávila-Peña et al. (2007)   |
| Leaves        |          |                     |                                            |                     |          |                                                                                                                                                                           |                            |
| Hydroethanolic | 400 mg/kg | Oral                | Gastric injury induced by HCl/ethanol to rats | Anti-ulcerogenic   | Brazil   | Reduction of the subchronic ulcer                                                                              | Donatini et al. (2009)     |
| Ethanol       | 400 mg/kg | Oral                | Rats, induced with acute inflammation     | Anti-inflammatory   | Bangladesh | Acute anti-inflammatory activity                                                                                | Hossain et al. (2016)      |
| Methanolic    | 200 mg/kg | Oral                | Rats, CCl₄ acute induced hepatic injury    | Hepatoprotective   | Egypt     | The extract decreased the levels of all measured liver markers, including ALT, AST, TB, TC, TG, and MDA, while increasing GSH and SOD. Decrease the intracellular ROS level in a dose dependent manner by 59.22%, the survival activity was also very low and dose dependent | Sobeh et al. (2018)        |
|               | 200 μg/ml | Juglone induced oxidative stress | Caenorhabditis elegans | Antioxidant        |          |                                                                                                                                                                           |                            |
| Methanolic    | 100-200 mg/kg | Oral                | Paracetamol-induced hepatic damage in Wistar albino rats | Hepatoprotective   | -         | The extract caused a significant decrease in the serum hepatic enzyme levels, SGOT, SGPT, ALKP, and serum Bilirubin in dose-dependent manner | Selvam et al. (2013)       |
| Ethanol       | 300 mg/kg | Intraperitoneal injection/oral | Rats, CCl₄ induced hepatic injury | Hepatoprotective   | Bangladesh | Gradual normalization of serum markers enzyme (SGPT, SGOT, ALP), total bilirubin, total protein, and liver weight | Islam et al. (2012)        |
| Methanolic    | 250 mg/kg | NS                  | Rats, Ethylene glycol-induced urolithiasis model | Antiurolithiatic    | India     | reduced the phosphorus, calcium, urea, and creatinine levels in the serum                                       | Deka et al. (2021)         |
| Ethanol       | 500 μg/ml | NS                  | S. cerevisiae (wild type and mutant strain) | Antioxidant         | India     | H₂O₂ scavenging potential                                                                                       | Rajkumari et al. (2018b)   |
| Decoction     | 220 mg/kg | Oral                | C57BL/J ob/ob Mice                       | Hypoglycemic        | Puerto Rico | Better blood glucose modulation over time                                                                        | Gavilán-Suárez et al. (2015) |
| Bark          |          |                     |                                            |                     |          |                                                                                                                                                                           |                            |
| Aqueous       | 100-200 mg/kg | Oral                | Streptozocotin-induced diabetes in rats | Antidiabetic        | Egypt     | Protective effects against STZ-induced diabetes Improvement in glycemic parameters Suppression of pancreatic oxidative stress, inflammation, apoptosis, and insulin signaling pathway in the liver | Mahmoud et al. (2021)     |
| Fruit         |          |                     |                                            |                     |          |                                                                                                                                                                           |                            |
| Pectic polysaccharides | 150, 250 mg/kg | Intraperitoneal injection | Mice bearing Ehrlich solid tumor | Antitumor         | Brazil     | Reduced tumor growth and improved the body weight of tumor bearing mice                                         | Tamiello et al. (2018a)    |

Ns: Not specified.
proanthocyanins), ellagitannins, phenolic acids, triterpenoids, volatiles compounds and fatty analogues. Compounds were either isolated following chromatographic techniques or identified by online methods like HPLC-MS/MS and GC-MS. Flavonoids and saponins as well as phenolic acids are the main constituents of the plant.

Activities of the plant towards pathogens and cells are also diverse and rich, consecutive to the broad spectrum of applications of the plant in traditional medicine to alleviate some illnesses. Plant extracts showed considerable anti-inflammatory activity and a synergistic effect to antibiotics activity of some popular drugs correlating the uses of the plant to relieve pains and infection. Extracts have also antiviral, anti-dermatophyte, hepatoprotective, and anticancer effects. Numerous compounds were isolated and initially screened for their bioactive potential. Further investigations are needed to complete the phytochemical profile, pharmacology mechanisms and pharmacokinetics studies of the plant. In the same line, toxicity study of S. jambos is indispensable in the future to assess the safety of the plant and its bioactive compounds to support possible future medicinal applications and before proceeding to the development of pharmaceutical formulations.

AUTHOR CONTRIBUTIONS

MAO and WBB drafted the manuscript; GTMB and MFM reviewed the manuscript; MS revised the manuscript and designed and conceived the study. All authors approve the final version.

FUNDING

The APC was paid by UM6P.

REFERENCES

Abad, M. J., Bermejo, P., Villar, A., Sanchez Palomino, S., and Carrasco, L. (1997). Antiviral Activity of Medicinal Plant Extracts. Phytother. Res. 11 (3), 198–202. doi:10.1002/(sici)1099-1573(199705)11:3<198::aid-ptr78>3.0.co;2-1

Apaza Ticona, L., Souto Pérez, B., Martín Alejano, V., and Slowíng, K. (2021). Anti-inflammatory and Anti-arthritic Activities of Glycosylated Flavonoids from Syzygium Jambos in Edematogenic Agent-Induced Paw Edema in Mice. Rev. Bras. Farmacogn. 31 (4), 429–441. doi:10.1016/s1345-0210-00167-0

Athikomkulchai, S., Lipipun, V., Leelawittayanont, T., Khanboon, A., and Ruangrungsi, N. (2008). Anti-herpes Simplex Virus Activity of Syzygium Jambos. J. Health Res. 22 (1), 49–51.

Ávila-Peña, D., Peña, N., Quintero, L., and Suárez-Roca, H. (2007). Antinociceptive Activity of Syzygium Jambos Leaves Extract on Rats. J. Ethnopharmacol. 112 (2), 380–385. doi:10.1016/j.jep.2007.03.027

Baliga, M. S., Ranganath Pai, K. S., Saldanha, E., Ratnou, V. S., Priya, R., Adnan, M., et al. (2017). "Rose Apple (Syzygium Jambos (L. Alston)) in Fruit and Vegetable Phytochemicals: Chemistry and Human Health. Editor E. M. Yahia. Second Edition 2 (Boeken, NJ, USA: John Wiley and Sons), 1235–1242.

Bonfanti, G., Bitencourt, P. R., Bona, K. S., Silva, P. S., Jantsch, L. B., Pigatto, A. S., et al. (2013). Syzygium Jambos and Solanum Guaranitica Show Similar Antioxidant Properties but Induce Different Enzymatic Activities in the Brain of Rats. Molecules 18 (8), 9179–9194. doi:10.3390/molecules18089179

Chakravarty, A. K., Das, B., Sarkar, T., Masuda, K., and Shiojima, K. (1998). ChemInform Abstract: Ellagic Acid Derivatives from the Leaves of Eugenia Jambos Linn. ChemInform 30 (25), no. doi:10.1002/chin.199925211

Chua, L. K., Lim, C. L., Ling, A. P. K., Chye, S. M., and Koh, R. Y. (2019). Anticancer Potential of Syzygium Species: a Review. Plant Foods Hum. Nutr. 74 (1), 18–27. doi:10.1007/s11130-018-0704-z

Cock, I. E., and Cheesman, M. (2018). "Bioactive Compounds of Medicinal Plants," in Bioactive Compounds of Medicinal Plants: Properties and Potential for Human Health. Editors M. R. Goyal and A. O. Ayeleso (Williston: Apple Academic Press), 35–84.

Daly, J., Hamrick, D., Gary, G., and Guinn, A. (2016). Maize Value Chains in East Africa. London, United Kingdom: International Growth Centre, 1–50.

Deka, K., Kakoti, B. B., and Das, M. (2021). Antiulcerative Activity of Leaf Extracts of Syzygium Jambos (L.) Alston and its Zinc Nanoparticles: an In-Vitro and In-Vivo Approach. Int. J. Pharm. Sci. Res. 12 (1), 336–346. doi:10.13040/IJPSR.0975-8232.12(1).336-46

Dhanaban, R. M. P., and Devakumar, J. (2014). In Vivo antiplasmoidal Activity of Four Folklore Medicinal Plants Used Among Tribal Communities of Western Ghats, Coimbatore, Tamil Nadu. J. Pharm. Res. 8 (6), 751–759.

Djipa, C. D., Delmée, M., and Quetin-Leclercq, J. (2000). Antimicrobial Activity of Bark Extracts of Syzygium Jambos (L.) Alston (Myrtaceae). J. Ethnopharmacol. 71 (1–2), 307–313. doi:10.1016/s0378-8741(99)00186-5

Donatini, R. S., Ishikawa, T., Barros, B. S. M., and Bacchi, E. M. (2009). Atividades antinociceptoras e antioxidantes de extratos de folhas de Syzygium jambos (L.) Alston (Myrtaceae). Rev. Bras. Farmacogn. 19, 89–94. doi:10.1590/s0102-093520090001000018

Donatini, R. S., Kato, E., Ohara, M. T., and Bacchi, E. M. (2013). Morphoanatomy and Antimicrobial Study of Syzygium Jambos (L.) Alston (Myrtaceae) Leaves. Lat. Am. J. Pharm. 32 (4), 518.

Dutta, P., Bordoloi, M., Gogoi, K., Roy, S., Narzary, B., Bhattacharyya, D. R., et al. (2017). Antimalarial Silver and Gold Nanoparticles: Green Synthesis, Characterization and In Vitro Study. Biomed. Pharmacother. 91, 567–580. doi:10.1016/j.biopha.2017.04.032

Gavilán-Suárez, J., Aguilar-Pérez, A., Rivera-Ortiz, N., Rodríguez-Tirado, K., Figueroa-Cuñan, W., Morales-Santiago, L., et al. (2015). Chemical Profile and In Vivo Hypoglycemic Effects of Syzygium Jambos, Costus Speciosus and Tapeinochilos Ananassae Plant Extracts Used as Diabetes Adjuvants in Puerto Rico. BMC Complement. Altern. Med. 15, 244. doi:10.1186/s12906-015-0772-7

Ghareeb, M. A., Saeed, A. M., Abdel-Azeem, A.-a., H. Saad, A. M., Abdel-Aziz, M. S., and Hadad, A. (2017). Extraction, Isolation, and Characterization of Bioactive Compounds and Essential Oil of Syzygium Jambos. Asian J. Pharm. Clin. Res. 10 (8), 194. doi:10.22159/ajpcr.2017.v10i8.18849

Ghareeb, M. A., Saad, A. M., Abdel-Aleem, A. H., Abdel-Aziz, M. S., Hamed, M. M., and Hadad, A. H. (2016). Antioxidant, Antimicrobial, Cytotoxic Activities and Biosynthesis of Silver and Gold Nanoparticles Using Syzygium Jambos Leave Growing in Egypt. Der Pharm. Chem. 8, 277–286.

Guedes, C. M., Pinto, A. B., Moreira, R. F. A., and De Maria, C. A. B. (2004). Study of the Aroma Compounds of Rose Apple (Syzygium Jambos Alston) Fruit from Brazil. Eur. Food Res. Technol. 219 (5), 460–464. doi:10.1007/s00217-004-0967-5

Haque, M. (2015). Investigation of the Medicinal Potentials of Syzygium Jambos (L.) Extract and Characterization of the Isolated Compounds. Am. J. BioScience 3 (2), 12. doi:10.11648/j.jbis.2015030201.13

Harsha, P. V., Ashoka, S. M., Karunakar, H., and Shabaraya, A. R. (2021). Syzygium Jambos: A Brief Review. World J. Pharm. Pharm. Sci. doi:10.20959/wjpps2021-18583

Hossain, H., Rahman, S. E., Akbar, P. N., Khan, T. A., Rahman, M. M., and Jahan, I. A. (2016). HPLC Profiling, Antioxidant and In Viro Anti-inflammatory Activity of the Ethanol Extract of Syzygium Jambos Available in Bangladesh. BMC Res. Notes 9, 191. doi:10.1186/s13104-016-2000-z

Inostroza-Nieves, Y., Valentín-Berrios, S., Vega, C., Prado, G. N., Luciano-Montalvo, C., Romero, J. R., et al. (2021). Inhibitory Effects of Syzygium
Proinflammatory Stimulus. *Int. J. Biol. Macromol.* 107, 35–41. doi:10.1016/j.ijbiomac.2017.08.148

Teixeira, C. C., Fuchs, F. D., Blotta, R. M., Knijnik, J., Delgado, I. C., Netto, M. S., et al. (1990). Effect of tea Prepared from Leaves of Syzygium Jambos on Glucose Tolerance in Nondiabetic Subjects. *Diabetes Care* 13 (8), 907–908. doi:10.2337/diacare.13.8.907

Thamizh Selvam, N., Acharya, M., Venkatakrishnan, V., and Murugesan, S. (2016). Effect of Methanolic Extract of *Syzygium Jambos* Linn. Leaves at Intra Syzygium Jambos Cellular Level in Selective Liver Cancer Cell Line: Molecular Approach for its Cytotoxic Activity. *Adv. Pharm. J.* 1 (5), 139.

Ticona, L. A., Pérez, B. S., Alejandro, V. M., and Slowing, K. (2021). Anti-inflammatory and Anti-arthritic Activities of Glycosylated Flavonoids from Syzygium Jambos in Edematogenic Agent-Induced Paw Edema in Mice. *Rev. Bras. Farmacogn.* 31, 429–441. doi:10.1007/s43450-021-00167-0

Twilley, D., Langhansová, L., Palaniswamy, D., and Lall, N. (2017). Evaluation of Traditionally Used Medicinal Plants for Anticancer, Antioxidant, Anti-inflammatory and Anti-viral (HPV-1) Activity. *South Afr. J. Bot.* 112, 494–500. doi:10.1016/j.sajb.2017.05.021

Vagula, J. M., Visentainer, J. V., Lopes, A. P., Maistrovicz, F. C., Rotta, E. M., and Suzuki, R. M. (2019). Antioxidant Activity of Fifteen Seeds from Fruit Processing Residues by Different Methods. *Acta Sci. Technol.* 41, e35043. doi:10.4025/actascitechnol.v41i2.35043

van Wyk, B.-E., and Wink, M. (2015). *Phytomedicines, Herbal Drugs, and Poisons*. Chicago: The University of Chicago Press.

Vernin, G., Vernin, G., Metzer, J., Roque, C., and Pierbattesti, J.-C. (1991). Volatile Constituents of the Jamrosa Aroma*Syzygium jambos*. Aston from Reunion Island. *J. Essent. Oil Res.* 3 (2), 83–97. doi:10.1080/10412905.1991.9697916

Wamba, B. E. N., Nayim, P., Mbaveng, A. T., Voukeng, I. K., Dzotam, J. K., Ngalin, O. J. T., et al. (2018). Syzygium Jambos Displayed Antibacterial and Antibiotic-Modulating Activities against Resistant Phenotypes. *Evid. Based Complement. Alternat. Med.* 2018, 5124735. doi:10.1155/2018/5124735

Wen, Z., Ling, M., Yu, S., Zhuang, Y., Luo, X., Pan, Z., et al. (2019). Study on Inhibitory Effects of Ethanol Extract of Different Medicinal Parts from Syzygium Jambos on the Activities of α-Glycosidase and α-Amylase. *China Pharm.*., 3246–3251.

Wong, K. C., and Lai, F. Y. (1996). Volatile Constituents from the Fruits of *Syzygium Jambos* Species Grown in Malaysia. *Flavour Fragr. J.* 11 (1), 61–66. doi:10.1002/sfc1099-1026(19960111):1<61::aid-ffj539>3.0.co;2-1

Yang, L. L., Lee, C. Y., and Yen, K. Y. (2000). Induction of Apoptosis by Hydrolyzable Tannins from Eugenia Jambos L. On Human Leukemia Cells. *Cancer Lett.* 157 (1), 65–75. doi:10.1016/S0304-3835(00)00477-8

Yunus, S. N. M., Abas, F., Jaafar, A. H., Azizan, A., Zolkeeffy, N. K. Z., and Abd Ghafar, S. Z. (2021). Antioxidant and α-glucosidase Inhibitory Activities of Eight Neglected Fruit Extracts and UHPLC-MS/MS Profile of the Active Extracts. *Food Sci. Biotechnol.* 30 (2), 195–208. doi:10.1007/s10068-020-00856-x

Zheng, N. L., Wang, Z., Chen, F., and Liu, J. (2011). Evaluation to the Antioxidant Activity of Total Flavonoids Extract from Syzygium Jambos Seeds and Optimization by Response Surface Methodology. *Afr. J. Pharm. Pharmacol.* 5 (21), 2411–2419. doi:10.5897/ajpp11.691

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

**Publisher’s Note:** All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

**Copyright © 2022 Ochieng, Ben Bakrim, Bitachago, Mahmoud and Sobeh. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.