ISSN: 0975-8585

Research Journal of Pharmaceutical, Biological and Chemical Sciences

Physicochemical characterization of Jackfruit (*Artocarpus integer (*Thumb.).) Peel.

Antony Allwyn Sundarraj[1*] and Thottiam Vasudevan Ranganathan[2].

[1]Research Scholar, Department of Food Processing and Engineering, Karunya University, Coimbatore – 641 114, Tamil Nadu, India.
[2]*Professor, Department of Food Processing and Engineering, Karunya University, Coimbatore – 641 114, Tamil Nadu, India.

ABSTRACT

Jackfruit (*Artocarpus integer*) peel is one among the under-utilized waste substances that have potential in the manufacture of functional food additives. The study was conducted to quantify a detailed investigation of their chemical structures. The average particle size and zeta potential value is (0.116µm) and (-19.3mV). Proximate analysis showed that jackfruit peel contains the high amount of cellulose (27.75%), pectin (7.52 ± 0.12 %), protein (6.27 ± 0.03%) and starch (4%). SEM image showed a porous structure and XRD values of 85% crystallinity, indicated typical cellulose I form inferring higher crystallinity. FTIR spectroscopy showed the various functional groups with strong absorption bands. Thermal analyses revealed that the degradation arise in a minimum of three steps, connected with the major constituents (hemicellulose, cellulose, and lignin). Results obtained suggest the Jackfruit peel can be a principal alternate source of cellulose and pectin materials which can be further manipulated for food ingredient applications.

Keywords: Jackfruit peel, Proximate composition, Pectin, Cellulose, Food Additive.

Corresponding author

ISSN: 0975-8585

INTRODUCTION

Fruit and Vegetable peel wastes are typically generated from household and food-processing industries. Although the amount of these organic wastes generated from households is negligible, that generated from food-processing industries is large, as they are a major by-product in these industries [1]. In addition, using these wastes in varied different potential applications will eradicate them from the environmental and reduce solid-waste handling, which is able to add some values to these wastes [1,2].

Artocarpus is a genus of roughly sixty trees and shrubs of Southeast Asian and Pacific origin, belonging to the mulberry family, *Moraceae* [3].

Jackfruit was initially from India and spread out into tropic regions, together with Republic of Indonesia [4]. A. *integer* is regionally famed in Malaysia as 'Cempedak', is a close relative of jackfruit and wide jack trees. It has been wide scattered in Thailand, Peninsular Malaysia, Republic of Indonesia and Myanmar [5] A. *integer* plant has been used as ancient drugs to treat infection and symptom [6)]. According to [7], the isolate of the woody system of A. *integer* showed cytotoxic activity against leukemia neoplastic cell.

Jackfruit (A*rtocarpus heterophyllus*) is one of the popular fruits in India. Owing to its wide variety of applications, a major amount of peel (which constitutes ~ 59% of the ripe fruit) is discarded as waste [8,9]. The roughly annual jackfruit peel manufacture is estimated to be 2714 - 11,800 kg per tree [10]. These residues create a potential threat as a waste product. Appropriate ways to convert these wastes into value-added merchandise by means that of by-product recovery will serve the twin purpose of environmental protection and value addition [11] Pectin is a valuable by-product that may be secured from these fruit wastes [12]. The aim of this study is to evaluate the physicochemical characteristics and to investigate the other properties like Particle size, Zeta Potential, SEM, FTIR, XRD and TGA of Jackfruit peel.

MATERIALS AND METHODS

Raw material collection

Mature Jackfruits were collected from the local market of Pudukkottai (district), TamilNadu, India. It was identified as A*rtocarpus integer* ((Thumb.). Merr. - Moraceae). Plant species authentication was done at Botanical Survey of India (BSI), Coimbatore, South India (Ref no. BSI/SRC/5/23/2013-14/Tech/1714).

Preparation of Jackfruit peel powder

Jackfruit was peeled manually to discard the edible part together with seeds. The peels were cut into smaller pieces and treated per the strategy reportable by [11,13]. The treated jackfruit peels were then cleansed with boiling water and pressed to remove excess quantity of H2O. Subsequently, the Jackfruit peels were dried throughout a Cross Flow Dryer at 65ºC for eight hours [14]. The dried peels were ground and packed in polyethylene bags and keep at room temperature.

Proximate Composition / Quantitative Analysis

Moisture content was determined per AOAC methodology [15]. Ash content was analyzed gravimetrically by combustion of the sample in a muffle chamber for six hours at 525°C [16]. Total soluble sugars, reducing sugars and non-reducing sugars were calculable according to Nelson's methodology. Protein content (estimated as % nitrogen x 6.25) was determined by the Kjeldahl methodology [17]. Cellulose, Starch, Crude fiber estimation and pectin was done by gravimetric methodology [18].

Characterization of Jackfruit peel

Particle Size Distribution

The Particle size of the jackfruit peel procured from sieving mesh with completely varied sizes was determined by Laser Diffraction in a Malvern particle size analyzer. Particle size distribution parameters were conveyed as Sauter mean diameter [19] [$D_{3,2}$ (µm)].

Zeta potential Analysis

Zeta potential of 0.1 wt % aqueous the jackfruit peel was measured using a Zetasizer Nano S90 - Malvern Instrument. The zeta potential was calculated from the electrophoretic mobility using Huckel approximation [20].

Microstructure analysis by Scanning electron microscopy (SEM)

Scanning electron microscope JEOL JSM 6390, SEM, Japan was used to evaluate the microstructure of Jackfruit peel. Jackfruit peel micrographs was observed at a magnification of 500X (scale bar 50µm) at an accelerated voltage of 20kV [21 - 23].

Fourier Transform Infrared Spectroscopy (FTIR)

Functional groups of jackfruit peel were analyzed by FTIR transmission spectra of powder samples by KBr technique. The mixed powder was ascended to the instrument to form a simple measurement within the transmittance %T mode [4]. The analysis was dispense by Shimadzu IR PRESTIGE 21, FTIR instrument in frequency vary of 4000 to 500 cm-1 with a resolution of the 4cm-1and total of ten scans [21,24].

X - ray Diffraction (XRD)

The powder X - ray diffractometry patterns was measured using a SHIMADZU - XRD 6000 at ambient temperature using Cu kα with the wavelength of (λ=0.154nm) radiation at 45kV and an incident current of 30 mA. The angular region ranges from 0° to 80° with a scanning speed of 0.01°/min [4,21].

Thermogravimetric Analysis (TGA)

Thermal degradation performance of peel was evaluated. Thermogravimetric Analysis (SDT Q600). The specimen was initial placed into an aluminum pan on the platinum basket in the chamber so heated from room temperature to 600°C with a constant heating rate of 20°C/ min under a nitrogen atmosphere. Roughly 10 mg of sample mass was utilized in each trial [25,26].

RESULTS AND DISCUSSION

Proximate Composition of Jackfruit peel

The proximate composition revealed that the jackfruit dried peel consists, mainly of Cellulose (27.75± 0.06%) is shown in Table 1. This can be considerably higher than the pomelo (*Citrus grandis*) albedo peel (21.29% - cellulose) [27], orange rind (13.6% - cellulose) [28], lemon peel (12.7% - cellulose) [28], orange peel (11.93% - cellulose) [26]. The Ash content of the jackfruit peel was 7.01 ± 0.19%. This is also ascertained chosen slightly higher than the variability of A*rtocarpus heterophyllus* (jackfruit) (4% - ash) [29], orange bagasse - 2.87%, orange peels - 2.82%, mango peels - 3.90% [26] and Passion fruit peel - 6.04 ± 0.19 % [30] respectively. The ash content of raw material is lesser than the mango peel - 11.19% [26].

Total sugars of Jackfruit peel was 19.75 ± 0.16 % obtained and it is higher than the Indian varieties of Pomegranate peel (Ganesh - 14% and Arakta - 14.5%) [31] and as shown in Table 1. Crude fiber content of peel was found to be 13.42 ± 0.18%. This value is determined to occur more than that of F. *carica* peel - 9.8% [32] and mango peel - 9.33 ± 0.61% [33].

ISSN: 0975-8585

Table 1: Proximate composition of Dried Jackfruit peel powder :-

PARAMETERS	WEIGHT (%)
Moisture content	12.98 ± 0.42
Ash content	7.01 ± 0.19
Total sugars	19.75 ± 0.16
Crude fiber	13.42 ± 0.18
Protein	6.27 ± 0.03
Pectin	7.52 ± 0.12
Cellulose	27.75 ± 0.06
Starch	4.12 ± 0.02

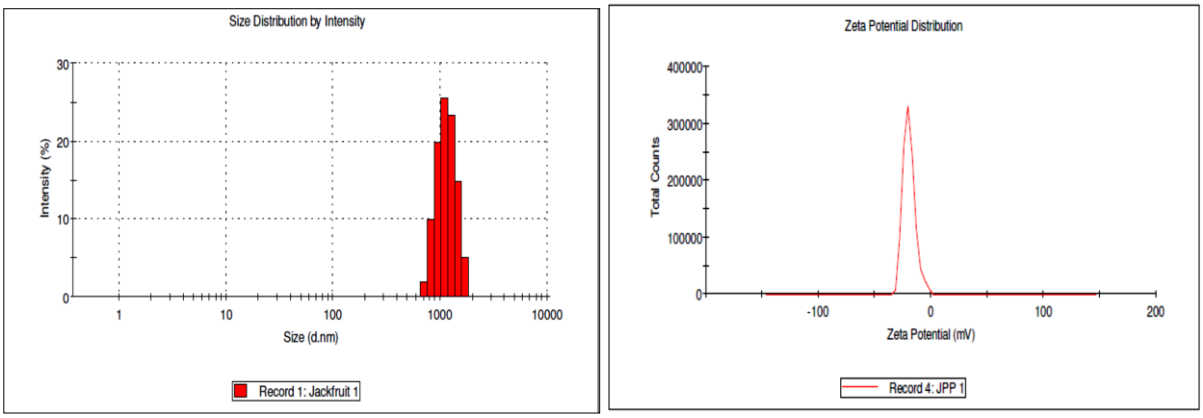
*for (%) = Percentage

The total protein content in the *Artocarpus integer* peel was found to exist (6.27 ± 0.03%), just like the Pomelo Albedo peel (6.27 ± 0.23) [34]. The Protein content of peel is slightly higher than that of 3.6% (Mango peels) [35], 3.77% (Cactus peels) [36], 5.93% (Orange peel) [37], 5.97% (Orange peel) and 5.6% (Mango peel) [26]. The protein content of Jackfruit peel is lesser than that of 7.59% (Orange bagasse) and 7.00% (Mango peel) [26], 7.48% (Maazoum melon peel) [38] and 9.07% (Sharlyn melon peels) [39] respectively.

Pectin content of peel was found to be 7.52 ± 0.12. This can be slightly higher than that of the species, A*rtocarpus heterophyllus*. (pectin content -7.33%) [40]. The pectin content was found to be less compared to citrus fruit peel - 18.21% [41] and Guava Fruit peel - 16.8%, [42].

Particle Size Distribution

Particle size plays an important role in physicochemical and functional properties, that relates to aldohexose and digestive tract (transit time, fermentation, fecal excretion) [43 - 45]. Investigation of particle size distribution generally dispensed by dry sieving through a series of sieves with reducing mesh size [19]. The Particle size of jackfruit peel is shown in fig 1(a). Laser diffraction unconcealed that particles secured are the polydisperse mixture, with an average diameter of the particles to be 1168 nm / (0.116µm).



(a) Particle Size Distribution Curve **(b) Zeta potential Measurement**

Fig: 1 Particle Size distribution and Zeta Potential Measurement of Jackfruit peel.

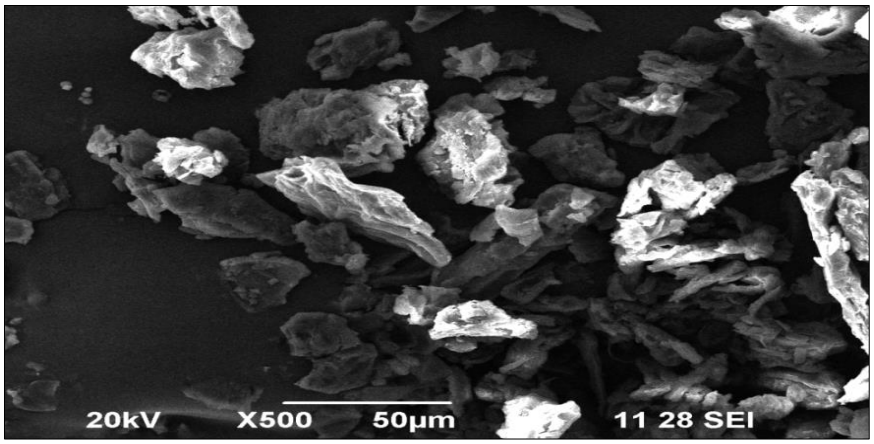
Zeta Potential

The zeta potential is an important parameter for examining the dispersion stability of colloidal, it indicates the degree of repulsion between adjacent, equally charged particles of dispersion. The zeta potential measures the quality of a distribution of charged particles as they are subjected to an electrical field [46]. During this study, the zeta potential was negative (-19.3mV) confirming the incipient instability of Jackfruit peel (fig 1b). As the zeta potential will increase, the surface charge of the particle are conjointly

exaggerated. The zeta potential greatly influences particle stability in interruption through the electrostatic repulsion between particles [47,48].

Scanning Electron Microscopy (SEM)

The particle microstructure and geometry of the A*rtocarpus integer* peel surface were identified by scanning electron microscopy. The SEM result indicates that the surface of Jackfruit peel is porous present on the surface. The surface of A*rtocarpus integer* peel is porous structure with varied shapes (fig 2). It might be due to the presence of various components that constitute the peel. This is likely to affect the microstructural characteristics, thus exhibiting the non-homogeneity. Similar microstructural characteristics were determined with banana skin [49,50], orange peel [51], watermelon peel [1,52].



size 500 mesh; Bar = 50 microns

Fig 2: Scanning Electron Microscopy Image of the Jackfruit peel.

Fourier Transform Infrared Spectroscopy (FTIR)

The functional groups present on the surface of Jackfruit (A*rtocarpus integer*) peel is very important and these can be determined using FTIR. The Fourier Transform Infrared Spectrographic analysis is a acceptable capabilities to determine the vibrations or stretch on the chemical structure of the peel [21]. The FT -IR spectra of jackfruit peel was elucidated in fig 3. The spectra present the predictable bands that may be found on IR spectra of cellulose and lignin [53,54] and are in good concurrence with the documentation [55,56].

Most of the bands are common to those observed in cellulose, hemicellulose, and lignin FT-IR spectra [26,57,58]. Usually, the band in the high-energy region is due to a large amount of OH groups of Carbohydrates and lignin [26]. The infrared spectroscopy peaks were dominated by the presence of intense bands at 3000 - 3500 cm-1, that corresponds to the hydrogen bonded O-H Stretching of hydroxyl groups originating primarily from cellulose and hemicelluloses [59 -63].

Very weak peak around 3000 - 2800cm-1 was substitute of C-H stretching vibrations from some methylene groups of carbohydrates [19,64,65]. The signal at 2314.38cm-1 is identical to the C≡ C stretch to alkynes [66].

The peak at 1622.13 cm-1 corresponded to characteristic bending or stretching of aromatic hydrocarbons of lignin [19,67] and these aromatic hydrocarbons were conjointly ascribed in wheat bran dietary fiber [65]. A strong band at 1590 cm-1 are typically attributed to C=C aromatic ring stretching vibration increased by polar functional groups [4,68,69].

ISSN: 0975-8585

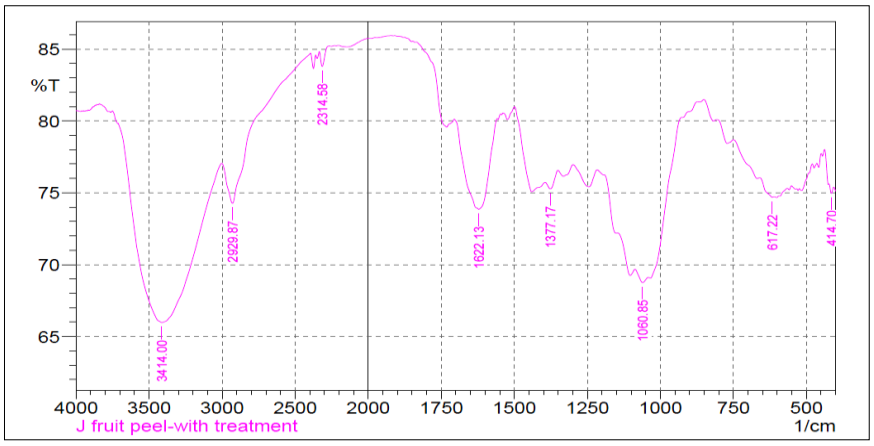


Fig 3: Fourier Transform Infrared Spectroscopy of the Jackfruit peel.

There is also a presence of broadband between 1400 - 1000 cm-1 with the sturdy band around 1200 cm-1 and a shoulder around 1060.85 cm-1 [4]. According to [70,71], the peak at 1200 - 850cm-1 is dominated by stretching vibrations of C-O, C-C, ring structures and deformation of -CH2 groups vibration characteristic for polysaccharides. Therefore, the broad range of 1200 - 850cm-1 suggested the presence of glycoprotein carbohydrates [72].

X - ray Diffraction (XRD)

In the present study, the X - ray diffraction pattern of peel obtained by Cu kα with the wavelength of 0.154nm [4] was investigated. The XRD graph clearly disposed sharp peaks at 2θ - 16° and 2θ - 21.5°, which represented typical cellulose I form indicating higher crystallinity as shown in fig 4 [21].

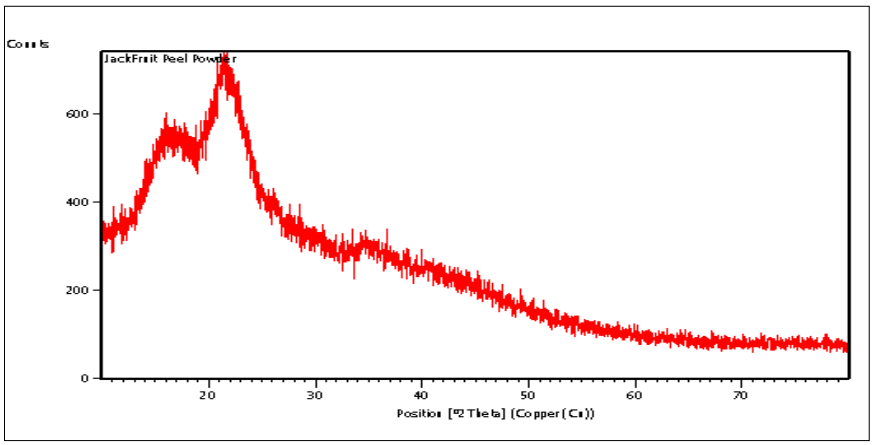


Fig 4: X- ray Diffraction of Jackfruit peel.

Jackfruit peel consists of 85% orderly crystalline regions and 15% amorphous regions. A sharp XRD peak is characteristic of crystalline cellulose with an extended crystal line and complete crystal surface. Similar crystalline surface was determined [19]. On the other hand, amorphous regions consists of non-crystalline cellulose, hemicellulose, and lignin respectively. Therefore the diffraction peaks of 2θ angles at 16° and 21.5°; crystallographic planes 101 and 002 reflections, specified parallel glucan chains with continuance β-(1→4)-D-glucopyranose units; similar cellulose I with diffraction peaks were determined from banana fibre waste at a 2θ angles at 14° and 22° [73,74]; Tomato peel at an 2θ angles at 15° and 25° [20]; Mandarin (*Citrus unshiu*) peel at an 2θ angles at 16° and 24° [75]; Pomelo (*Citrus grandis*) Albedo peel at an 2θ angles at 18° and 22° [27]; Banana (*kachkal*) variety *Musa* ABB peel at an 2θ angles at 16° and 22° [21].

ISSN: 0975-8585

Thermogravimetric analysis (TGA)

The Thermogravimetric analysis was applied to examine the thermal degradation of Jackfruit peel. TGA curve of the peel in a nitrogen atmosphere as shown in fig 5. According to the obtained thermal profiles, the jackfruit peel degradation occurs in at least three steps associated with its three main components (hemicellulose, cellulose, and lignin), which can be clearly distinguished up to 600°C. TGA of raw material showed an initial weight loss within the region of 25° - 176.91°C, similar weight loss were observed from Banana (*kachkal*) variety *Musa* ABB peel of 25° - 150° C [21]; banana peel (25° - 174°C) and orange peel of 25° - 175°C [49].

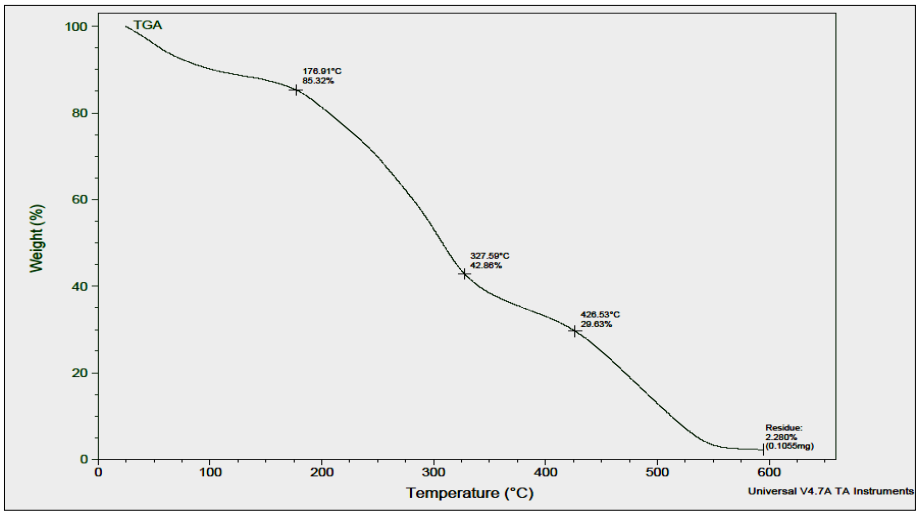


Fig 5: Thermogravimetric Analysis (TGA) of Jackfruit peel.

The glycosidic linkage of peel broke down as a results of depolymerization of hemicelluloses within the region ranging from 176.91° to 327.59°C; similar results are reported within the region starting from 200°-400°C of Indonesian sort of Jackfruit peel [76] and 220 - 300°C of Banana (*kachkal*) variety *Musa* ABB peel powder [21].

Afterwards, between 327.59° - 426.53°C, depolymerization and chain breaking of cellulose occurs. Lignin is an amorphous cross-linked with no actual structure, and its degradation happens between 426.53°C - 600°C, weight reduction of Jackfruit peel is caused by the decomposition of lignin [77, 78]. Lignin degradation is hindered by the decomposition of the hemicelluloses and cellulose, excepting at high temperature [26]. This is often in concurrence with the report of [73].

CONCLUSION

The present work shows that Jackfruit peel consists mainly of cellulose (27.75%), pectin (7.52 0.12%), protein (6.27 0.03%), crude fiber (13.42 ± 0.18%) and starch (4.12 ± 0.02%). The peels are considered waste and hence available an occasional price. Considering that the cellulose content is high as compared to the other naturally available sources, except wood, this could be a promising different source of cellulose. In the case of pectin, the peel can be a possible source of less occurring LMP (based on the studies conducted in our laboratory and yet to be published). The average particle size of the jackfruit peel was found to be 0.116µm with a zeta potential of -19.3mV) confirming its stability. Scanning electron microscopy displayed the morphology of Jackfruit peel was the porous structure with numerous shapes. The increase in crystallinity to 85% was confirmed, at a 2θ -21.5°, that depicted typical cellulose I form indicating higher crystallinity by the X-ray diffraction analysis. From the results obtained, it can be concluded that Jackfruit peels of *Artocarpus* can be utilized as a potential source for extraction of valuable ingredients such as cellulose and low methoxyl pectin for application in functional / therapeutic foods and health product, so proving to be a financially viable different to waste utilization and environmental protection.

ACKNOWLEDGEMENTS

This research was partially funded by Silver Jubilee Scholarship from Karunya University, Coimbatore, TamilNadu, India. The authors are thankful to the management for providing the adequate laboratory facilities in the execution of this work. The authors are also grateful to CSIR - CECRI, Karaikudi, for TGA analysis, and the authors would really like to specific their thanks to Mr. Shaun Pravin (Research Scholar/Lab technician) at the Department of Nanoscience and technology, Karunya University, Coimbatore for SEM and Zeta potential analysis

REFERENCES

[1] Pathak, PD., Mandavgane, SA., Kulkarni, BD, Characterizing fruit and vegetable peels as bioadsorbents. *Current Sci.*,2016; 110(11): 2114 - 2123.

[2] Palma, C., Contreras, E., Urra, J., Martunez, MJ, Eco-friendly technologies based on banana peel use for the decolourization of the dyeing process waste water. *Waste Biomass Valorization*, 2011;(2): 77 - 86.

[3] Zerega, NJC., Motley, TJ, *Artocarpus* (Moraceae) molecular phylogenic and the systematic and origins of breadfruit. *Artocarpus artilis Botanical society of America Annual meeting*. Albuquerque, N.M., (2001) August, 12 - 16.

[4] Ismadji, S., Prahas, D., Kartika, K., Indraswati, N, Activated carbon from jackfruit peel waste by H3PO4 chemical activation: Pore structure and surface chemistry characterization. *Chemi. Engg. J.*, 2008; (14): 32 - 42.

[5] Bakar, MFA., Karim, FA., Periasamy, E, Comparison of phytochemicals and antioxidant properties of different fruit parts of selected *Artocarpus* species from Sabah, Malaysia. *Sains Malaysiana*, 2015; 44(3): 355 - 363.

[6] Syah, YM., Juliawaty, LD., Achamd, AS., Hakim, EH., Ghisalberti, EL, Cytotoxic prenylated flavones from *Artocarpus integer*. *J. of Natural Medicines*, 2006; (60): 308 - 312.

[7] Hakim, HE., Juliawaty, LD., Syah, YM., Achmad, SA, Molecular diversity of *Artocarpus integer* (Moraceae): A species endemic to Indonesia. *Molecular Diversity,* 2005; (9): 149 - 158.

[8] Chadha, YR, *The Wealth of India - Raw Materials*. Publications and Information Directorate, CSIR, New Delhi, (1985) 450.

[9] Inbaraj, BS., Sulochana, N, Use of Jackfruit peel carbon (JPC) for adsorption of rhodamine - B, a basic dye from aqueous solution. *Indian J. of Chem. Tech.*, 2006; (13): 17 -23.

[10] Sulochana, N., Inbaraj, BS, Carbonized jackfruit peel as an adsorbent for the removal of Cd (II) from aqueous solution. *Biores. Tech.*, 2004; (94): 49 - 52.

[11] Noranizan, MA., Koh, PC., Leong, CM, Microwave - assisted extraction of pectin from jackfruit rinds' using different power levels. *Interna. Food Res. J.*, 2014; 21 (5): 2091 - 2097.

[12] Begum, R., Aziz, MG., Uddin, MB., Yusof, YA, Characterization of Jackfruit (A*rtocarpus heterophyllus*) waste pectin influenced by various Extraction conditions. *Agricul. and Agricu.l Sci. Proce.*, 2014; (2): 244 - 251.

[13] Mohamed, S., Hasan, Z, Extraction and characterization of pectin from tropical agro wastes. *ASEAN Food J.*, 1995; 10 (2): 43 - 50.

[14] Rashid, H., Hussain, T., Baig, MQ, Extraction and evaluation of pectin from mango peel. *Pakistan J. of Agri. Res.*, 1991; (12): 3.

[15] Association of Official Analytical Chemists (AOAC), Vitamins and other nutrients. In Horwitz, W. (Ed). *Official Methods of Analysis of Association of Analytical Chemists International*, (2000) p. 12 - 20. Maryland USA: AOAC International Publications.

[16] Ahmad, S., Nanda, A., Dhiman, A, The Metal analysis in *Citrus Sinensis* fruit peel and *Psidium Guajava* leaf. *Toxicology Interna*, 2011; 18 (2): 163 - 167.

[17] Ranganna, S, *Handbook of Quality Control for Fruit and Vegetable Products*, 2010; (2): 1 - 34.

[18] Thayumanavan, B., Sadasivam, S, *Qualita. of plant Foods Human Nutri.*, 1984; (34): 253.

[19] Mu, TH., Ma, MM, Effects of extraction methods and particle size distribution on the structural, physicochemical, and functional properties of dietary fiber from deoiled cumin. *Food Chem.*, 2016; (194): 237 - 246.

[20] Hsieh, YL., Jiang, F, Cellulose nanocrystal isolation from tomato peels and assembled nanofibers. *Carbohy. Poly.*, 2015; (122): 60 - 68.

[21] Deka, SC., Khawas, P, Isolation and characterization of cellulose nanofibers from culinary banana peel using high - intensity ultrasonication combined with chemical treatment. *Carbohy. Poly.*, 2016; (137): 608 - 616.

[22] Vaidya, AA., Gaugler, M., Smith, DA, The Green route to modification of wood waste, cellulose and hemicellulose using reactive extrusion. *Carbohy. Poly.*, 2016; (136): 1238 - 1250.

[23] Chandra, JCS., George, N., Narayanankutty, SK, Isolation and Characterization of cellulose Nanofibrils from Arecanut husk fiber. *Carbohy. Poly.*, 2016; (142): 158 - 166.

[24] Penjumaras, P., Rahman, RBA., Talib, RA., Abdan, K, Extraction and characterization of cellulose from durian rind. *Agri. and Agri. Sci. Proceed.*, 2014; (2): 237 - 243.

[25] Lv, GJ., Wu, S., Lou, R, Kinetic study of the thermal decomposition of hemicellulose isolated from the corn stalk. *Biores. Tech.*, 2010; 5 (2): 1281 - 1291.

[26] Orozco, RS., Hernandez, PB., Morales, GR., Nunez, FU., Villafuerte, JO., Lugo, VL., Ramirez, NF., Diaz, CEB., Vazquez, PC, Characterization of Lignocellulosic fruit waste as an alternative feedstock for bioethanol production. *Biores. Tech.*, 2014; 9 (2): 1873 - 1885.

[27] Zain, NFM., Yusop, SM., Ahmad, I, Preparation and characterization of cellulose and nanocellulose from Pomelo (*Citrus grandis*) albedo. *J. of Nutri. Food Sci.*, 2014; (5): 334, doi:104172/2155-9600.1000334.

[28] Ververis, C., Georghiou, K., Danielidis, D., Hatzinikolaou, D., Santas, G., Santas, P., Corleti, R, Cellulose, hemicelluloses, lignin and ash content of some organic materials and their suitability for use as paper pulp supplements. *Biores. Tech.*, 2007; 98 (2): 296 - 301.

[29] Hameed, BH, Removal of cationic dye from aqueous solution using jackfruit peel as non-conventional low-cost adsorbent. *J. of Hazardous Materi.*, 2009; (162): 344 - 350.

[30] Macagnan, FT., Santos, LRD., Roberto, BS., Moura, FAD., Bizzani, M., Silva, LPD, Biological properties of apple pomace, orange bagasse and passion fruit peel as alternative sources of dietary fiber. *Carbohy. Poly.*, 2015; 6(1): 1 - 6.

[31] Priyanka, P., Sayed, HM., Joshi, AA., Jadhav, BA, Comparative evaluation of physicochemical properties of two varieties of pomegranate fruits - Ganesh and Arata. *African J. of Food Sci.*, 2013; 7 (11): 428 - 430.

[32] Satchithanandam, S., Grundel, E., Roach, J., White, KD, Mazzola, Alkaloids and saponins in dietary supplements of blue cohosh (*Caulophyllum thalictroides*). *J. of AOAC Interna*., 2008; (91): 21 - 32.

[33] Maisuthisakul, P., Gordon, MH, Antioxidant and tyrosinase inhibitory activity of mango seed kernel by product. *Food Chem.*, 2009; (117): 332 -341.

[34] Ahmad, A., Fatlawi, AAA., Fatlawi, AAA., Irshad, Md., Zafaryab, Md., Rizvi, MMA, Rice Bran Phytic acid Induced Apoptosis through regulation of Bcl-2 / Bax and p53 Genes in HepG2 Human Hepatocellular Carcinoma cells. *Asian Pacific J. of Cancer Prevention*, 2014; (15): 3731 - 3736.

[35] Ajila, CM., Aalami, M., Leelavathi, K., Prasada, UJR, Mango peel powder: A potential source of antioxidant and dietary fiber in macaroni preparations. *Innov. Food Science and Emerging Techn*, 2010; (11): 219 - 224.

[36] Koubaa, M., Ktata, A., Barba, F.J., Grimi, N., Mhemdi, H., Bouaziz, F., Ellouz, CS, Water-soluble polysaccharides from Opuntia stricta Haw. fruit peels: Recovery, identification and evaluation of their antioxidant activities. *Intern. Agrophysics*, 2015; (29): 299 - 306.

[37] Orozco, RS., Hernandez, PB., Ramirez, NF., Morales, GR., Luna, JS., Montoya, AJC, Gamma Irradiation Induced Degradation of Orange Peels. *Energies*, 2012; (5): 3051 - 3063.

[38] Mallek-Ayadi, S., Bahloul, N., Kechaou, N, Characterization, phenolic compounds and functional properties of *Cucumis melo* L. peels. *Food Chem.*, 2017; (221): 1691 - 1697.

[39] Al-Sayed, HMA., Ahmed, AR, Utilization of watermelon rinds and sharlyn melon peels as a natural sources of dietary fiber and antioxidants in cake. *Annals of Agri. Sci.*, 2013; 58(1): 83 - 95.

[40] Wani, KS., Lokhande, AR., Siddiqui, MAS, Study of pectin from peels of M*agnifera Indica* and A*rtocarpus heterophyllus. Interna. Conference on Global Trends in Engg., Tech. and Manag.*, 2016; 375 - 381.

[41] Khule, NR., Mahale, NB., Shelar, DS., Rokade, MM., Chaudhari, SR, Extraction of pectin from citrus fruit peel and use as the natural binder in paracetamol tablet. *Scholars Res. Library*, 2012; 4(2): 558 - 564.

[42] Singh, R., Bhat, SA., Extraction and Characterization of pectin from Guava Fruit Peel. *Internat. J. of Res. in Engg. and Adv. Tech.*, 2014; 2 (3): 2320 -8791.

[43] Rosell, CM., Santos, E., Collar, C, Physicochemical properties of commercial fibres from different sources: A comparative approach. *Food Res. Interna.*, 2009; 42 (1): 176 - 184.

[44] Peerajit, P., Chiewchan, N., Devahastin, S, Effects of pretreatment methods on health-related functional properties of high dietary fiber powder from lime residues. *Food Chemi.*, 2012; 132 (4): 1981 - 1898.

[45] Oliveira, CF., Gurak, PK., Cladera-Olivera, F., Marczak, LDF, Evaluation of physicochemical, technological and morphological characteristics of powdered yellow passion fruit peel. *Internat. Food Res. J.*, 2016; 23 (4): 1653 - 1662.

[46] Alves, L., Medronho, B., Antunes, FE., Garcia, MPF., Ventura, J., Araujo, JP., Romano, A., Lindman, B, Unusual extraction and characterization of nanocrystalline cellulose from cellulose derivatives. *J. of Molecular Liquids*, 2015; (210): 106 - 112.

[47] Taylor, TM., Gaysinsky, S., Davidson, PM., Bruce, BD., *Weiss, Journal of Food Biophysics*. 2007; (2): 1 - 9.

[48] Kaur, P., Thakur, R., Chaudhury, A, Biogenesis of Copper nanoparticles using peel extract of *Punica granatum* and their antimicrobial activity against opportunistic pathogens. *Green Chemistry Letters and Rev.*, 2016; 9 (1): 33 - 38.

[49] Kamsonlian, S., Suresh, S., Majumder, C.B., Chand, S, Characterization of banana and orange peels: biosorption mechanism. *Inter. J. of Sci. Tech. and Manage.,* 2011; 2 (4): 1 - 7.

[50] Singanusong, R., Tochampa, W., Kongbangkerd, T., Sodchit, C, Extraction and Properties of Cellulose from Banana Peels. *Suranaree J. of Sci. and Tech.*, 2014; 1 - 19.

[51] Thirumavalavan, M., Lai, YL., Lin, LC., Lee, JF, Cellulose - based native and surface modified fruit peels for the adsorption of heavy metal ions from aqueous solution: Langmuir adsorption isotherms. *J. of Chemi. Engg. Data*, 2010; (55): 1186 - 1192.

[52] Mandavgane, SA., Pathak, PD., Kulkarni, BD, Characterizing fruit and vegetable peels as bioadsorbents. *Current Sci.*, 2016; 110 (11): 2114 - 2123.

[53] Yang, H., Yan, R., Chem, H., Lee, D.H., Zheng, C, Characteristics of hemicellulose, cellulose and lignin pyrolysis. *Fuel*, 2007; (86): 1781 - 1788.

[54] George, B., Boumediene, M., Benaissa, H., Molina, S., Merlin, A, Characterization of two cellulosic waste materials (Orange and Almond peels) and their use for the removal of methylene blue from aqueous solution. *Maderas Sync Tech.*, 2015; 17 (1): 1 - 23.

[55] Li, Y., Tang, Y., Cao, X., Lu, D., Luo, F., Shao, W, Preparation and evaluation of orange peel cellulose adsorbents for effective removal of cadmium, zinc, cobalt and nickel. *Colloid surface Physicochemi. Engg. Aspects*, 2008; (317): 512 - 521.

[56] Zapata, B., Balmaseda, J., Fregoso, IE., Torres, GE, Thermo - kinetics study of orange peel in air. *J. of Thermal Analysis Calorime.*, 2009; (98): 309 - 315.

[57] Bodirlau, R., Teaca, CA., Spiridon, I, Chemical modification of beech wood: Effect on thermal stability. *Bioresour.*, 2008; 3 (3): 789 - 800.

[58] Xu, F., Yu, J., Tesso, T., Dowell, F., Wang, D, Qualitative and quantitative analysis of Lignocellulosic biomass using infrared techniques: A mini -review. *Applied Ener.*, 2013; 104 (1): 801 - 809.

[59] Tamez, UM., Rukanuzzaman, M., Maksudur, RKM., Akhtarul, IM, Adsorption of methylene blue from aqueous solution by jackfruit (*Artocarpus heterophyllus*) leaf powder: A fixed bed column study. *J. of Environ. Manag.*, 2009; (90): 3443 - 3450.

[60] Bhat, IUH., Abdul, KHPS., Ismail, H., Alshammari, T, Morphological, and thermal properties of alkali-treated and chemically modified oil palm empty fruit bunch and oil palm frond fibers: A comparative study. *Biores. Tech.*, 2011; (6): 4673 - 4685.

[61] Ong, HR., Prasad, R., Khan, MMR., Chowdhury, MNK, Effect of palm kernel meal as melamine urea formaldehyde adhesive extender for plywood application: Using a Fourier Transform Infrared Spectroscopy (FTIR) study. *Applied Mechanical and Mater.*, 2012; 121 (126): 493 - 498.

[62] Ramli, R., Khan, Md. MR., Yunus, RM., Ong, RH., Halim, RH., Aziz, AA., Ibrahim, Z., Zainul, NH, In- situ impregnation of copper nanoparticles on palm empty fruit bunch powder. *Advances in nanoparti.*, 2014; (3): 65 - 71.

[63] Chaudhari, SA., Singhal, RS, Cutin from watermelon peels: A novel inducer for cutinase production and its physiochemical characterization. *Interna. J. of Biolog. Macromolec.*, 2015; (79): 398 - 404.

[64] Boonamnuavitaya, V., Saeung, S., Tanthapanichakoon, W, Preparation of activated carbons from coffee residue for the adsorption of formaldehyde. *Separ. Purif. Tech.*, 2003; (42): 159 - 168.

[65] Tao, YJ, Study on the modification and application of wheat bran dietary fiber, (2008) Jiangnan University.

[66] Foo, KY., Hameed, BH, Potential of jackfruit pee as precursor for activated carbon prepared by microwave induced NaOH activation. *Biores. Tech.*, 2012; (112): 143 - 150.

[67] Zhao, YY., Chen, J., Chen, FL., Wang, XC., Zhu, QJ., Ao, Q, Surface characterization of corn stalks superfine powder studied by FTIR and XRD colloids and surfaces B. *Biointerf.*, 2013; (104): 207 - 212.
[68] Puziy, AM., Poddubnaya, OI., Martinez, AA., Suarez, GF., Tascon, JMD, Synthetic carbons activated with phosphoric acid I surface chemistry and ion binding properties. *Carbon*, 2002; (40): 1493 - 1505.
[69] Puziy, AM., Poddubnaya, OI., Martinez, AA., Suarez, GF., Tascon, JMD, Surface chemistry of phosphorus-containing carbons of lignocellulosic origin. *Carbon*, 2005; (43): 2857 - 2868.
[70] Kacurakova, M., Capek, P., Sasinkova, V., Wellner, N., Ebringerova, E, FT-IR study of plant cell wall model compounds: Pectic polysaccharides and hemicelluloses. *Carbohy. Poly.*, 2000; 43 (2) 195 - 203.
[71] Zhu, K., Zhang, Y., Nie, S., Xu, F., He, S., Gong, D., Wu., L. Tan, Physicochemical properties and in vitro antioxidant activities of polysaccharide from *Artocarpus heterophyllus* Lam. pulp. *Carbohy. Poly.*, 2017; (155): 354 - 361.
[72] Fang, X., Yin, X., Yuan, G., Chen, X, Chemical and biological characterization of polysaccharides from the bark of *Avicennia marina*. *Euro*. *Food Res. and Tech.*, 2015; 1 - 9.
[73] Bondeoson, D., Mathew, A., Oksman, K, Optimization of the isolation of nanocrystals from microcrystalline cellulose by acid hydrolysis. *Cellu.,* 2006; (13): 171 - 180.
[74] Elanthikkal, S., Gopalakrishnapanicker, U., Varghese, S., Guthire, JT, Cellulose microfibres produced from plant wastes: Isolation and characterization. *Carbohy. Poly.*, 2010; (80): 852 - 859.
[75] Hiasa, S., Iwamoto, S., Endo, T., Edashige, Y, Isolation of cellulose nanofibrils from Mandarin (*Citrus unshiu*) peel waste. *Indust. crops and Produ.*, 2014; (62): 280 - 285.
[76] Ismadji, S., Soetareji, JP., Widjaja, C., Djojoraharjo, Y., Soetaredjo, FE, Bio-oil from jackfruit peel waste. *Proce. Chem.,* 2014; (9): 158 - 164.
[77] Pattiya, A., Suttibak, S, Production of bio-oil via fast pyrolysis of agricultural residues from Cassava plantation in fluidized - bed reactor with a hot vapor filtration unit. *J. of Analytical Applied Pyroly.*, 2012; (95): 227 - 235.
[78] Girrar, JP, *Smoking In: Technology of Meat and Meat Products.* Ellis Horwood Limited., (1992) New York.