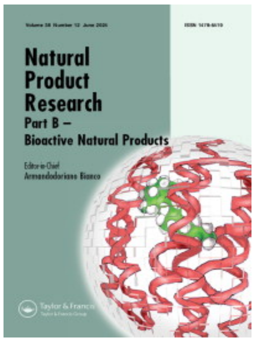

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Pachira aquatica: biological activity and chemical composition of leaves, flowers, and seeds

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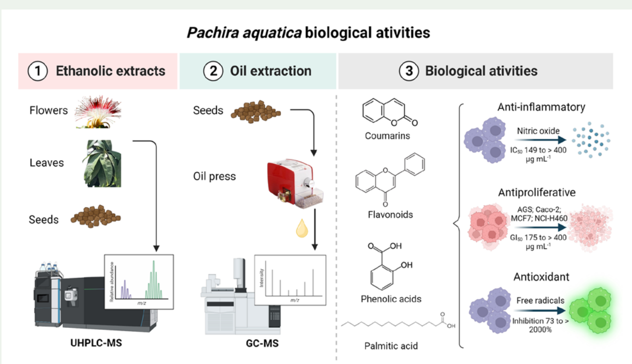
ABSTRACT

The chemical composition of *Pachira aquatica* crude extracts flowers, leaves, and seeds was obtained by UHPLC-ESI/qTOF and GC/MS. The antiproliferative activity was evaluated against the human tumour cell lines AGS (gastric), CaCo-2 (colorectal), MCF-7 (breast), and NCI-H460 (lung). The anti-inflammatory and cellular antioxidant activities were also studied. Flavonoids, phenolic acids, coumarins, and saturated fatty acids were identified in the samples. The concentration of extracts responsible for inhibiting 50% of nitric oxide production ranged from (149 to > 400 μg mL^{-1}). Antiproliferative activity against the tumour cell lines was: AGS (GI_{50} 175 to > 400 μg mL^{-1}), Caco-2 (GI_{50} 215 to > 400 μg mL^{-1}), MCF7 (GI_{50} 232 to > 400 μg mL^{-1}) and NCI-H460 (GI_{50} 208 to > 400 μg mL^{-1}). Cellular antioxidant activity remained between 73% to > 2000%. The selectivity index (SI) ranged from 1.00 to 2.78, indicating low antiproliferative activity.



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1. Introduction

Pachira aquatica belongs to the Malvaceae family and the Bombacaceae subfamily. It is native to southern Mexico, northern Peru, and north of Brazil. Popularly known as wild cacao, Guiana nut, and munguba, this species is used in urban landscaping and the restoration of wetlands, degraded soils, and forests (Silva Correia et al. 2022).

In traditional medicine, monguba has been utilised by indigenous people and midwives for the treatment of some diseases (Rodrigues and Pastore 2021). The seeds are employed in human and animal food due to their high lipid content (38.4%) (Jorge and Luzia 2012) and to address earache and eye inflammation. The bark of the stem treats diabetes, cholesterol, scabies (Pantoja et al. 2020), rheumatism, spider bites, and liver problems (Silva and Fraxe 2014). The husks of the seeds are applied to treat diarrhoea, skin rashes, wounds, and anaemia (Coe et al. 2011). The leaves address skin rashes and urticaria (Alfaro 1984). In addition, the flowers are employed in cooking and preserving pollinators such as bees, bats, and moths (Hernández-Montero and Sosa 2016).

The fatty acid profile of *P. aquatica* seeds was determined by Jorge and Luzia (2012), identifying palmitic acid (44.9%), oleic acid (39.3%), and linoleic acid (11.4%) as the most abundant. Sunday et al. (2019) identified as major fatty acids palmitic acid (49.3%) in the hexane extract obtained by soxhlet from *P. aquatica* seeds. Additionally, flavonoids, phenolic acids, and organic acids were identified in the ethanolic extracts of the leaves and seeds of *P. aquatica* (Rezende et al. 2021).

The seed oil obtained by pressing showed antitumor activity (Marcelino et al. 2020). The leaf extract of *P. aquatica* showed activity against infection by *Mycobacterium tuberculosis* and *Helicobacter pylori* (Gamal El-Din et al. 2018). The stem extract of *P. aquatica* presented anti-inflammatory activity (Cheng et al. 2017).

Considering the ethnobotanical importance and the biological properties of *P. aquatica*, this study investigated the leaves, flowers, and seeds' anti-inflammatory, antiproliferative, and antioxidant activities.

2. Results and discussion

The yield of the crude extracts obtained by dynamic maceration with the renewal of solvent (ethyl alcohol) was 15.1% for leaves, 36.9% for flowers, and 51.9% for seeds. The solvent choice can influence the yield of the extracts. In our study, ethanol: water, in different proportions, were used as extractor solvents (Experimental section 1.2). The results indicated a higher yield of seed extract when compared to Souza et al. (2014), who obtained a gain of 1.2% of *P. aquatica* seed extract using acetone and the same extractive method (dynamic maceration). The oil yield obtained by pressing the seeds (43%) was similar to that reported by Marcelino et al. (2020), who got 38% seed oil yield by cold pressing. Raiser et al. (2018) used ultrasound-assisted extraction with hexane to get oil from seeds of *P. aquatica*, with a 42.7% yield.

The compounds identified in the crude extracts of leaves, flowers, and seeds are in Table S1, and the distribution of compounds identified is presented in a Venn diagram (Figure S1). Twenty-three compounds were identified in the oil obtained by pressing the seeds, mostly palmitic acid (20.1%) (Table S2). Palmitic acid (C16:0) is a saturated fatty acid used in the preparation of soaps and in the manufacture of personal care products and is considered a surfactant used as a cleaning agent (Japir et al. 2021; Jayawardena et al. 2021). The high content of saturated fatty acids gives this oil a buttery appearance (Marangoni and Ghazani 2021). The comparative analysis of the compounds identified in the leaves and seeds of *P. aquatica* in this study with previously published data (Table S6) revealed that seeds are the most investigated.

Flavonoids and phenolic acids were identified in the extracts from leaves, flowers, and seeds (Table S1). Rodrigues et al. (2019) identified ten phenolic compounds in *P. aquatica* seeds, mainly flavonoids (142 μg/g DW) and phenolic acids (773.75 μg/g DW). Complementarily, da Silva et al. (2020) found total flavonoids (29.40 mg/100g) and anthocyanins (1.42 mg/g) in the seeds, suggesting that *P. aquatica* seeds are good sources of phenolic compounds. The presence of catechins identified only in the seed extract may explain the high antioxidant power found (>2000%) (Table S5). Sheng et al. (2023) state that catechins have potent antioxidant activity. This activity largely depends on the structure of the molecules, the number and location of hydroxyl groups or their substituents, and the distribution of hydroxyl groups. A vicinal dihydroxyl group in ring B and a galloyl group in position 3 are essential for eliminating free radicals.

The crude seed extract showed more significant inhibition of nitric oxide production (IC_{50} =149 μg mL^{-1}) when compared to the other samples (IC_{50} > 400 μg mL^{-1}) (Table S3). Here, we again suggest that catechins may be responsible for the anti-inflammatory potential found. Sunil et al. (2021) and Xu et al. (2021) investigated catechins' anti-inflammatory and cellular antioxidant potential (CAA), respectively. According to Sunil et al. (2021), in RAW 264.7 macrophages pre-treated with catechin (100 μg mL^{-1}), the secretion of TNF-α (tumour necrosis factor-α) was reduced by 6.7 times after stimulation with lipopolysaccharide (LPS). Xu et al. (2021) investigated the CAA of catechins, determined by the production of cellular reactive oxygen species (ROS). The combination of catechins (67.4% epigallocatechin and 32.6% epigallocatechin gallate) exerted CAA against OVCAR-3 (human ovarian carcinoma) and HFL1 (human foetal lung fibroblast) cells. The catechins reduced the fluorescence in OVCAR-3 cells at the highest dose (100 μg mL^{-1}), and in the HFL1 strain, they decreased hydrogen peroxide-induced oxidation at low dosages (10 μg mL^{-1}).

The studied extracts and seed oil showed low or none antiproliferative potential against the tested human tumour cell lines (GI_{50} between 175 and >400 μg mL^{-1}) when compared to the ellipticine positive control (GI_{50} = 1.01 to 1.41 μg mL^{-1}) (Table S4). However, ellipticine is an isolated compound, but in the extracts and seed oil, the compounds are found in crude form, thus justifying the low antiproliferative potential.

The crude extracts of the leaves exhibited an inhibitory effect on AGS tumour cells with a GI_{50} of 175 μg mL^{-1}. Therefore, we can suggest that the presence of amentoflavone identified only in the leaves of *P. aquatica* (Table S1) could have been responsible for this activity. In addition, amentoflavone isolated from *Selaginella doederleinii* extract ('da ye cai') exhibit high antiproliferative potential against A549 cells (GI_{50} = 36.3 μg mL^{-1}), and PC-9 cells from human lung carcinoma (GI_{50} = 6.49 μg mL^{-1}); K562 cells from human erythroleukemia (IC_{50} = 5.25 μg mL^{-1}); HL60 cells from human acute promyelocytic leukaemia (IC_{50} = 46.3 µg mL^{-1}) and CNE2 cells from human nasopharyngeal carcinoma (IC_{50} = 17.30 µg mL^{-1}) (Li et al. 2014).

The crude extract of seeds also presented antiproliferative potential on the AGS cell line with GI_{50} of 194 µg mL^{-1}, suggesting that catechins found only in the seeds (Table S1) could be responsible for this activity. In a related manner, a catechins mixture (67.4% epigallocatechin and 32.6% epigallocatechin gallate) from *Chrysanthemum morifolium* presented antiproliferative activity against OVCAR-3 cells (GI_{50} = 1094 µg mL^{-1}), HEK293 cells from the human embryonic kidney (GI_{50} = 599.6 µg mL^{-1}), and HFL1 cells (GI_{50} = 412.9 µg mL^{-1}) (Xu et al. 2021).

3. Conclusions

The crude extract of *Pachira aquatica* seeds shows high cellular antioxidant activity (>2000%) and anti-inflammatory potential (IC_{50} = 149 µg mL^{-1}). When evaluated in tumour cells, the crude extract of leaves (GI_{50} = 175 µg mL^{-1}) and the seeds (GI_{50} = 194 µg mL^{-1}) show activity against gastric adenocarcinoma cells. This is the first study about *P. aquatica* flowers. The antioxidant, anti-inflammatory, and antiproliferative activities found in the seeds, flowers, and fruits of *P. aquatica* support future studies.

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Disclosure statement

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