

Research Article

Volume 5 Issue 1 – July 2017
DOI: 10.19080/AIBM.2017.05.555653

Adv Biotech & Micro

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Phytochemical, Proximate, Antimicrobial, Antioxidant and FTIR Analyses of Seeds of *Artocarpus heterophyllus* Lam



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Submission: June 15, 2017; Published: July 28, 2017

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Abstract

The aim of the present study was to perform the fluorescence, proximate and FTIR analyses along with the determination of phytochemical composition, antimicrobial and antioxidant activities of the seeds of *Artocarpus heterophyllus* (jack fruit). The fluorescence analysis showed varying colours when exposed to UV and fluorescent light. The different solvent extracts showed the presence of a variety of phytochemicals like carbohydrates, proteins, fats, phenols and flavonoids. The proximate analysis revealed the presence of moisture (49.59%), fat (0.4%), carbohydrates (25%), proteins (13.6%), energy 206Kcal/100g in seed flour. The jack fruit seed flour contains appreciable amounts of calcium (1.82mg/g), potassium (9.72mg/g), magnesium (1.3mg/g), phosphorus (1.77mg/g), sodium (0.18mg/g), zinc (0.051 mg/g) and copper (0.019mg/g). Ethyl acetate extract showed the highest antibacterial activity against *Staphylococcus aureus* and acetone extract showed the highest antifungal activity against *Aspergillus flavus*. The antioxidant efficiency studies (DPPH method) on hexane, chloroform, ethyl acetate, acetone, benzene, methanol, and aqueous extracts showed varying percentages of free radical scavenging activity. The methanol and ethyl acetate extracts showed an IC₅₀ values of 636.5µg/ml and 715.86µg/ml respectively. Fourier Transform Infrared Spectroscopic Analysis (FTIR) revealed the presence of OH group (carboxylic acid group), C-C bond and R-O-R (ether) group and it can be due to pectin type polysaccharides, with varying degrees of esterification, in the case of most of the extracts studied.

Keywords: Antioxidant activity; Artocarpus; FTIR; Jack fruit; Proximate analysis

Abbreviations: BHA: Butylated Hydroxyl Anisol; DPPH: 2,2-Diphenyl-1-picrylhydrazyl; FTIR: Fourier Transform Infrared Spectroscopy; PDA: Potato Dextrose Agar

Introduction

A. heterophyllus (jack fruit) belongs to the family Moraceae. The generic name comes from the Greek words 'artos' (bread) and 'karpos' (fruit); the fruits are eaten and are commonly called breadfruit. The specific name, 'heterophyllus', in Latin means, with leaves of different sizes and shapes and the word "heteros" in Greek corresponds to the word 'different'. The word «jackfruit» comes from Portuguese jaca, which in turn, is derived from the term 'chakka' in Malayalam language. The ancient Indian language Sanskrit refers this fruit as Atibruhatphala [1]. Jackfruit tree is native to India and is popular in several tropical and sub-tropical countries. The fruit is known as the 'poor man's fruit' in eastern and southern parts of India because it is a major

part of their diet as a vegetable and nutritious dish during the season [2]. The ripe fruit contains well flavoured yellow sweet bulbs and seeds. The edible bulbs of ripe fruits are consumed fresh or processed into canned products [3]. Seeds usually make up 10-15% of the total fruit weight and they are light brown in colour, oval, or oblong ellipsoid or round in shape, 2-3cm in length and 1-1.5cm in diameter. Up to 500 seeds can be found in each fruit. They are recalcitrant and can be stored in cool, humid conditions up to a month [4]. A single seed is enclosed in a white aril encircling a thin brown endosperm, which covers the fleshy white cotyledons [5]. In India, often the seeds are boiled in sugar and eaten as dessert or used in some local dishes. A fresh seed cannot be kept for a long time, whereas seed flour can be an

alternative product, which can be used in some food varieties [6]. Jackfruit seeds are usually eaten after boiling or roasting and they are not so popular as a vegetable [7].

Being a native tree of India and Malaysia, the plant *Artocarpus heterophyllus* was brought into Africa by Arabs and afterwards into South America and has got acclimatized in Mexico also. It has got great commercial, nutritional and medicinal value in Southeast Asia. It was used as a traditional medicine for the treatment of asthma, wound healing, ulcers, dermatitis and cough [8]. Anti-inflammatory activity, antibacterial activity [9], antioxidant properties [10] and antidiabetic activity [11] of *A. heterophyllus* were also studied. The phenolic types of compounds were mainly reported as the chemical constituent of *Artocarpus* species [12]. So, in the present paper, a detailed phytochemical, proximate, nutritional, antimicrobial, antioxidant and FTIR studies were performed to unravel the quality of *A. heterophyllus* seeds.

Materials and Methods

Collection of seeds

The matured seeds were collected from the Bhagavathinada village (8° 23' 0" N, 77° 5' 0" E), Balaramapuram, Trivandrum district, Kerala state, India. The seeds were sliced into thin chips and shade dried. Dried pieces were finally ground and the flour obtained was stored for further studies.

Chemicals used

All the solvents (hexane, chloroform, acetone, ethyl acetate, benzene and methanol) used for the extraction process, ninhydrin, alpha naphthol, nitric acid, sodium bicarbonate, FeCl₃, NaOH, H₂SO₄, Butylated hydroxyl anisol (BHA) and 2,2-Diphenyl-1-picryl hydrazyl (DPPH), Muller Hinton agar, Nutrient agar, Potato Dextrose agar were purchased from HiMedia Laboratories Pvt. Limited, Mumbai, India. All the chemicals and reagents used were of analytical grade and were prepared in deionized water.

Fluorescence analysis

One gram of jack fruit seed powder was taken and two to three drops of different organic solvents like methanol, acetic acid, petroleum ether, water, 1N NaOH, 50% HNO₃, 1N HCL, 5% FeCl₃, chloroform, 5% H₂SO₄ and 5% KOH were added separately and mixed well. The slides were studied under short UV (254 nm), long UV (366nm) and visible light [13].

Qualitative phytochemical analysis

The seed slices for extractions were heated overnight at a temperature of 60 °C and then powdered to get the flour. One gram of seed flour was suspended in 10ml of respective solvents, such as hexane, chloroform, acetone, ethyl acetate, benzene, methanol and water and kept 24h with stirring using magnetic stirrer. After 24h, the extracts were centrifuged at 1000rpm for 10 minutes and the extract was then made solvent free by applying vacuum at a temperature of 60 °C using a water bath.

The presence of phytochemicals were determined as per the standard protocol [14-16].

Carbohydrates

Molisch's test was performed to detect carbohydrates. A few drops alcoholic solution of alpha naphthol was added to the extracts. Then about 1ml of concentrated sulphuric acid was added along the sides of the test tube. Formation of violet ring at the junction of the liquids indicated the presence of carbohydrates.

Proteins

Ninhydrin test was employed to detect the presence of proteins. Crude extract when boiled with 2ml of 0.2% solution of ninhydrin, violet color appeared suggesting the presence of amino acids and proteins.

Fats

Spot test was performed for fats and oils. This was done by prepared spot on the filter paper with the test solution Oil staining on the filter paper indicated the presence of fats.

Alkaloids

Crude extract was mixed with 2ml of Wagner's reagent. Reddish brown colored precipitate indicated the presence of alkaloids.

Phenols

Crude extract was mixed with 2ml of 2% solution of FeCl₃. A blue-green or black coloration indicated the presence of phenols.

Flavonoids

Alkaline reagent test was performed to test the presence of flavonoids. Crude extract was mixed with 2ml of 2% solution of NaOH. An intense yellow colour was formed which turned colourless on addition of few drops of diluted acid which indicated the presence of flavonoids.

Phytosterols

Salkowski test was used to detect phytosterols. To 2ml of aqueous extract, 2ml of chloroform and 2ml of concentrated H₂SO₄ was added. The solution was shaken well. As a result chloroform layer turned red and acid layer showed greenish yellow fluorescence.

Quinones

One ml of the extract was treated with alcoholic potassium hydroxide solution. Quinones showed colouration ranging from red to blue.

Xanthoprotein

To 1 ml of the extract few drops of concentrated nitric acid and ammonia solution were added. Formation of reddish orange precipitate indicated the presence of xanthoprotein.

Coumarin glycoside

To the extract, 10% NaOH was added and chloroform was added for observation of yellow colour, which showed the presence of coumarin.

Carboxylic acid

To 1 ml of the extract few drops of saturated solution of sodium bicarbonate was added. Observation of effervescence indicated the presence of carboxylic acid.

Saponins

Foam test was performed to test the presence of saponins. To 2ml of extract was added 6ml of water in a test tube. The mixture was shaken vigorously and observed for the formation of persistent foam that confirms the presence of saponins.

Proximate Analysis

Dry matter and moisture contents of *A. heterophyllum* seeds were calculated by heating the slices of seeds at 110 °C for 24h and by finding out the weight difference before and after heating. The carbohydrates, proteins and fat contents of the seeds were determined by the method of Association of Official Analytical Chemist, AOAC [17]. The pH of the flour was checked by dipping the probe of pH meter in 10% solution. The calorific value or energy value in Kcal/100g was estimated following the method of FAO [18]. The energy value was determined using the formula.

Energy value (Kcal/100g) = [% crude protein x 4.0] + [% crude fat x 9.0] + [% carbohydrate x 4.0]

Mineral Analysis

The mineral composition of the jackfruit seeds were analyzed by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES, Thermo Electron Iris Intrepid II XSP Duo). 1g of the seed powder was digested in 10ml of ultrapure metal free nitric acid in a microwave digester. After digestion, the content was diluted to 25ml with distilled water. The microwave digested sample was aspirated into ICP-AES to estimate, potassium, magnesium, phosphorus, calcium, copper, zinc and sodium. The calibration standards were prepared by diluting the stock multi-elemental standard solution (1000mg/l) in nitric acid.

Determination of Antimicrobial Activity

Microorganisms used

Bacterial strains such as *E. coli* (MTCC 118), *Klebsiella pneumoniae* (MTCC 432), *Pseudomonas aeruginosa* (MTCC 424), *Bacillus cereus* (MTCC 430) and *Staphylococcus aureus* (MTCC 96) and fungal strains such as *Aspergillus niger* (MTCC 1344), *Aspergillus flavus* (MTCC 277), *Penicillium chrysogenum* (MTCC 160), *Rhizopus oryzae* (MTCC 262) and *Candida albicans* (MTCC 183) were used for this study. All these strains were procured from the Microbial Type Culture Collection and Gene Bank (MTCC), Chandigarh, India. These bacterial and fungal

strains were sub cultured frequently in nutrient agar and potato dextrose agar slants and stored at 4 °C for further studies.

Antibacterial assay

The antibacterial sensitivity assay was carried out by disc diffusion method [19] and different solvent extracts of the seed powder was tested against the selected test bacterial strains. The test bacterial cultures were evenly spread over Mueller Hinton agar plates using a sterile cotton swab. The sterile discs (6mm in diameter) were impregnated with extract solution and placed in the inoculated agar. The plates were then incubated at 37 °C for 24 hours. After incubation, the zones of inhibition developed were measured with the scale to the nearest in mm. The experiment was done in triplicates and the mean values were presented.

Antifungal assay

Antifungal activity was measured using disc diffusion method [19]. The fungal cultures to be tested were evenly spread over potato dextrose agar plates using sterile cotton swab. Then, sterile paper discs (6mm diameter) impregnated with different solvent extracts were placed on agar plate. Inhibition zones were determined after incubation at 25 °C for 48 hours. All tests were done in triplicate and the mean values were presented.

DPPH free radical scavenging assay

The free radical scavenging activity of seed extracts at different concentrations were measured from bleaching of the purple colour of 2,2 Diphenyl-1-picryl hydrazyl (DPPH) [20]. Hexane, chloroform, acetone, ethyl acetate, benzene, methanol and aqueous extracts of *A. heterophyllum* seed were tested for antioxidant activity. About 0.1ml solution of different concentrations of extracts were added to 1.4ml of DPPH and kept in dark for 30min. The absorbance was measured at 517nm (Shimadzu UV/VIS NIR 3600) and the percentage inhibition was calculated by using the following equation.

$$\text{Percentage inhibition (\%)} = (A_0 - A_1) / A_0 \times 100$$

Where: A₀ is the absorbance of the control and A₁ the absorbance of the test solution. The results can also be expressed in terms of IC₅₀ value which is the effective concentration at which the antioxidant activity is 50%. BHA was used as the standard antioxidant.

Fourier Transform Infrared Spectroscopic Analysis (FTIR)

Ethyl acetate, methanol and aqueous extracts were used for FTIR spectroscopy. Two milligram of the sample was mixed with 100mg KBr (FTIR grade) and then compressed to prepare a sale-disc (3mm diameter). The disc was immediately put into the sample holder and the FTIR (Thermo Nicolet, Avatar 370) spectrum was recorded in the absorption range between 400 and 4000cm⁻¹.

Results

Fluorescence analysis

Table 1: Fluorescent characteristics of *A. heterophyllus* seed powder.

Sl. No.	Chemical/Solvent	Visible Light	Short UV	Long UV
1	Powder as such	Yellow	Yellow	White
2	Methanol	Yellow	Yellow	White
3	Acetic acid	Yellow	Yellow	White
4	Petroleum ether	Yellow	Yellow	White
5	Water	Yellow	White	White
6	1N NaOH	Yellow	Yellow	Yellow
7	50% HNO ₃	Yellow	Yellow	Yellow
8	1N HCl	Yellow	Yellow	White
9	5% FeCl ₃	Yellow	Yellow	Black
10	Chloroform	Yellow	Yellow	White
11	5% H ₂ SO ₄	Yellow	Yellow	White
12	5% KOH	Yellow	Yellow	Yellow

The characteristics of fluorescent properties or colours emitted by *A. heterophyllus* seed before and after treating

Table 2: Phytochemical constituents of *A. heterophyllus* seed.

Test	Hexane	Chloroform	Acetone	Ethyl Acetate	Benzene	Methanol	Distilled Water
Carbohydrates	-	-	-	-	-	+	+
Protein	-	-	-	-	-	-	+
Fat	-	-	-	-	-	-	+
Alkaloid	-	-	-	-	-	-	-
Phenol	-	-	-	+	-	-	+
Flavanoids	-	+	+	+	+	+	+
Phyto Sterol	-	-	-	+	+	-	-
Quinone	-	-	-	-	-	-	-
Xanthoprotein	-	-	-	-	-	-	-
Coumarin	-	-	+	-	-	-	-
Carboxylic acid	-	-	-	-	-	-	-
Saponin	-	-	-	-	-	+	-

Proximate analysis

The results of proximate analysis are given in Table 3. The moisture content of the seed flour was 49.59% and the dry matter content was 50.12%. The pH of the seed flour was 5.3. The protein content of seed flour was 13.6%. The fat content of the flour was 0.4% and the carbohydrate was found to be the major component of the seed flour amounting to 25%. The calorific value of the flour was estimated at 206 Kcal/100g.

with various reagents were recorded. After treating with various reagents such as FeCl₃, methanol, chloroform and acetone it showed black, white and yellow under different wavelengths of light. Similarly different shades of yellow and white colour appeared in the case of untreated seed powder. The characteristics fluorescence properties or colours recorded through this study could be used as a standard in the identification and authentication of the *A. heterophyllus* seeds. Fluorescence analysis of dried powder of *A. heterophyllus* seeds were examined under visible light, short UV and long UV which signifies their colour characteristics observed for different chemicals are given in Table 1.

Phytochemical analysis

The qualitative phytochemical analyses of the extracts of *A. heterophyllus* seed powder with seven solvents viz. hexane, chloroform, acetone, ethylacetate, benzene, methanol and water revealed the presence of flavonoids, phenols, phytosterols, carbohydrates, proteins, fats, phytosterol, coumarin and saponins. The aqueous extract showed the presence of carbohydrates, proteins, fats, phenols and flavonoids. Flavonoids were present in all the solvent extracts except that of hexane. The results of phytochemical analysis are given in Table 2.

Mineral analysis

The ICP-AES studies demonstrated that the flour of *A. heterophyllus* seeds contained high amount of potassium (9.72mg/g), calcium (1.82mg/g) followed by phosphorus (1.77mg/g), magnesium (1.30mg/g) and sodium (0.18 mg/g). The other mineral composition of *A. heterophyllus* seed are given in Table 3.

Table 3: Proximate and mineral composition of *A. heterophyllus* seed flour.

Proximate Chemical Composition (weight %) and Energy Content (Kcal/100g)						
Moisture	Dry matter	Proteins	Carbohydrates	Fats	Energy	pH
49.59	50.12	13.6	19.2	0.4	206	5.3
Mineral composition (mg/g)						
Na	K	P	Ca	Mg	Cu	Zn
0.18	9.72	1.77	1.82	1.3	0.01932	0.05173

Antibacterial activity

Different solvent extracts were tested against five pathogenic bacterial species. The results were recorded in the Table 4. Ethyl acetate and acetone extracts showed the highest antibacterial

activity against *Staphylococcus aureus* (20mm) and *Klebsiella pneumonia* (16mm). Hexane extract showed no activity against tested bacterial pathogens except *Staphylococcus aureus* (8mm). The aqueous extract did not show any activity against the test bacterial pathogens.

Table 4: Antibacterial activity of *A. heterophyllus* seed.

Bacteria	Zone of Inhibition (in mm) of Different Solvent Extracts (- no activity)						
	Hexane	Chloroform	Ethyl Acetate	Acetone	Benzene	Methanol	Distilled Water
<i>E. coli</i>	Nil	Nil	2±0.1	8±0.22	8±0.2	13±0.15	Nil
<i>Klebsiella pneumonia</i>	Nil	5±0.02	10±0.15	16±0.26	Nil	3±0.2	Nil
<i>Pseudomonas aeruginisae</i>	Nil	Nil	14±0.25	15±0.1	Nil	1±0.2	Nil
<i>Bacillus cereus</i>	Nil	Nil	8±0.15	14±0.22	Nil	Nil	Nil
<i>Staphylococcus aureus</i>	8±0.15	10±0.2	20±0.15	14±0.22	12±0.05	Nil	Nil

Antifungal activity

The aqueous extract did not show any activity against the five pathogenic fungal species. The acetone extract is found promising and it exhibited the highest antifungal activity against

A. flavus with a zone of inhibition of 16mm, *P. chrysogenum* with 15mm and also against *R. oryzae* with 14mm respectively. Ethyl acetate extract was also active against *P. chrysogenum* with an inhibition zone of 14mm. The results of antifungal activity obtained for other extracts are given in the Table 5.

Table 5: Antifungal activity of *A. heterophyllus* seed.

Fungi	Zone of inhibition (in mm) of Different Solvent Extracts						
	Hexane	Chloroform	Ethyl Acetate	Acetone	Benzene	Methanol	Distilled Water
<i>Aspergillus niger</i>	Nil	Nil	2±0.1	8±0.21	8±0.22	13±0.16	Nil
<i>Aspergillus flavus</i>	Nil	5±0.21	1±0.2	16±0.250	Nil	3±0.21	Nil
<i>Pencillium chrysogenum</i>	Nil	Nil	14±0.25	15±0.11	Nil	1±0.2	Nil
<i>Rhizopus oryzae</i>	Nil	Nil	8±0.2	14±0.25	Nil	Nil	Nil
<i>Candida albicans</i>	8±0.16	1±0.2	2±0.1	14±0.2	12±0.15	Nil	Nil

Antioxidant activity

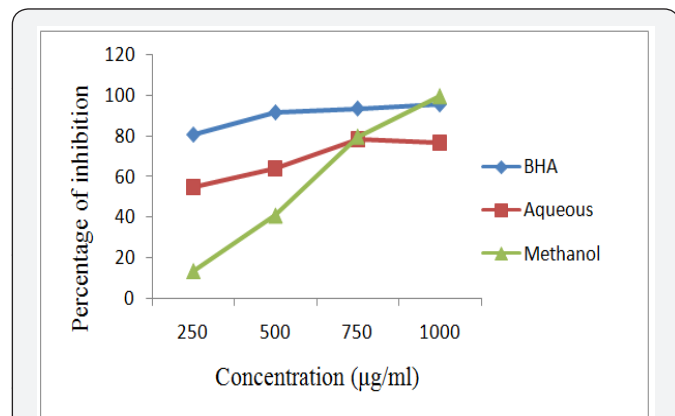


Figure 1: Antioxidant activity of aqueous and methanol extracts.

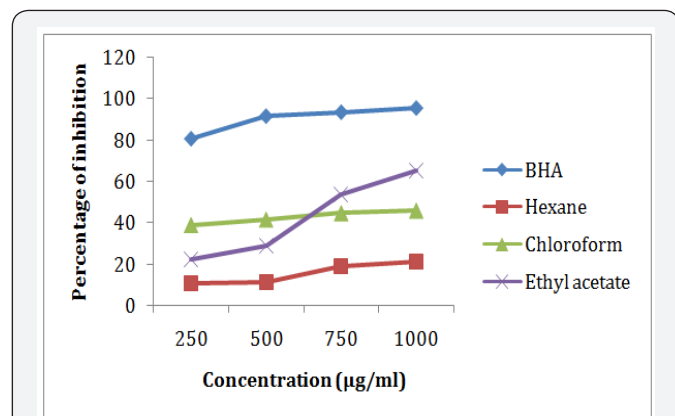


Figure 2: Antioxidant activity of hexane, chloroform and ethyl acetate extracts.

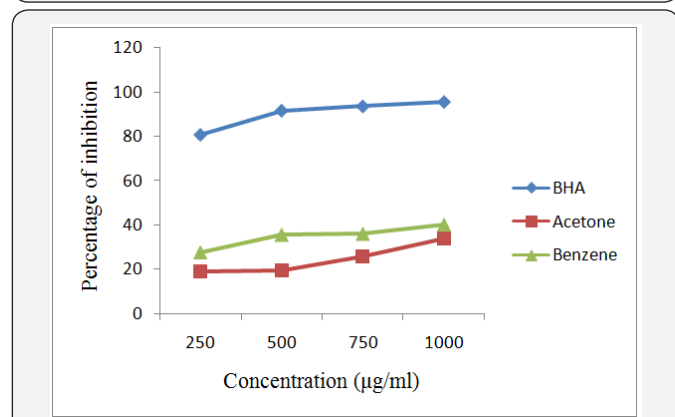


Figure 3: Antioxidant activity of acetone and benzene extracts.

Fourier transform infrared spectroscopic analysis

The fourier transform infrared spectra of ethyl acetate extract of *A. heterophyllus* seed showed major peaks like 1740cm⁻¹, 1377cm⁻¹, 1243cm⁻¹ and 1048cm⁻¹ which are due to the solvent used i.e., ethyl acetate. This does not show the existence of pectin (i.e. no peak at 1639cm⁻¹ or 1649cm⁻¹) which is normally

expected. The peaks in the beginning around 2985-2929 cm⁻¹ are due to some carboxylic acid groups (Figure 4), may be due to the low degree of esterification.

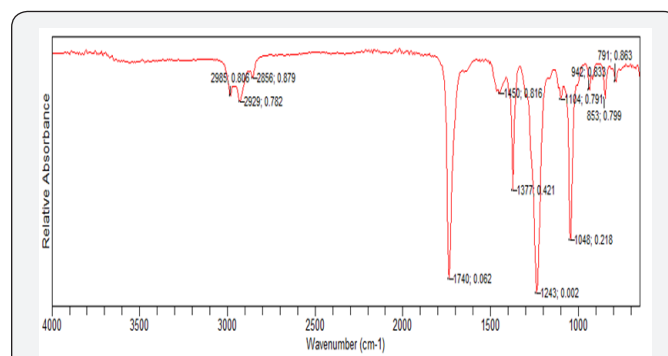


Figure 4: FTIR analysis of ethyl acetate extract.

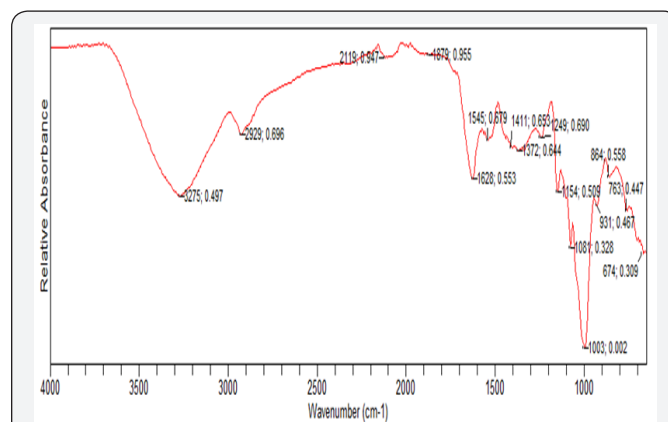


Figure 5: FTIR analysis of methanol extract.

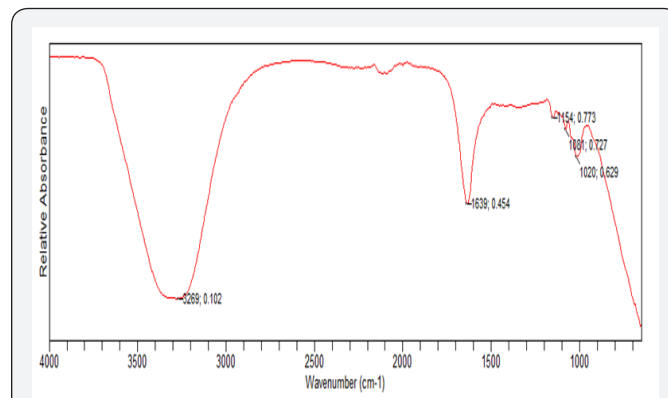


Figure 6: FTIR analysis of aqueous extract.

The methanol extract showed the presence of the following functional groups. Broader peaks at 3275 cm⁻¹ and 2929cm⁻¹ are due to moisture and some carboxylic acid groups respectively, where as the peak at 674cm⁻¹ can be due to free carboxyl groups in perulic acid (Figure 5). Other peaks below 1350cm⁻¹ up to 1000cm⁻¹ (or 998cm⁻¹) usually are found along with pectin (a polysaccharide with varying degrees of esterification). The aqueous extract of *A. heterophyllus* seed showed a similar result.

The peak 3269cm^{-1} is due to moisture. The band 1639cm^{-1} is due to free carboxyl groups in pectin. The remaining bands below 1200cm^{-1} correspond to the finger print region of carbohydrates like polysaccharides, which can be ether linkage i.e. R-O-R or cyclic C-C bond (Figure 6). Spectra of distilled water extract showed the presence of moisture at 3269cm^{-1} , and carboxylic acid groups at 1639cm^{-1} (Figure 5).

Discussion

During fluorescence analysis, the seed powders exposed to UV at 254 and 366nm produced different colours. This was used as a standard in the identification, authentication and identification of the purity of plant products in its crude form [21]. This also helps in the identification and standardization of crude drugs and the major compounds present in it [22]. Fluorescence analysis also helps in the assessment of active constituents of a drug, which is responsible for its pharmacological action. It is the presence of this active constituent that makes it useful for ayurvedic preparations.

Phytochemicals in general are natural bioactive compounds found in plants that work with nutrients and fibers to act as a defence system against disease or more accurately, to protect against disease [23]. Plants are considered as biosynthetic laboratory for a multitude of secondary metabolites like alkaloids, glycosides, polyphenols, volatile oil, tannins etc. [24]. The presence of saponin in higher quantities was observed in jack fruit seed and it has been known for their medicinal uses, including antispasmodic activity and toxicity to cancer [25]. Bioactive compounds such as sterols and anthraquinones were present in acetone and chloroform extracts of *A. heterophyllum* seeds [24]. The present study revealed the presence of phytochemicals such as carbohydrates, proteins, fats, phenol, flavonoids, phytosterols, coumarins and saponins. Phenols and flavonoids are reported to have antibacterial, antifungal and antioxidant properties [26].

The moisture content was found to be 49.59% and it is a measure of the water content in the seed flour. It is also an index of storage stability of the flour. Lower the moisture content, larger is its shelf life [27]. The dry matter content in the present study was 50.12% and this was more or less comparable to the reported value of 47% [28]. Varying protein contents of 6.34 to 8.57% have also been reported for jackfruit seed flour [29] and in the present investigation the protein content was 13.6%. The difference in protein content may be attributed to varietal differences, maturation of the seeds and environmental conditions [30]. The fat content can be compared with the result of Swami et al. [31]. Carbohydrate content of 19.2 % was found in *A. heterophyllum* seeds and this result can be compared with the reported observation of 25 % [32]. *Akinmutimi* [33] reported a higher energy value of 292-313 Kcal/100g whereas the present study reported an energy value of 206Kcal/100g. The pH value obtained in the present investigation (5.3) was comparable with

the reported pH of 5.7 [34]. The pH gives a measure of the acidity or alkalinity of the flour, which corresponds to the quality of the flour.

In the present study, potassium accounts for the major share (9.72mg/g) and among the mineral components previous studies showed that food rich in potassium helps to lower blood pressure [35]. According to the studies of *Akinmutimi* [33] the jackfruit seed flour was rich in potassium (4.66mg/g), calcium (0.9mg/g) and sodium (0.25mg/g). In contrast to the present results, higher contents of calcium (3.087mg/g), magnesium (3.38mg/g) and potassium (14.781mg/g) in jackfruit seeds were reported [34].

Ethylacetate, acetone, benzene and methanol extracts showed positive antibacterial activity. Nair et al. [36] studied about the partially purified lectins from the seed of *A. heterophyllum* and revealed that the jackfruit seed lectin had a potent antibacterial activity against *S. aureus*, *E. coli* and *Klebsiella*. Khan et al. [9] conducted antibacterial activity of methanol extract of *A. heterophyllum* stem, root, bark and root-heart wood, leaves, fruits and seeds and reported broad spectrum of antibacterial activity. Madhavi et al. [37] studied the antifungal activity of jackfruit latex. The result showed that the methanolic, ethanolic and chloroform extracts of *A. heterophyllum* fruit latex did not show any activity on *A. niger*, *A. flavus* and *C. albicans* of these organisms.

The DPPH system involves stable radical generation and it is a simple method to determine the capability of antioxidants to trap free radicals. This property of DPPH is due to the delocalization of the unpaired electron all over the molecule [38]. According to the studies of Burci et al. [39] ethanol extract of seed showed higher activity and this may be due to the presence of high hydroxyl groups, which is proportionate to their phenolic content. A large number of degenerative diseases can be triggered due to the action of free radicals. Due to this property samples having free radical scavenging activity can be used as an effective medicine. Crude ethanol, hexane, chloroform and ethanolic fractions of *A. heterophyllum* seeds showed a significant increase in DPPH free radical scavenging power. This in turn confirms the antioxidant property of *A. heterophyllum* seeds. Crude ethanol, hexane, chloroform and ethanolic fractions of *A. heterophyllum* seeds showed EC₅₀ (free radical scavenger) values of 76.71, 399.64, 534.83 and 65.51µg/ml respectively. The potent antioxidant ascorbic acid had a lower EC₅₀ value of 4.92µg/ml than ethanol fraction. However, in the present study the percentage of inhibition varied from 10.88 to 54.65% (aqueous extract) and the standard antioxidant BHA showed 80.8% at 250µg/ml concentration. Only methanol and ethyl acetate extracts showed IC₅₀ values of 636.53µg/ml and 715.86µg/ml respectively.

In the present study, the FTIR spectroscopy revealed the presence of OH group (carboxylic acid group), C-C bond

and R-O-R (ether) group and it can be due to pectin type polysaccharides, with varying degrees of esterification. Barua & Boruah [40] studied about the Fourier transmission infrared spectra of jackfruit seed in its powdered form. The analysis confirmed the presence of two hitherto undetected elements such as manganese and magnesium. And it also showed some specific bands and it may be due to specific functional groups. Further investigation is to be carried out for the identification of these functional groups. FTIR is one of the most widely used methods to identify the chemical constituents and to elucidate the functional groups in the extract [41] FTIR investigations of nano sized particles of jackfruit seeds were also reported [42].

Conclusion

Jackfruit seeds are rich source of several high value compounds and it can serve as a vital food for good health. The flour is rich in proteins, carbohydrates and minerals (sodium, potassium, magnesium and zinc) with low fat content. This makes the seed flour a good constituent in functional foods and can be consumed safely without any health risk. This study will promote the increased consumption of cooked seeds and enhance the production of value added food products. The Jackfruit seeds possess antioxidant properties which can scavenge free radicals. The seeds can be consumed as a good source of nutritional, mineral, antimicrobial, antioxidant components and it has potential for value addition and nutraceutical developments.

Acknowledgement

The authors are thankful to Sophisticated Test and Instrumentation Centre, Cochin, Kerala State, India.

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DOI: [10.19080/AIBM.2017.05.555653](https://doi.org/10.19080/AIBM.2017.05.555653)

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