HSPC The Open Access Publisher

IJCMBT ISSN 2766-3264 INTERNATIONAL JOURNAL OF CLINICAL MICROBIOLOGY AND BIOCHEMICAL TECHNOLOGY

Research Article

Chemical constituents and biological activities of *Artocarpus heterophyllus* lam (Jackfruit): A review

Pranay Raja Bhad, Meeneri Vilas Bobde and Sibi G*

Department of Biotechnology, Indian Academy Degree College, Autonomous, Bangalore, India

Abstract

Artocarpus (Moraceae) is a deciduous tree with appreciable importance as a source of edible fruit and is widely used in folk medicines. The extracts and metabolites of *Artocarpus heterophyllus* particularly those from leaves, bark, stem and fruit possess several useful bioactive compounds. This review indents to compile various studies on *A. heterophyllus* and critically evaluates its ethnomedical and ethnopharmacological properties. Several pharmacological studies from *A. heterophyllus* have conclusively established their mode of action in anti-inflammatory, antimicrobial, antioxidant and anticancer activities. Based on the available data, it is concluded that *Artocarpus* as a promising source of useful products and opens up new avenues for novel therapeutics.

More Information

***Address for Correspondence:** Sibi G. Head of the Department, Department of Biotechnology, Indian Academy Degree College, Autonomous, Bangalore, India, Email: gsibii@gmail.com

Submitted: December 24, 2020
Approved: January 19, 2021
Published: January 20, 2021

How to cite this article: Bhad PR, Bobde MV, Sibi G. Chemical constituents and biological activities of *Artocarpus heterophyllus* lam (Jackfruit): A review. Int J Clin Microbiol Biochem Technol. 2021; 4: 005-009.

DOI: 10.29328/journal.ijcmbt.1001019

Keywords: *Artocarpus heterophyllus*; Jackfruit; Antimicrobial; Anticancer; Antioxidant

Introduction

Artocarpus heterophyllus Lam (Jackfruit), belonging to the family Moraceae is distributed through tropics and subtropics. The tree has a straight rough stem and a green or black bark exuding milky latex. The leaves are broad, elliptic, dark green in colour and alternate. Jackfruit flesh and seeds contain more protein, calcium, iron, and Thiamine [1]. Jackfruit contains many classes of phytochemicals such as carotenoids, flavonoids, volatile acids sterols, and tannins, with varying concentrations. The exceptional medicinal value of *Artocarpus* has long been recognized.

Various parts of the tree such as seeds, leaves, latex, roots have been used as traditional medicines. Jackfruit is a rich source of phenolics and flavonoids having good antioxidant properties [2,3]. Jackfruit pulp is rich in carbohydrates, protein, amino acid, polyphenol, fatty acid, vitamin and minerals, which can be used as good sources for some important nutrients [4-7]. Jackfruit peel extract contains phenolics, flavonoids in which prenylflavonoids, hydroxycinnamic acids and glycosides are the predominant bioactive compounds. Leaves are leaves are rich in phenolic acids, flavonoids, terpenoids, stilbenoids [8] and used for asthma, diarrhea, anemia and dermatitis treatment [9]. Wood and bark of this plant are rich sources of prenylated flavonoids, stilbenoids, triterpenoids, and steroids [10]. This review aimed to summarize the biological activities of bioactive compounds from various parts of *A. heterophyllus* reported in earlier studies.

Sources and methodology

The search was done in electronic databases of PubMed, Scopus, ScienceDirect, Web of Science and Google Scholar for studies using the key terms: *Artocarpus heterophyllus,* jackfruit, anticancer, antimicrobial, anti-inflammatory and bioactive compounds. The inclusion was based reported articles on biological activities of *A. heterophyllus* which are discussed in detail. All the data were extracted and explained in respective subheadings.

Phytochemicals

Tetracyclic triterpenoids, 9,19-cyclolanost-3-one-24,25-diol and 9,1-cyclolanost-3-one-24, 2Sdiol along with cycloartenone and cycloartenol have been isolated by Barik, et al. [11]. Yuan, et al. [12] isolated flavonoids such as Artoheteroids A-D, morin, artocarmin A, albanin A, euchrenone A, norartocarpanone and steppogenin from *A. heterophyllus.*

A new prenylated flavonoid, 3-prenyl luteolin (1) was isolated from *A. heterophyllus* wood extract [13]. In another study, an 2-arylbenzofuran derivative, artocarstilbene B and

benzaldehyde derivative, (E)-3,5- dihydroxy-4-(3-methyl-but-1-enyl)benzaldehyde were obtained from the leaves of *A. heterophyllus* [14]. Liu et al., [15] isolated seven prenylated chromones and five prenylated flavonoids, including two new prenylated chromones, artoheterophines A and B. Zheng, et al. [16] isolated new phenolic compounds, artoheterophyllins E-J, 4-geranyl-2',3,4',5-tetrahydroxy-cis-stilbene, and 5-methoxymorican M. Also 2 new natural compounds, 2,3-dihydro-5,7-dihydroxy-2-(2-hydroxy-4-methoxyphenyl)-4H-benzopyran-4-one and 6-[(1S,2S)-1,2-dihydroxy-3-methylbutyl]-2-(2,4-dihydroxyphenyl)-5-hydroxy-7-methoxy-3-(3-methyl-2-buten-1-yl)-4H-1-benzopyran-4-one were also isolated from the ethanol extract of *A. heterophyllus* wood. In the earlier studies, Zheng, et al. [17] isolated furanoflavone,7-(2,4-dihydroxyphenyl)-4-hydroxy-2-(2-hydroxypropan-2-yl)-2, 3-dihydrofuro(3, 2-g)chromen-5-one (artocarpfuranol), together with 14 known compounds, dihydromorin, steppogenin, norartocarpetin, artocarpanone, artocarpesin, artocarpin, cycloartocarpin, cycloartocarpesin, artocarpetin, brosimone I, cudraflavone B, carpachromene, isoartocarpesin, and cyanomaclurin were isolated from the wood of *A. heterophyllus*.

Zheng, et al. [18] isolated phenolic compounds, including one isoprenylated 2-arylbenzofuran derivative, artoheterophyllin A, and three isoprenylated flavonoids, artoheterophyllin B, artoheterophyllin C, and artoheterophyllin D from the ethanol extract of the twigs of *A. heterophyllus*. Fu, et al. [19] purified artocarheterones A-E from the ripe fruits of *A. heterophyllus*. In a study by Septama, et al. [20], dihydromorin and norartocarpetin were isolated from *A. heterophyllus* heartwoods.

Anti-inflammatory

Extracts of jackfruit pulp showed anti-inflammatory activity by suppressing the lipopolysaccharide (LPS)-induced production of nitric oxide and prostaglandin E2 reactive oxygen species in RAW264.7 cells [21]. Similarly, prenylated chromones from *A. heterophyllus* exhibited significant inhibitory activities against nitric oxide production showing IC_{50} values in range of 0.48 to 19.87 μM [15]. Artoheterophoid displayed inhibitory effects against nitric oxide production with the IC_{50} values in the range of 0.72 to 5.93 μM [22]. Artocarpanone and artocarpin strongly inhibited myeloperoxidase activity of human phagocytes with an IC_{50} value of 23.3 μm and have potential to be developed into potent anti-inflammatory agents [23]. Meera, et al. [24] studied the anti-inflammatory effect of ethanolic extracts of spine, skin and rind of jack fruit. The results revealed that skin extract exhibited maximum anti-inflammatory activity, rind had preferential inhibition on Cyclooxygenase-2 and spine and skin inhibited both Cyclooxygenase-1 and 2 *in vitro*.

Moracin significantly inhibited lipopolysaccharide-activated reactive oxygen species and nitric oxide release without marked cytotoxicity [25]. Furthermore, it effectively reduced LPS stimulated up-regulation of mRNA and protein expression of inducible nitric oxide synthase, cyclooxygenase-2 and serval pro-inflammatory cytokines, interleukin-6 and tumor necrosis factor α. The administration of jackfruit leaves extracts to streptozotocin-diabetic rats significantly reduced fasting blood glucose from 200 to 56 and 79 mg%, respectively; elevated insulin from 10.8 to 19.5 and 15.1 μU/ml, respectively; decreased lipid peroxides from 7.3 to 5.4 and 5.9 nmol/ml, respectively; decreased %glycosylated hemoglobin A1C (%HbA1C) from 6.8 to 4.5 and 5.0%, respectively; and increased total protein content from 2.5 to 6.3 and 5.7 mg%, respectively [26].

Antioxidant activity

Jackfruit contains many carotenoids including all-trans-β-carotene with an important antioxidant activity for human health [27,28]. Jackfruit exhibited not only free radical scavenging activities but also acted as a significant protective agent against H_2O_2 + UV and γ-irradiation induced DNA damage [29]. Zhu, et al. [30] found polysaccharide from jackfruit pulp as a dietary source of antioxidant phytochemicals that survive the gastrointestinal digestion process. The authors also showed that jackfruit pulp exhibited strong DPPH and OH radical scavenging activities, with a relatively lower reducing power [31]. Similarly, ethyl acetate fraction of jackfruit showed radical scavenging activities between 80% - 94% inhibition due to the presence of phenolic compounds [32]. Another study revealed that protocatechuic acid and chlorogenic acid in rind and rachis extracts of jackfruit contribute to the antioxidant activity [33]. Whereas, Ko, et al. [34] reported flavonoids from the leaf, root and bark methanol extracts of *A. heterophyllus* contributed significantly to the antioxidant activities.

Antioxidant activities of non-extractable polyphenols from jackfruit pulp were tested by ABTS+, oxygen radical scavenging activity and peroxyl radical scavenging ability assays [35]. The results indicated that polyphenols recovered from alkaline hydrolysis showed the most scavenging abilities. Biworo, et al. [36] reported that jackfruit extract exhibited antioxidant activities by decreasing the formation of reactive oxygen species. Leaf extracts of *A. heterophyllus* showed significant antioxidant activity tested in DPPH, ABTS, FRAP and Fe^{2+} chelating activity assays [37]. In DPPH assay, *A. heterophyllus* total extract exhibited a strong antiradical activity with an IC_{50} value of 73.5 μg/ml while aqueous fraction exerted the highest activity in FRAP assay (IC_{50} value of 72 μg/ml). Jagtap, et al. [2] showed jackfruit pulp extract has higher ability to reduce DPPH, Fe^{3+} to Fe^{2+} and N, N-dimethyl-p-phenylenediamine *in vitro*.

Antimicrobial activity

Jackfruit leaves exhibited antifungal activity against *Colletotrichum gloeosporioides* and *Penicillium italicum* due to the presence of quinic acid, catechin and chlorogenic acid [9].

In another study, butanol fractions of the root bark and fruits exhibited a broad spectrum of antibacterial activity [38]. Antimicrobial activity of protease from jackfruit latex was evaluated by Siritapetawee, et al. [39] and the results revealed that it could inhibit the growths of *Pseudomonas aeruginosa* ATCC 27853 and *Candida albicans* at minimum inhibitory concentration of 2.2 mg/ml and minimum microbicidal concentration of 8.8 mg/ml. Similarly, antifungal activity of *A. heterophyllus* latex against post-harvest fungal pathogens was reported by Sibi, et al. [40]. Dihydromorin had a strong effect against Streptococcus pyogenes with MIC and MBC values of 15.62 and 31.25 µg/ml, respectively [20].

In a study by Septama and Panichayupakaranant [41], antibacterial compounds such as cycloartocarpin, artocarpin, artocarpanone and cyanomaclurin were isolated from heartwood of *A. heterophyllus*. The compounds exhibited the strongest antibacterial activity *Streptococcus mutans, S. pyogenes, Bacillus subtilis, Staphylococcus aureus* and *S. epidermidis* with MICs of 4.4, 4.4, 17.8, 8.9 and 8.9 µM, respectively and MBCs of 8.9, 8.9, 17.8, 8.9 and 8.9 µM, respectively. The authors also reported that artocarpin showed antibacterial activity against methicillin-resistant *Staphylococcus aureus* and *E. coli* with an MIC value of 62.5 µg/ml, and against *P. aeruginosa* with an MIC value of 250 µg/ml. The authors also also investigated the activity of artocarpanone against diarrheal pathogenic bacteria including *Escherichia coli, Vibrio cholera, Shigella sonnei, Salmonella typhimurium*, and *S. typhi*. Artocarpanone displayed strong antibacterial activity against *E. coli* with MIC and MBC value of 3.9 and 7.8 µg/mL, respectively by altering membrane cell [42].

A. heterophyllus leaves extracts exhibited minimum inhibitory concentration in the range of 221.9-488.1 µg/ml against *E. coli, Listeria monocytogenes, Salmonella typhimurium, Salmonella enterica, Bacillus cereus, Enterococcus faecalis* and *Staphylococcus aureus* [37]. Chromones from *A. heterophyllus* fruits showed remarkable anti-HIV-1 effects with EC_{50} values ranging from 0.09 to 9.72 µM [19].

Anticancer activity

Swami, et al. [7] reported about the dietary supplementation with jackfruit pulp may help to prevent and control the development of certain cancers. Organic extracts obtained from jackfruit pulp reduced the number of revertants caused by aflatoxin B1 (AFB1) and proliferation of cells M12.C3.F6 [43]. Bioactive compounds from *A. heterophyllus* leaves showed inhibitory activity against the proliferation of the PC-3, NCI-H460, and/or A549 cancer cell lines [14]. Anticancer effects of the isolated phenolic compounds were examined in MCF-7, H460, and SMMC-7721 human cancer cell lines by Zheng, et al. [16]. The compounds exhibited IC_{50} values of 15.85 and 12.06 µM in MMC-7721 cell line and IC_{50} value of 5.19 µM in NCI-H460 cell line.

Apigenin C-glycoside identified as 2″-O-β-D-xylosylvitexin showed good antiproliferative activities against HepG2 and MCF-7 cells in the range of 0–400 µM. The IC_{50} values were 38.5 and 29.6 µM to HepG2 and MCF-7 cells, respectively [44]. Arung, et al. [45] reported that artocarpin caused a reduction of cell viability in a concentration-dependent manner and an alteration of cell and nuclear morphology on human T47D breast cancer cells. Moreover, the percentage of the sub-G1 phase formation was elevated dose-dependently. Artocarpin induced activation of caspase 8 and 10 as indicated by stronger signal intensity of cleaved-caspase 8 and weaker signal intensity of caspase 10 markers detected after artocarpin treatment. Jackfruit seeds extract was effective in cancer cell lines like T47D, TH29 and B16F10 [46]. IC_{50} obtained from extracts was 46.67 µg/ml of chloroform extract in T47D cells, 23.42 µg/ml of ethanolic extract in HT29 cells, and 74.31 µg/ml of ethyl acetic extract in B16F10 cells.

In a study by Sun, et al. [47], artocarpin impaired the anchorage-independent growth capability, suppressed colon cancer cell growth, and induced a G1 phase cell cycle arrest which was followed by apoptotic as well as autophagic cell death. Mechanistic studies revealed that artocarpin directly targeted Akt 1 and 2 kinase activity evidenced by in vitro kinase assay, ex vivo binding assay as well as Akt downstream cellular signal transduction. Recently, *A. heterophyllus* exhibited significant biological activity towards many types of both normal and cancerous cells [48]. In melanin formation inhibition on B16 melanoma cells, 3-prenyl luteolin exhibited IC_{50} of 56.7 µM with less cytotoxicity [45] thus making it a promising compound that could be useful for treating hyperpigmentation, as a skin-whitening agent. Heterophyllene C from this tree exhibited cytotoxicity against the MCF-7 cell line with an IC_{50} value of 12.56 µM [49]. Additionally, norartocarpin and artocarpin showed cytotoxic activity against MCF-7 and KB cell lines with IC_{50} values of 10.04 and 13.57 µM, respectively.

Anti-osteoporotic activity

Cathepsin-K (Cat-K) is known to play a pivotal role in osteoclast-mediated bone resorption and is evidenced as an important target for the treatment of osteoporosis. Flavonoids from *A. heterophyllus* found to have suppression capabilities against Cat-K with IC_{50} values ranging from 1.4 to 93.9 µM [12].

Other Pharmacological activities

Tyrosinase inhibitory activity of morachalcone A from wood of *A. heterophyllus* was determined by Nguyen, et al. [50]. Similarly, bioactive compounds from *A. heterophyllus* wood showed strong mushroom tyrosinase inhibitory activity with IC_{50} values lower than 50 µM, more potent than kojic acid, a well-known tyrosinase inhibitor [17]. It was also found that norartocarpetin and artocarpesin in the twigs and woods of *A. heterophyllus*, contributed to the tyrosinase inhibitory activity [18].

α-glucosidase inhibitors are suppressor of postprandial hyperglycaemia in diabetic mellitus patients by inhibiting the activity of α-glucosidase in the intestine, this reduces glucose absorption by delaying carbohydrate digestion and increases digestion time [51]. In another study, extracts of jackfruit peel, pulp, fruit flake and seeds were capable of inhibiting the α-glucosidase activity which was correlated with total phenolics content [4]. α-amylase inhibitors contain substances that prevent dietary starch from being absorbed into the body system, which may be useful in the management of diabetes [52]. Ethanolic extract of *A. heterophyllus* stem bark was observed to show inhibitory activities on α-amylase and α-glucosidase with IC_{50} of 4.18 and 3.53 mg/ml, respectively [53].

Conclusion

There are many studies that have focused on biological activities of *A. heterophyllus* and the results devoted for discovering possible bioactive compounds with potential lead compounds. Active compounds from parts of *A. heterophyllus* could be considered as potential drugs for the further development novel drugs. The evidence presented in this review suggests the potential of *Artocarpus* as source of useful products and opens up new avenues for novel therapeutics.

References

1. Bhatia BS, Siddapa GS, Lal G. Composition and nutritive value of jackfruit. Indian J Agric Sci. 1955; 25: 303–306.
2. Jagtap UB, Panaskar SN, Bapat VA. Evaluation of antioxidant capacity and phenol content in jackfruit (Artocarpus heterophyllus Lam.) fruit pulp. Plant Foods Hum Nutr. 2010; 65: 99–104. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/20198442/
3. Soong YY, Barlow PJ. Antioxidant activity and phenolic content of selected fruit seeds. Food Chem. 2004; 88: 411-417.
4. Zhang L, Tu ZC, Xie X, Wang H, Wang H, et al. Jackfruit (Artocarpus heterophyllus Lam.) peel: A better source of antioxidants and α-glucosidase inhibitors than pulp, flake and seed, and phytochemical profile by HPLC-QTOF-MS/MS, Food Chem. 2017; 234: 303-313. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/28551240/
5. Zhang Y, Zuo H, Xu F, Zhu K, Tan L, et al. The digestion mechanism of jackfruit seed starch using improved extrusion cooking technology. Food Hydrocolloids. 2004; 110: 106154.
6. Shafiq M, Mehmood S, Yasmin A, Khan SJ, Khan NH, et al. Evaluation of phytochemical, nutritional and antioxidant activity of indigenously grown jackfruit (Artocarpus heterophyllus Lam). J Scienti Res. 2017; 9: 135-143.
7. Swami SB, Thakor NJ, Haldankar PM, Kalse SB. Jackfruit and its many functional components as related to human health: A Review. Comprehensive Reviews in Food Science and Food Safety. 2012; 11: 565-576.
8. Saha RK, Jamiruddin M, Acharya S. Analysis of lectins isolated from seed and testa of Artocarpus heterophyllus LAM. International J Curr Res Chem Pharmaceut Sci. 2015; 2: 65-75.
9. Vazquez-Gonzalez Y, Ragazzo-Sanchez JA, Calderon-Santoyo M. Characterization and antifungal activity of jackfruit (Artocarpus heterophyllus Lam.) leaf extract obtained using conventional and emerging technologies. Food Chem. 2020; 330: 127211. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/32540527/
10. Baliga MS, Shivashankara AR, Haniadka R, Dsouza J, Bhat HP. Phytochemistry nutritional and pharmacological properties of Artocarpus heterophyllus Lam. Food Res Int. 2011; 44: 1800-1811.
11. Barik BR, Bhaumik T, Dey AK, Kundu AB. Triterpenoids from Artocarpus heterophyllus. Phytochemistry. 1994; 35: 1001-1004.
12. Yuan WJ, Yuan JB, Peng JB, Ding YQ, Zhu JX, et al. Flavonoids from the roots of Artocarpus heterophyllus. Fitoterapia. 2017; 117: 133–137. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/28163073/
13. Arung ET, Shimizu K, Tanaka H, Kondo R. 3-Prenyl luteolin, a new prenylated flavone with melanin biosynthesis inhibitory activity from wood of Artocarpus heterophyllus. Fitoterapia. 2010; 81: 640-643.
14. Wang XL, Shen XXT, Wang SQ, Wang XN. New phenolic compounds from the leaves of Artocarpus heterophyllus. Chin Chem Lett. 2017; 28: 37-40.
15. Liu YP, Yu XM, Zhang W, Wang T, Jiang B, et al. Prenylated chromones and flavonoids from Artocarpus heterophyllus with their potential antiproliferative and anti-inflammatory activities. Bioorg Chem. 2020; 101: 104030. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/32615467/
16. Zheng ZP, Xu Y, Qin C, Zhang S, Gu X, et al. Characterization of antiproliferative activity constituents from Artocarpus heterophyllus. J Agric Food Chem. 2014; 62: 5519-5527.
17. Zheng ZP, Cheng KW, To JK, Li H, Wang M. Isolation of tyrosinase inhibitors from Artocarpus heterophyllus and use of its extract as anti-browning agent. Mol Nutr Food Res. 2008; 52: 1530-1538. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/18683821/
18. Zheng ZP, Chen S, Wang S, Wang XC, Cheng KW, et al. Chemical components and tyrosinase inhibitors from the twigs of Artocarpus heterophyllus. J Agric Food Chem. 2009; 57: 6649-6655. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/19588925/
19. Fu YH, Guo JM, Xie YT, Yu XM, QT SU, et al. Prenylated chromones from the fruits of Artocarpus heterophyllus and their potential anti-HIV-1 activities. J Agric Food Chem. 2020; 68: 2024–2030. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/32037814/
20. Septama AW, Jantan I, Panichayupakaranant P, Aluwi MFFM, Rahmi EP. Immunosuppressive and antibacterial activities of dihydromorin and norartocarpetin isolated from Artocarpus heterophyllus heartwoods. Asian Pacific J Trop Biomed. 2020; 10: 361-368.
21. Fang SC, Hsu CL, Yen GC. Anti-inflammatory effects of phenolic compounds isolated from the fruits of Artocarpus heterophyllus. J Agric Food Chem. 2008; 56: 4463-4468. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/18500810/
22. Liu YY, Wang T, Yang RX, Tang HX, Qiang L, et al. Anti-inflammatory steroids from the fruits of Artocarpus heterophyllus. Nat Prod Res. 2018; 22: 1–7. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/31755785/
23. Septama AW, Jantan I, Panichayupakaranant P. Flavonoids of Artocarpus heterophyllus Lam. heartwood inhibit the innate immune responses of human phagocytes. J Pharm Pharmacol. 2018; 70: 1242–1252. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/29943393/
24. Meera M, Ruckmani A, Saravanan R, Lakshmipathy Prabhu R. Anti-inflammatory effect of ethanolic extract of spine, skin and rind of Jack fruit peel - A comparative study. Nat Prod Res. 2018; 32: 2740–2744. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/28990815/
25. Yao X, Wu D, Dong N, Ouyang P, Pu J, et al. Phenolic compound isolated from Artocarpus heterophyllus, suppresses lipopolysaccharide-activated inflammatory responses in murine raw 264.7 macrophages. Int J Mol Sci. 2016; 17: 1199.
26. Omar HS, El-Beshbishy HA, Moussa Z, Taha KF, Singab ANB. Antioxidant activity of Artocarpus heterophyllus Lam. (Jack Fruit) leaf extracts: remarkable attenuations of hyperglycemia and hyperlipidemia in streptozotocin-diabetic rats. The Scientific World J. 2011; 11: 788-800. **PubMed:** https://pubmed.ncbi.nlm.nih.gov/21479350/

27. De Faria A, de Rosso V, Mercadante A. Carotenoid composition of jackfruit (Artocarpus heterophyllus), determined by HPLC-PDA-MS/MS. Plant Foods Hum Nutr. 2009; 64: 108-115.
PubMed: https://pubmed.ncbi.nlm.nih.gov/19437120/

28. Cadenas E, Packer L. (eds.), 1996, Handbook of Natural Antioxidants, Marcel Dekker Inc, New York. 1996.

29. Jagtap UB, Waghmare SR, Lokhande VH, Suprasanna P, Bapat VA. Preparation and evaluation of antioxidant capacity of Jackfruit (Artocarpus heterophyllus Lam.) wine and its protective role against radiation induced DNA damage, Industrial Crop and Products. 2011; 34: 1595–1601.

30. Zhu K, Yao S, Zhang Y, Liu Q, Xu F, et al. Effects of in vitro saliva, gastric and intestinal digestion on the chemical properties, antioxidant activity of polysaccharide from Artocarpus heterophyllus Lam. (Jackfruit) Pulp, Food Hydrocolloids. 2019; 87: 952-959.

31. Zhu KX, Zhang Y, Nie SP, Xu F, He SZ, et al. Physicochemical properties and in vitro antioxidant activities of polysaccharide from Artocarpus heterophyllus Lam. pulp. Carbohyd Polym. 2017; 155: 354-361.
PubMed: https://pubmed.ncbi.nlm.nih.gov/27702522/

32. Daud MNH, Wibowo A, Abdullah N, Ahmad R. Bioassay-guided fractionation of Artocarpus heterophyllus L. J33 variety fruit waste extract and identification of its antioxidant constituents by TOFLCMS, Food Chem. 2018; 266: 200-214.
PubMed: https://pubmed.ncbi.nlm.nih.gov/30381177/

33. Daud M, Fatanah DN, Abdullah N, Ahmad R. Evaluation of antioxidant potential of Artocarpus heterophyllus L. J33 variety fruit waste from different extraction methods and identification of phenolic constituents by LCMS. Food Chem. 2017; 232: 621–632.
PubMed: https://pubmed.ncbi.nlm.nih.gov/28490120/

34. Ko FN, Cheng ZJ, Lin CN, Teng CM. Scavenger and antioxidant properties of prenylflavones isolated from Artocarpus heterophyllus. Free Radic Biol Med. 19978; 25: 160-168.
PubMed: https://pubmed.ncbi.nlm.nih.gov/9667491/

35. Zhang X, Zhu K, Xie J, Chen Y, Tan L, et al. Optimization and identification of non-extractable polyphenols in the dietary fiber of jackfruit (Artocarpus heterophyllus Lam.) pulp released by alkaline, acid and enzymatic hydrolysis: content, composition and antioxidant activities. LWT-Food Science and Technology. 2020.

36. Biworo A, Tanjung E, Khairina I, Suhartono E. Antidiabetic and antioxidant activity of jackfruit (Artocarpus heterophyllus) extract. J Med Bioengine. 2015; 4: 318-323.

37. Loizzo MR, Tundis R, Chandrika UG, Abeysekera AM, Menichini F, et al. Antioxidant and antibacterial activities on foodborne pathogens of Artocarpus heterophyllus Lam. (Moraceae) leaves extracts. J Food Sci. 2020; 75: M291-295.
PubMed: https://pubmed.ncbi.nlm.nih.gov/20629886/

38. Khan MR, Omoloso AD, Kihara M. Antibacterial activity of Artocarpus heterophyllus. Fitoterapia. 2003; 74: 501–505.
PubMed: https://pubmed.ncbi.nlm.nih.gov/12837372/

39. Siritapetawee J, Thammasirirak S, Samosornsuk W. Antimicrobial activity of a 48-kDa protease (AMP48) from Artocarpus heterophyllus latex. Eur Rev Med Pharmacol Sci. 2012; 16: 132–137.
PubMed: https://pubmed.ncbi.nlm.nih.gov/22338560/

40. Sibi G, Wadhavan R, Singh S, Shukla A, Dhananjaya K, et al. Plant latex: A promising antifungal agent for postharvest disease control. Pak J Biol Sci. 2013; 16: 1737-1743.

41. Septama AW, Panichayupakaranant P. Antibacterial assay-guided isolation of active compounds from Artocarpus heterophyllus heartwoods. Pharm Biol. 2015; 53: 1608-1613.
PubMed: https://pubmed.ncbi.nlm.nih.gov/25856717/

42. Septama AW, Panichayupakaranant P. Antibacterial activity of artocarpanone isolated from Artocarpus heterophyllus heartwoods against diarrheal pathogens and its mechanism of action on membrane permeability. J Appl Pharm Sci. 2017; 7: 64-68.

43. Ruiz-Montanez G, Burgos-Hernandez A, Calderon-Santoyo M, Lopez-Saiz CM, Velazquez-Contreras CA, et al. Screening antimutagenic and antiproliferative properties of extracts isolated from Jackfruit pulp (Artocarpus heterophyllus Lam). Food Chem. 2015; 175: 409-416.
PubMed: https://pubmed.ncbi.nlm.nih.gov/25577099/

44. Wen L, Zhao Y, Jiang Y, Yu L, Zeng X, et al. Identification of a flavonoid C-glycoside as potent antioxidant. Free Radic Biol Med. 2017; 110: 92–101.
PubMed: https://pubmed.ncbi.nlm.nih.gov/28587909/

45. Arung ET, Wicaksono BD, Handoko YA, Kusuma IW, Shimizu K, et al. Cytotoxic effect of artocarpin on T47D cells. J Nat Med. 2010; 64: 423-429.
PubMed: https://pubmed.ncbi.nlm.nih.gov/20544395/

46. Burci LM, da Silva CB, Rondon JN, da Silva LM, de Andrade SF, et al. Acute and subacute (28 days) toxicity, hemolytic and cytotoxic effect of Artocarpus heterophyllus seed extracts. Toxicol Rep. 2018; 6: 1304-1308.
PubMed: https://pubmed.ncbi.nlm.nih.gov/31993330/

47. Sun G, Zheng Z, Lee MH, Xu Y, Kang S, Dong Z, et al. Chemoprevention of Colorectal Cancer by Artocarpin, a Dietary Phytochemical from Artocarpus heterophyllus. J Agric Food Chem. 2017; 65: 3474-3480.
PubMed: https://pubmed.ncbi.nlm.nih.gov/28391699/

48. Wiater A, Paduch R, Trojnar S, Choma A, Pleszczynska M, et al. The effect of water-soluble polysaccharide from jackfruit (Artocarpus heterophyllus Lam.) on human colon carcinoma cells cultured in vitro. Plants (Basel). 2020; 9: 103.
PubMed: https://pubmed.ncbi.nlm.nih.gov/31947694/

49. Boonyaketgoson S, Rukachaisirikul V, Phongpaichit S, Trisuwan K. Cytotoxic arylbenzofuran and stilbene derivatives from the twigs of Artocarpus heterophyllus. Tetrahed Lett. 2017; 58: 1585-1589.

50. Nguyen NT, Nguyen MHK, Nguyen HX, Bui NKN, Nguyen MTT. Tyrosinase inhibitors from the wood of Artocarpus heterophyllus. J Nat Prod. 2012; 75: 1951-1955.
PubMed: https://pubmed.ncbi.nlm.nih.gov/23113717/

51. Johnston CS, Steplewsk I, Long CA, Harris LN, Ryals RH, Examination of the antiglycemic properties of vinegar in healthy adults. Ann Nutr Metab. 2010; 56: 74-79.
PubMed: https://pubmed.ncbi.nlm.nih.gov/20068289/

52. Kazeem MI, Raimi OG, Balogun RM, Ogundajo AL. Comparative study on the α-amylase and α-glucosidase inhibitory potential of different extracts of Blighia sapida Koenig. Am J Res Commun. 2013; 1: 178-192. www.usajournals.com

53. Ajiboye BO, Ojo OA, Adeyonu O, Imiere O, Olayide I, et al. Inhibitory effect on key enzymes relevant to acute type-2 diabetes and antioxidative activity of ethanolic extract of Artocarpus heterophyllus stem bark. J Acute Dis. 5: 423-429.