**PREPARATION, CHARACTERIZATION AND USES OF ACTIVATED CARBON FROM DIFFERENT AGRICULTURAL WASTE AND THEIR COMPARISON WITH RIDGE GOURD**



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**Preparation, Characterization And Uses Of Activated Carbon From Different Agricultural Waste And Their comparison With Ridge Gourd**

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BY

Chemical Engineering Department

Under the guidance of

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**CERTIFICATE**

This is to certify that the project titled “PREPARATION OF ACTIVATED CARBON FROM DRIED RIDGE GOURD AND ITS CHARACTERISATION” is a bona fide record of the work carried out by ANKITA ROUTRAY-33506, DEBERPEETA SAHOO-33511,DEBASISH PATNAIK-33512, JYOTI RANJAN SAHU-3516, MD ZAFFAR ZESHAN-33524, PRABHUDUTTA DASH-33528, SATYAJIT BISWAL-33536,. under my supervision and guidance for the partial fulfilment of the requirements for the degree of Bachelor of Technology in Chemical Engineering during the academic session 2014-2018 in the Department of Chemical Engineering, Indira Gandhi Institute of Technology, Sarang-759146.

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ABSTRACT

In this work activated carbon was prepared from dried ridge gourd by chemical activation method and was characterised. Different physical properties like proximate analysis which include moisture content, volatile matter content, ash percentage and ultimate analysis which include carbon, hydrogen, sulphur, nitrogen, and oxygen percentage were investigated. The result shows that the fixed carbon content is 64.34%, moisture content is 5.53%, ash content is 6.72% and volatile matter is 23.41%. The ultimate analysis shows that it contains about carbon 43.06%, hydrogen 6.08%, nitrogen 1.21%, sulphur 0.11% and oxygen 49.54%.

Activated Carbon are extensively used in the abatement of hazardous contaminants, treatment of municipal & industrial waste water, as catalyst or catalyst support in medicine, & the recovery of valuable metals because it is specially treated to create a highly developed internal pore structure & thus this pore structure is responsible for the superior performance of activated carbons.

In this report the production of activation carbon from a large number of abundant and low cost materials and agricultural waste such as camellia oleifera shell, bamboo, cherry stones, waste tea and paulownia flower are discussed. Chemical or physical activation methods and microwave radiation methods are commonly used techniques adopted for preparation of activation carbon.

Keywords – Activated carbon, proximate analysis and ultimate analysis.

INTRODUCTION

- In the world of 21st century, the main threat that catches attention of the whole world is our own endangered and fragile planet Earth. Today environmental pollution is a serious problem and is of main concern. Activated carbon removes environmental pollutants, contaminants and impurities from soil, water and air and its demand has increased over the years. One of the main challenges in the commercial manufacture of activated carbon is to identify new precursor that are cheap, accessible and available in large quantity that has potential for significant economic benefit. Activated carbon is a special type of carbonaceous substance. It has highly crystalline form and extensively developed internal pore structure. Due to activation, internal pore network is created which imparts certain surface chemistry (functional groups) inside each particle. Thus carbon gets its unique characteristics leading to high surface area, porosity and greater strength. The absorptivity of the adsorbent depends on both the size of the molecule being adsorbed and the pore size of the adsorbent. Activated Carbon is a high porosity material which is used in adsorption of both gas and solute from aqueous solution. Activated carbon is most important adsorbent in modern society and for future. Activated carbon with high surface area and pore volume are produced from a variety of carbonaceous source material like wood, agricultural by product and coal.

The agricultural waste include some number of nutshells as almond shell[1]; coconut shell[2]; hazelnut shell[3]; olive, peach, apricot and cherry stone[4,5,6]; grape seed[7] and eucalyptus leaves[8]. Now a day, the agricultural wastes are preferred more due to raw material renewability and low cost.

Various research studies the production of AC from palm tree cob [9], plum kernel [10], cassava peel [11], bagasse [12], jute fiber [13], rice husk [14], olive stone [15], date pit [16], fruit stone [17] and nutshell.

Raw materials for its preparation should possess some characteristics like high carbon content, low inorganic content, high density, sufficient volatile content, inexpensive and availability [18].

Considering the above characteristics and available resource, ridge gourd has been selected as the raw material. Adsorption has appeared as one of the promising methods for CO2 capture and sequestration due to its low energy consumption, cost effectiveness, relatively simple technological process and non-corrosive to the equipment and it is applicable over a relatively wide range of temperature and pressure. Zeolites or activated carbon are good adsorbents that are used for capturing CO2 from flue gas through physical adsorption, due to its porous structure. The extensive use of activated carbon is now a days, due to its large micro porosity and large specific surface area [19].

It classified according to its particle shape and size of AC and it has 3 form of AC.

Granulated activated carbon

Powder activated carbon

Pellet activated carbon

GAC – it has relatively larger particle size compared to PAC and consequently presents a smaller external surface. The size range is form .5-4.0 mm. this type of AC is commonly used in water treatment facilities where granule carbon remove bed to remove tastes, odor and dissolved organics.it can also be used for gas phase application.

PAC –the size of PAC is less than100µm in size with an avg. diameter between 15-25µm. thus, they present a large internal surface with a small diffusion distance. PAC used in liquid phase adsorption and flue gas treatment. In waste water treatment, the most common use of PAC is in the secondary treatment called PAC treatment process.

PELLET- it consists of extruded and cylindrical shaped AC with diameter in the range of 4-7 mm and 8-15 mm length. Pac is mainly used for gas phase application because of their low pressure drop, high mechanical strength and low dust content.

Activated carbon has often been associated with the existence of the heteroatoms like oxygen, sulfur, hydrogen, nitrogen, halogen and other elements in the forms of functional groups and/or atoms which bonded chemically to the structure. Oxygen is found to be predominant which exist in the form of functional groups such as carboxyl, carbonyl, phenols, lactone and others. The nature and the amount of the oxygen surface groups that are found in the activated carbon also depend on the precursor and the activation treatment. These carbon–oxygen groups of acidic (carboxylic, lactonic) and non-acidic (carbonyl, ether, Quinone) evolve as CO2 and CO, respectively, upon thermal decomposition. The phenol groups also evolve as CO, similar to those non-acidic, while anhydride gives rise to both CO and CO2. Activated carbon have either protonated (COH2+), neutral (COH), or ionized (CO-) on its surface. Those with protonated surfaces are called as H-type carbons, while ionized surfaces are called as L-type carbons [20]. Preparation of activated carbon from chemical activation was carried out by steps are carbonization step and activation step. Raw material is impregnated with an activating reagent before carbonization step in chemical activation method. The effect of different chemical reagents on the production and quality of activated carbon was studied extensively by different researchers. Different chemicals are used like Zinc chloride (ZnCl2), phosphoric acid (H2PO4), Sulphuric acid (H2SO4), potassium hydroxide (KOH), sodium hydroxide (NaOH), and K2CO3. Chemical activation is better than physical activation process because it generally takes place at a lower temperature and shorter time and the development of a porous structure is better than that of physical activation [19].

They have wide range of application in different industries which include gas purification [20], reduction of organic pollutant from drinking water as well as waste water [21], several medical application [22], catalyst support [23], owning their surface area, pore structure, thermal stability and low acid/base reactivity and environmental pollution [24].

HISTORY OF ACTIVATED CARBON

The useful properties of activated carbon have been known since ancient times. This traces back to 1500 BC when Egyptians used charcoal as an adsorbent for medicinal purposes and a purifying agent. Around 420 BC it was observed that Hippocrates dusted wounds with powdered charcoal to remove their odor. Ancient Hindu societies purified their water by filtration through charcoal. In 1773, the Swedish chemist Karl Wilhelm Scheele was the first to observe adsorption of gases on charcoal. A few years later activated carbons began being used in the sugar industry as a decolorizing agent for syrup.

In the early 20th century the first plant to produce activated carbon industrially was built for use in sugar refining industry in Germany. Many other plants emerged in the early 1900’s to make activated carbons primarily for decolourisation. During World War I activated carbon was used in gas masks for protection against hazardous gases and vapors. Today, activated carbons are used to remove color from pharmaceutical and food products, as air pollution control devices for industrial and automobile exhaust, for chemical purification, and as electrodes in batteries. 500,000 tons per year of activated carbon are produced globally. 80% of this is used for liquid phase applications, and 20% is used for solid phase applications.

METHOD OF PREPARATION

There are two different processes for activated carbon preparation chemical and physical treatment. Both treatments are responsible in varying the shapes and the sizes. In physical treatment, precursors will be first carbonized followed by activation step by steam or carbon dioxide. The physical activation involves two steps; carbonization step and activation step [25].

**PHYSICAL ACTIVATION:**

Physical or “thermal” treatment is a two-step process; i.e. carbonization and activation. It is basically referred to dry oxidation which involves the reaction between the samples and gaseous (CO2 and air), steam or mixture of gaseous and steam at temperature reaching above 7000C. The use of CO2 has been commonly preferred due to its clean, easy to be handled and the activation process can be easily controlled at temperature around 800 0C due to its slow reaction rate. A greater uniformity of pore also can be achieved with the activation of CO2 as compared to steam [25].

The steps of physical activation by steam oxidation involve pre oxidation, pyrolysis, and steam activation. In pre oxidation, the air is diluted in half using N2 initially. It is of paramount to reduce the concentration of oxygen to avoid the increasing temperature from an exothermic reaction between oxygen and coal. Therefore, pre oxidation step could minimize the coal caking formation and agglomeration during pyrolysis step. The sample will undergo the pyrolysis step and followed by steam activation by replacing the N2 flow with a mixture of 50% H2O and 50% N2.

**CHEMICAL ACTIVATION:**

Chemical activation is also called as wet oxidation requires catalyst to be impregnated into the precursor and washed to produce the activated carbon [25]. According to Molino-Sabio and Rodriguez-Reinoso [26], chemical activation has been commonly done at 450–600 0C. Activating agents basically act as dehydrating agents and oxidants which could influence the pyrolytic decomposition .It also could prevent the formation of the tar or ash hence developing the carbon yield .The chemical catalysts (oxidizing agents) that usually used are ZnCl2, H3 PO4, H2SO4, K2S, KCN, HNO3, KMnO4, (NH4)S2O8 , NaOH, KOH , and K2CO3. The surface oxygen functional groups can be introduced to the carbon of the precursor when react with activating agents.

Chemical activation is avoided in industrial application due to environment concern and cost.

The advantage of chemical activation is low energy requirements, as chemical activation is usually conducted at lower temperatures, while providing higher yields and higher porosity [27, 28, 29]. It has been reported that ACs with a very large surface area and large micro-pore volume can be synthesized by KOH activation [30, 31-32].

Literature survey indicates that there have been many attempts to obtain low-cost AC or adsorbent from agricultural wastes such as wheat [33], corn straw [33], olive stones [34,35], bagasse [34,35], birch wood [34,35], miscanthus [34,35], sunflower shell [36],pinecone [36], rapeseed [36,37], cotton residues [36], olive residues [36], pine rayed [38], eucalyptus maculata [38], sugar cane bagasse [38,39], almond shells [40,41,42], peach stones [43], grape seeds [40], straw [34,35,44], oat hulls [43,45], corn stover [43,45], apricot stones [40,41], cotton stalk [46], cherry stones [40], peanut hull [47], nut shells [40,48–51], rice hulls [39], corn cob [71,52–54], corn hulls [45], hazelnut shells [41], pecan shells [39], rice husks [55,56] and rice straw [41,57].

CHARACTERIZATION

Physical characterization

In physical characterization of the actual activated carbon are measures different physical properties such as bulk density, the surface area generated, the pore size distribution, total pore volume.

Bulk density is measured by water displacement method and the surface area generated is measured by BET method. Mesopore and Micropore volume combinly gives the total volume and is calculated by converting the amount of nitrogen gas absorbed at relative pressure 0.95 atm to equivalent liquid volume absorbent.

**Chemical characterization**

Chemical characterization include determination of percent moisture, volatile matter and fixed carbon content, surface inorganic content.

The surface inorganic content is measured by x-ray diffractometer by x-ray pattern under the scan at the rate of 0.10C per minute.

The surface functional groups and structure is studied by FTIR spectroscopy.

**1. PROXIMATE ANALYSIS -**ASTM defines proximate analysis as the determine by prescribed method of moisture, volatile matter, ash & fixed carbon.

**Moisture Content-**A small amount of activated carbon sample weight was measured and then taken in a petri dish. It was spread nicely on the dish. It was then heated in an oven at a temperature of (105-110) ˚c for 1.5hr. The petri dish was left open or not covered during heating process. After heating petri dish was removed and cooled in a desicator. After cooling the weight of dried sample was measured.

Moisture content M=100(B-F)/ (B-G)

B=weight of petri dish +original sample

F=weight of petri dish+ dried sample

G= weight of petri dish

**Ash content**- 1 gm of sample was taken in a silica crucible. It was heated in a muffle furnace to 750˚c for 1.5hr. During this heating process the crucible was left open. After the required heating, the crucible was cooled in a desicator and then weight of the ash was measured.

Ash content A=100(F-G)/(B-G)

G=Mass of empty crucible

B=Mass of crucible + sample

F=Mass of crucible+ ash sample

**Volatile matter content-** A known quantity of sample was taken in cylindrical crucible closed with a lid. It was then heated to 925˚c for exactly 7minutes in a muffle furnace. Then the crucible was cooled in a desicator and weighted.

VM=100[100(B-F)-M (B-G)]/[(B-G)(100-M)]

B=Mass of crucible, lid and sample before heating

F=Mass of crucible, lid and contents after heating

G=Mass of empty crucible & lid

M=% of moistures determined above

**Fixed carbon content-**

Fixed carbon FC = 100 – (% moisture content+ % volatile matter + % ash content)

ULTIMATE ANALYSIS - it more comprehensive, is dependent on qualitative analysis of various element present in the sample such as C, H, S, O and N.

Information on the available and existing data on the activated carbon prepared from different sources are presented in the tables below.

Table-1 gives information about the activating agent, activation condition and carbonisation condition.

**Table** **1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **SL NO** | **RAW MATERIALS** | **PARTICLE SIZE(mm)** | **Process of Activated Carbon** | **ACTIVATION**  **CONDITION**  **(Temp °C/ Time)** | **CARBONIZATION**  **CONDITION**  **( Temp °C/Time)** | **REFERENCE** |
| 1 | Macadamia nutshell | 5-6 | Chemical activation with KOH and ZnCl2 | 500-700  1-3 hr | 500-700  1-3 hr | A. Ahmadpour et al. [58] |
| 2 | Viscous rayon |  | Physical activation | 70  90 min | 850  1 hr | A.C. Pastor et al. [59] |
| 3 | Corn cob agro waste | 1.19-1.68 | Physical activation | 900 | 900 | C.F. Chang et al. [60] |
| 4 | Lignin |  | Chemical activation | 800 | 500-900 | J. Hayashi et al. [61] |
| 5 | Palm shell | 1-2 | N2 , Steam | 820  20-250 min | 500-900  1 hr | Daud et al.[62] |
| 6 | Gelam wood bark | 5-10 | Chemical activation with ZnCl2 | 500  3 hr | 500  3 hr | A.H. Abdullah et al. [63] |
| 7 | Coconut shell | 1-2 | Chemical activation with CO2, ZnCl2 | 800  2-3 hr | 800 | Hu and Srinivasan[64] |
| 8 | Spanish anthracite | 0.6-1 | Chemical activation with KOH | 600  2 hr | 200  2 hr | D. Lozano-Castello et al. [65] |
| 9 | Coconut shell |  | Steam | 800  60-270 min | 400-800  1 hr | Cagnon et al.[66] |
| 10 | Coconut shell |  | N2 , Steam | 800  60-270 min | 400-800  1 hr | Cagnon et al.[66] |
| 12 | Coffee residue |  | Chemical activation with ZnCl2 | 600  4 hr | 300  12 hr | V. Boonamnuayvitaya et al. [67] |
| 13 | Phenolic resin | 0.5-1 | Supercritical water activation | 800  160 min | 800  30 min | Q. Cai et al. [68] |
| 14 | Pineapple peel | 0.15-0.25 | Chemical activation with H2SO4 | 300  3 hr | 300  3 hr | Q. Cai et al.[68] |
| 15 | Pistachio nut shell | 2-2.8 | Pyrolysis with CO2 | 900  30 min | 250-1000  2 hr | Lua et al. [69] |
| 16 | Palm shell  Coconut shell | 1-2 | Pyrolysis with CO2 | 850  5-80 min | 850  1 hr | Daud and Ali[70] |
| 17 | Babassu shells | 1-2.36 | Physical activation | 900  20 min | 500 | E. F. Jaguaribe et al. [71] |
| 18 | Sugarane bagasse- | 1-2.36 | Physical activation | 800  20 min | 500 | E. F. Jaguaribe et al. [71] |
| 19 | Bamboo | 1-2 | Chemical activation with KOH | 850  2 hr | 700  1 hr | B.H. Hameed et al. [72] |
| 20 | Cassava peel |  | Chemical activation with KOH | 110  24 hr | 450-750  1-3 hr | Y. Sudaryanto et al. [73] |
| 21 | Walnut shell | 1-2 | Physical activation followed by Chemical activation with KOH | 900  1 hr | 600-900  1 hr | M.L. Martin et al. [74] |
| 22 | Vineyard shoot |  | Chemical activation with H3PO4 | 300-600  1 hr | 300-600  1 hr | Corcho-Corral et al. [18] |
| 23 | Woody birch | 0.5-1.0 | Chemical activation with H3PO4,  steam | 600  1 hr | 600  1 hr | Budinova et al.[76] |
| 24 | Woody birch | 0.5-1.0 | Chemical activation with H3PO4,  steam | 700  2 hr | 700 | Budinova et al.[76] |
| 25 | Palm shell | 1-2 | Chemical activation with K2CO3 |  | 600-100  2 hr | Adinata et al. [77] |
| 26 | Mango pit | 6-7 | Physical activation | 550  2 hr | 550  2 hr | M.P. Elizalde-Gonz´alez et al. [78] |
| 27 | Coconut husk | 1-2 mm | Chemical activation with KOH | 700  2 hr | 700  2 hr | I.A.W. Tan et al.[79] |
| 28 | Olive waste cake | 0.15 | Chemical activation with H3PO4 |  | 350-650  2 hr | Baccar et al.[80] |
| 29 | Hazel nut bagasse | 0.6-0.8 | Chemical activation with KOH and ZnCl2 |  | 500-700  2 hr | Demiral et al.[81] |
| 30 | Palm shell | 0.5-1.5 | Chemical activation with ZnCl2 | 400-800  90 min | 400-800  3 hr | Allwar et al.[82] |
| 31 | Almond shell  Walnut shell  Almond tree purin  Olive stone | 1-2 | Steam | 850  30 min | 600  1 hr | Gonzalez et al.[83] |
| 32 | Activated sludge |  | Physical  Activation | 70  90min | 850  1 hr | Z. Al-Qodah et al.[84] |
| 33 | Tunisian olive waste cake | 0.1-0.16 | Chemical activation with H3PO4 | 350-650  2 hr | 350-650  2 hr | R. Baccar et al.[85] |
| 34 | Bamboo |  | Chemical Activation with HCl |  | 600-100  2hr | Ademiluyi et al[86] |
| 35 | Cattail |  | Chemical activation with H3PO4 | 500  80 min | 500 | Q. Shi et al.[87] |
| 36 | Coconut shell | 3.35-4.75 | Physical activation | 900 | 1000  2 hr | K. Yang et al. [88] |
| 37 | Neem husk |  | Chemical activation with H3PO4,KOH and ZnCl2 |  | 200-500  10 min | Alau et al. [89] |
| 38 | Ground nut shell | 2 | Chemical activation with H3PO4, KOH and ZnCl2 |  | 800  5 min | Gimba et al. [90] |
| 39 | Stink bean | 125 | Chemical activation with H3PO4 |  | 450-650  1 hr | Foo and Lee [91] |
| 40 | Jatropha hull | 2-5 | Physical activation | 800-1000  15-30 min | 600  1hr | D. Xin-hui et al.[92] |
| 41 | Rice husk |  | Chemical activation with K2CO3 | 700 | 700 | K.Y. Foo et al. [93] |
| 42 | Sorghum pith |  | Chemical activation with NaOH | 200  8 hour | 300-500  3 hour | S.T. Senthilkumar et al. [94] |
| 43 | Mango seed shell | 2-5 | Physical activation | 800-1000  15-30 min | 600  1hr | D. Xin-hui et al. [92] |
| 44 | Palm kernel shell | 1.18 | Chemical activation with KOH | 800-1000  15-40 min | 400  1 hr | Abechi et al.[95] |
| 45 | Date tree frond |  | Chemical activation with H3PO4 |  | 400  3 hr | Al-Swaidan and  Ahmad[96] |
| 46 | Rice husk |  | Chemical activation with ZnCl2 |  | 500  1 hr | Boonpoke et al.[97] |
| 47 | Bagasse |  | Chemical activation with ZnCl2 |  | 500  1 hr | Boonpoke et al.[97] |
| 48 | Eichhornia crassipes root | .00--1-.21 |  | 600,3h |  | A.K.GIRI et al[98] |
| 49 | Palm kernel nut shell,  Coconut shell,  Ground nut shell,  Obeche wood | 0.22 | Chemical activation with K2CO3 | 500-900  15 min | 250-750  1 hr | Olowoyo and Orere [99] |
| 50 | Kenaf fiber | 1-2 | Chemical activation with CO2, KOH | 700  1 hr | 400  2 hr | Chowdhury et al.[100] |
| 51 | Coffee waste | 1-2 | Chemical activation with ZnCl2, CO2 and CO2, KOH | 800  2-3 hr | 700 | Giraldo and Moreno-  Pirajan[101] |
| 52 | Apple peel | 1 | Microwave assisted H3PO4 activation | 110  4 hr | 110  12 hr | R.H. Hesas et al. [102] |
| 53 | Apple pulp | 1 | Microwave assisted H3PO4 activation | 110  4 hr | 110  12 hr | R.H. Hesas et al[102] |
| 54 | Fuel oil waste |  | Chemical activation with ZnCl2 |  | 400-500  2 hr | A.M. Mohammed et al[103] |
| 55 | BalsamodendronCaudatum Wood waste |  | Optical density method | 600  60 min | 120-130  24 hr | B. Siva Kumar et al.  [104] |
| 56 | Holm oak  Silver fir  Stone pine  Pyrenean oak |  |  |  | 800 | Félix A. Lopez et al [105] |
| 57 | Sour cherry stone |  | ZnCl2 | 700 |  | Dilek Angin Fuel [106] |
| 58 | Bagasse fly ash |  | zncl2/co2 | 600,1h |  | Işılay Ozdemir et al[107] |
| 59 | Peanut shell | 0.074 | Chemical activation with H3PO4– loaded sawdust | 560  50 min | 520  1 hr | D. Li et al.[108] |
| 60 | Reedy grass leaves |  | Chemical activation with KOH | 480  2 hr | 450  2hr | X. Jianzhong et al. / [109] |
| 61 | Grape stalk |  | Chemical activation with | 700,2h |  | Işılay Ozdemir et al[110] |
| 62 | Camelia nutshell |  | Water vapour gasification and H3PO4 modification |  | 450 | J. P. Zhang et al. [111] |
| 63 | Foxnut (Euryale forex)  Shell | 1.4-2 | Chemical activation with ZnCl2 |  | 500-700 | Un UT et al. [112] |
| 64 | Green coconut shell | 3-7 | Chemical activation with ZnCl2 | 650  1 hr | 500-600  1 hr | D. Das et al[113] |
| 65 | Holm oak |  | Physical followed by Chemical activation |  | 750 | J. Chang et al[114] |
| 66 | Paulownia flower |  | Chemical activation with KOH |  | 800  hr | M.N. Mahamad et al. / [115] |
| 67 | Snail shell waste |  | Chemical activation with ZnCl2and CaCl2 | 800  3 hr | 500-800  3hr | R.H. Gumus et al. [116] |
| 68 | Pineapple leaves |  | Chemical Activation with Zncl2 |  | 500,1hr | Mohammed Nabil Mahamad et al [117] |
| 69 | Grape waste |  | Chemical Activation with Zncl2 | 600,1hr |  | Hasan Sayğılı et al [118] |
| 70 | Liquefied wood |  | Chemical activation withZnCl2 | 500-800  1hr | 700  1 hr | Z. Liu et al[119] |
| 71 | Pumkin seed |  | Chemical Activation with H3PO4 | 500 |  | İlknur Demiral et al[120] |
| 72 | Sisal fiber waste |  | Chemical Activation with H3PO4 |  | 650,3hr | Uday K. Vaidya et al [121] |
| 73 | Spent compost mushroom |  | Chemical Activation with H3PO4 | 450,50min |  | Şeyda Karadirek et al [122] |
| 74 | Vegetable residue( prickly pear peel , white sapote seed ,  broccoli stem |  | Chemical Activation with H3PO4 | 400 |  | Alejandra-Alicia Pelaez-Cid et al [123] |
| 75 | Bamboo sawdust |  | Chemical Activation with H3PO4 | 400,1hr |  | Hongyan Pan et al [124] |
| 76 | Sawdust |  | Chemical Activation with Zncl2 and KOH | 600,1hr |  | Arunima Nayak et al [125] |
| 77 | Toilet paper |  | Chemical Activation with KOH | 750,1hr | 500,1hr | M. Nowrouzi et al [126] |
| 78 | Lignin |  | KOH | 700 |  | wenming hao et al [127] |
| 79 | OILY SLUDGE |  | De oiling step |  |  | Jun Wang et al [128] |
| 80 | Chestnut oak shell |  | H3PO4 |  |  | Leila Niazi et al [129] |
| 81 | Grape seeds  Apricot stones ,  Cherry stones |  | Pyrolysis with steam | 200  3 hr | 700  3 hr | N. Petrov [130] |

From the above table it was found that the most commonly used chemical activating agent is ZnCl2 at the activation temperature of 6500 C and activation time of 1 hour. So for the activation of the sample these values were used.

The particle size is an important aspect for determining the action of chemical activating agent on the sample for better action of activating agent. The particle size should be less so that there will be better contact between activating agent and activating material.

Particle size for raw material ranges from 0.074 mm for peanut shell to around 125 mm for stink bean.

Generally chemical activation techniques used over physical activation for generation of high surface area. Activating agent H3PO4, ZnCl2, K2CO3and KOH are used because they act as dehydrating agent and for weight reduction of sample.

The temperature and time nearly varies inversely, as the temperature increases as the activation temperature increases the time required for activation temperature decreases.

From the table apple peel takes 4 hrs at 110°c whereas mango shed take 20min at 1000°c. But it varies from material to material.

For carbonization the preferred temperature and time required should be less. The time required for carbonization ranges from 5min to 12hrs. (5 min for coconut shell)

Table 2 gives the information about the activation surfaces obtained from various methods and sources of preparing activated carbon.

**TABLE 2**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **SL. NO**. | **Raw materials** | **SBET (m2/g)** | **PORE SIZE**  **(nm)** | **Vmic  (cm3/g)** | **Vtot (cm3/g)** | **Reference** | |
| 1 | Macadamia nutshells | 1718 |  |  | 0.723 | A. Ahmadpour et al. [58] |
| 2 | Viscous rayon | 609 | - | - | 0.25 | A.C. Pastor et al. [59] |
| 3 | Corn cob agro waste | 1705 | 1.54 | 0.452 | 0.884 | C.F. Chang et al. [60] |
| 4 | Lignin | 2000 | - | - | 0.2-0.7 | J. Hayashi et al. [61] |
| 5 | Gelam wood bark | 1213 | 5 | 0.1306 | 0.426 | A.H. Abdullah et al.[63] |
| 6 | Spanish anthracite | 3290 | - | 0.85 | 1.92 | D. Lozano-Castello et al [65] |
| 7 | Peanut hull | 647 | – | 0.09 | 0.22 | Girgis et al[17] |
| 8 | Pistachio-nut shell | 1720 | – | 0.22 | 0.47 | Lua et al.[69] |
| 9 | Phenolic resins | 919 |  | 0.41 | 0.45 | Q. Cai et al. [68] |
| 10 | Pineapple peel | 914.67 |  |  | 0.56 | Q. Cai et al. [68] |
| 11 | Babassu shells | 874 | - | - | - | E. F. Jaguaribe et al. [71] |
| 12 | Sugarcane bagasse | 806 | - | - | 0.678 | E. F. Jaguaribe et al.[71] |
| 13 | Bamboo | 2237 | - | - | 1.23 | B.H. Hameed et al[72] |
| 14 | Cassava peels | 972-1378 | - | 0.383 | 0.421-0.583 | Y. Sudaryanto et al. [73] |
| 15 | Vineyard shoot | - | - | - | - | Corcho-Corral et al.[75] |
| 16 | Walnut shells | 737 | 2 | - | 0.404 | M.L. Martinez et al. [74] |
| 17 | Mango pit | 105 | - | - | - | M.P. Elizalde-Gonz´alez et al [78] |
| 18 | Hazelnut bagasse | 1642 | – | 0.60 | 0.96 | Demiral et al.[81] |
| 19 | Hazelnut bagasse | 1489 | – | 0.45 | 0.93 | Demiral et al.[81] |
| 20 | Coconut husk | - | - | - | - | I.A.W. Tan et al. [79] |
| 21 | Coconut shell | 490 | 2.6 | 0.93 | 1.26 | Li et al.[132] |
| 22 | Coconut shell | 927 | 2.7 | 0.88 | 1.14 | Guo et al.[133] |
| 23 | Activated sludge | 580 | - | - | 0.489 | Z. Al-Qodah et al. [84] |
| 24 | Tunisian Olive waste cakes | 514-1271 | - | - | 0.217-0.557 | R. Baccar et al. [85] |
| 25 | Almond shell | 814 | – | 0.34 | 0.37 | Gonzalez et al.[83] |
| 26 | Walnut shell | 910 | – | 0.44 | 0.52 | Gonzalez et al.[86] |
| 27 | Almond tree pruning | 217 | – | 0.57 | 0.95 | Gonzalez et al.[86] |
| 28 | Olive stone | 923 | – | 0.45 | 0.55 | Gonzalez et al.[83] |
| 29 | Coir pith | 910 | 1.60 | 0.13 | 0.36 | Subha and Namasivayam[134] |
| 30 | Hazelnut shell | 647 | 34.0 | – | 0.35 | Ozcimen and Ersoy-Mericboyu[135] |
| 31 | Apricot stone | 814 | 34.7 | – | 0.43 | Ozcimen and Ersoy-Mericboyu[135] |
| 32 | Cattail | 1279 | 5.585 | 0.088 | 1.786 | Q. Shi et al. [87] |
| 33 | Coconut shell | 712 | - | 0.3482 | 0.5319 | K. Yang et al. [88] |
| 34 | Durian shell | 1024 | 2.5 | 0.21 | 0.35 | Jun et al.[136] |
| 35 | Jatropha hull | 1350 | 3.1 | 0.4 | 1.07 | D. Xin-hui et al. [92] |
| 36 | Bagasse fly ash | 1200 |  | .528 | .634 | Chris Salim et al[137] |
| 37 | Sorghum pith | - | 0.02 | - | - | S.T. Senthilkumar et al. [94] |
| 38 | Rice husk | 752 | 3.41 | 0.26 | 0.64 | K.Y. Foo, B.H. Hameed [93] |
| 39 | Bagasse | 923 | 0.80 | – | 0.53 | Boonpoke et al.[97] |
| 40 | Bamboo | 1533 | – | – | 0.5 | Hirunpraditkoon et al.[138] |
| 41 | Wood apple outer shell | 794 | – | – | 0.47 | Bhadusha and Ananthabaskaran[139] |
| 42 | Acacia mangim wood | 525 | 11.79 | – | 0.015 | Danish et al.[140] |
| 43 | Palm kernel shell | 217 | – | 0.11 | 0.12 | Abechi et al.[95] |
| 44 | Eichhormia crassipes root | 109.23 |  |  |  | A.K.GIRI et al [98] |
| 45 | Cotton stalk | 1720 | – | 0.71 | 0.89 | Nahil and William[141] |
| 46 | Cocoa pod husk | 490 | 2.0 | – | 0.24 | Cruz et al.[142] |
| 47 | Cocoa pod husk | 615 | 2.0 | – | 0.31 | Cruz et al.[142] |
| 48 | Cocoa pod husk | 780 | 2.9 | – | 0.58 | Cruz et al.[142] |
| 49 | Apple peel | 1152 | 6.68 | 0.88 | 2.59 | R.H. Hesas et al. [102] |
| 50 | Apple pulp | 1103 | 7.81 | 0.47 | 1.76 | R.H. Hesas et al. [102] |
| 51 | BalsamodendronCaudatum Wood Waste | 458 | - | - | 0.43 | B. Siva Kumar et al. [104] |
| 52 | Fuel oils waste | - | - | - | - | A.M. Mohammed et al. [103] |
| 53 | silver fir | 815 |  |  | .45 | Félix A. Lopez et al [105] |
| 54 | Holm oak | 654 |  |  | .31 | Félix A. Lopez et al [105] |
| 55 | Stone pine | 661 |  |  | .39 | Félix A. Lopez et al [105] |
| 56 | Pyrenean oak | 543 |  |  | .26 | Félix A. Lopez et al [105] |
| 57 | Peanut shell | 1272 |  | 0.67 | 0.71 | D. Li et al.[108] |
| 58 | Reedy grass leaves | 1100 | 2.16 | - | 0.601 | X. Jianzhong et al. [109] |
| 59 | Grape stalk | 1411.75 | 2.049 |  | .7232 | Işılay Ozdemir et al[110] |
| 60 | Sour cherry stone | 1704 | 2.29 | .984 | 1.566 | Dilek Angin[106] |
| 61 | Camellia nut shells | 1608 | - | - | 1.17 | J. P. Zhang et al. [111] |
| 62 | Foxnut (Euryale forex)  Shell | 2869 | - | 1.68 | 1.96 | Un UT et al. [112] |
| 63 | Green coconut shell | 995.79 | 0.9 | 0.372 | 0.4487 | D. Das et al. [113] |
| 64 | Holm oak | 1305 | - | - | 0.621 | J. Chang et al [114] |
| 65 | Paulownia flower | 1471 |  |  | - | M.N. Mahamad et al[115] |
| 66 | Snail shell waste | - | - | - | - | R.H. Gumus et al. [116] |
| 67 | Grape waste | 1455 | 6.81 |  | 2.318 | Hasan Sayğılı et al [118] |
| 68 | Pineapple leaves | 914.67 | 2.4 | .154 | .56 | Mohammed Nabil Mahamad et al[117] |
| 69 | Liquefied wood | 1423 | - | 0.376 | 0.953 | Z. Liu et al. [119] |
| 70 | Pumkin seed | 1421 | 2.581 | .4817 | .968 | İlknur DEMİRAL et al[120] |
| 71 | Sisal fiber waste | 1297 |  | .27 | .64 | Uday K. Vaidya et al [121] |
| 72 | Spent mushroom compost | 1419.1 | .95 |  | .6728 | Şeyda Karadirek et al[122] |
| 73 | prickly pear peel | 1025 | 8.4 | .05 | 2.16 | Alejandra-Alicia Pelaez-Cid et al [123] |
| 74 | white sapote seed | 1177 | 5.2 | .08 | 1.52 | Alejandra-Alicia Pelaez-Cid et al [123] |
| 75 | broccoli stem | 1043 | 4.1 | .04 | 1.66 | Alejandra-Alicia Pelaez-Cid et al [123] |
| 76 | Sawdust | 2430.8 | 1.65 | 1.61 |  | Arunima Nayak et al [125] |
| 77 | Sawdust | 1506.2 | .032 | .32 |  | Arunima Nayak et al[125] |
| 78 | Toilet paper | 1820 | 1.68 | .833 | 1.113 | M. Nowrouzi et al [126] |
| 79 | Lignin | 2875 |  | .07 | 1.54 | wenming hao et al[127] |
| 80 | Sunflower pith | 2690 | 2.37 | .38 | 1.24 | Mustafa Baysal et al[143] |
| 81 | Sunflower pith | 2090 | 2.6 | .81 | 1.75 | Mustafa Baysal et al[143] |
| 82 | Chestnut oak shell | 989.4 | 2.85 | .45 | .71 | Leila Niazi et al [129] |
| 83 | Apricot stones | 1175 | - | 0.76 | 0.91 | N. Petrov [130] |
| 84 | Cherry stones | 361-1173 |  | 0.52 | 0.21-0.74 | N. Petrov [130] |
| 85 | Grape seeds | 485 | - | 0.58 | 0.62 | N. Petrov [130] |

As the BET surface area increases the active site for absorption increases which leads to larger volume at absorption. The surface area can go up around 3500 m²/g.

For chemical activation the surface area obtained larger than physical activation. For example mango pit using physical activation generates a surface area of 105 m²/g whereas chemical activation of Spanish anthracite generates a surface area 3290 m²/g.

As the pore size increases upto a certain extent the micropore(less than 2nm) volume increases and it results in higher surface area generation and then the formation of mesopore (2-50nm) takes place which reduces the surface area.

From the table we see that pore size ranges from 0.2 nm to 34.7 nm the lowest pore size is of sorghum pith is of .02 nm.

Table 3 gives the complete proximate and ultimate analysis of the activated carbon prepared from respective sources.

TABLE 3

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl. No.** | **Raw materials** | **Proximate Analysis** | | | **Ultimate analysis** | | | | | **Reference** |
| **MOISTURE (%)** | **ASH**  **(%)** | **VOLATILES**  **(%)** | **C (%)** | **H (%)** | **N (%)** | **S (%)** | **O (%)** |
| 1 | Corn cob agro waste | 4.3 | 0.9 | 78.7 | 45.21 | 6.12 | 0.94 | - | 47.73 | C.F. Chang et al. [60] |
| 2 | Lignin |  | 4 |  | 59.8 | 5.3 | 0.1 | - | 34.8 | J. Hayashi et al. [61] |
| 3 | Corn cob | 4.3 | 0.90 | 78.7 | 46.8 | 6.0 | 0.9 | – | 46.3 | Tsai et al.[144] |
| 4 | Birch | 4.4 | 0.18 | – | 48.4 | 5.6 | 0.2 | – | 45.8 | Zanzi et al.[145] |
| 5 | Salix | 7.3 | 0.75 | – | 48.8 | 6.2 | 1.0 | – | 43.4 | Zanzi et al.[145] |
| 6 | Sugarcane bagasse | 6.2 | 0.90 | – | 47.3 | 6.2 | 0.3 | – | 46.2 | Zanzi et al.[145] |
| 7 | Wheat straw | 3.3 | 3.23 | – | 46.5 | 6.3 | 0.9 | – | 46.3 | Zanzi et al.[145] |
| 8 | Hemp | 7.7 | 74.9 | 1.6 | 42.2 | 6.5 | 52.2 |  |  | p.t.william et al [146] |
| 9 | Flax | 7.4 | 75.2 | 1.8 | 43.3 | 6.5 | 50.2 |  |  | p.t.william et al[146] |
| 10 | Coffee residue | 4.29 | 3.92 | 82.81 | 13.27 |  |  |  |  | V. Boonamnuayvitaya et al. [67] |
| 11 | Peanut shell | - | 5.2 | 4 | 82.4 | - | - | - | - | Q. Cai et al. [68] |
| 12 | Pineapple peel | 19.09 | - | - | - | - | - | - | - | Q. Cai et al. [68] |
| 13 | Coconut shell | 8.21 | 0.1 | 73.09 | 48.63 | 6.51 | 0.14 | 0.08 | 44.64 | Daud and Ali[70] |
| 14 | Babassu shells | - | 6.49 | - | - | - | - | - | - | E. F. Jaguaribe et al. [71] |
| 15 | Sugarcane bagasse | - | 1.65 |  | 46.8 |  |  | - | - | E. F. Jaguaribe et al. [71] |
| 16 | Bamboo | – | 3.90 | 80.6 | 43.8 | 6.6 | 0.4 | 0.0 | – | Choy et al.[147] |
| 17 | Grape stalk | 15.69 | 10.16 | 51.08 | 46.14 | 5.74 | 0.37 | 0.0 | 36.60 | Amaya et al.[148] |
| 18 | Cassava peel | 11.4 | 0.3 | 59.4 | 59.31 | 9.78 | 2.06 | 0.11 | 28.74 | Sudaryanto et al.[73] |
| 19 | Woody birch | 6.6 | 0.2 | 81.2 | 48.4 | 5.6 | 0.2 | – | 45.8 | Budinova et al.[76] |
| 20 | Palm shell | 7.96 | 1.10 | 72.47 | 50.01 | 6.9 | 1.9 | 0.0 | 41 | Adinata et al.[77] |
| 21 | Mango pit | 4.34 | 0.58 | 75.77 | 47.9 | 6 | 0.09 | 0 | 46 | M.P. Elizalde-Gonz´alez et al. [78] |
| 22 | Almond shell | 10.00 | 0.60 | 80.30 | 50.50 | 6.60 | 0.20 | 0.01 | 42.69 | Gonzalez et al.[83] |
| 23 | Wallnut shell | 11.00 | 1.30 | 71.80 | 45.10 | 6.0 | 0.3 | 0.0 | 48.60 | Gonzalez et al.[83] |
| 24 | Almond tree pruning | 10.60 | 1.20 | 72.20 | 51.30 | 6.50 | 0.80 | 0.04 | 41.36 | Gonzalez et al.[83] |
| 25 | Olive stone | 10.40 | 1.40 | 74.40 | 44.80 | 6.0 | 0.1 | 0.01 | 49.09 | Gonzalez et al.[83] |
| 26 | Olive mill | 5.0 | 1.0 | – | 45.64 | 6.31 | 1.42 | – | – | Gokce et al.[149] |
| 27 | Chinese fir sawdust | 4.88 | 0.32 | 79.92 | 48.95 | 6.54 | 0.11 | 0.00 | 39.20 | Ke-qiang et al.[150] |
| 28 | Activated sludge | 10 | 12 | - | - |  |  |  |  | Z. Al-Qodah et al [84] |
| 29 | Pomegranate seed | 5.38 | 1.83 | 78.71 | 49.65 | 7.54 | 4.03 | 0.65 | 38.13 | Ucar et al.[151] |
| 30 | Coconut shell | 10.53 | 0.66 | 70.06 | 18.75 |  |  |  |  | K. Yang et al. [88] |
| 31 | Durian shell | 11.27 | 4.84 | – | 39.30 | 5.90 | 1.00 | 0.06 | 53.74 | Jun et al.[136] |
| 32 | Palm stem | 6.06 | 4.02 | 72.39 | 45.56 | 5.91 | 0.82 | – | 47.71 | Alothman et al.[152] |
| 33 | Bagasse | – | 6.2 | 83.3 | 41.55 | 5.55 | 0.03 | – | 52.86 | Boonpoke et al.[97] |
| 34 | Rice husk | – | 16.7 | 67.5 | 36.52 | 4.82 | 0.86 | – | 41.10 | Boonpoke et al.[97] |
| 35 | Bamboo | 2.44 | 6.51 | 69.63 | 45.53 | 4.61 | 0.22 | – | – | Hirunpraditkoon et al.[138] |
| 36 | Jatropha hull | - | - | - | 25.6 | - | - | - | - | D. Xin-hui et al. [92] |
| 37 | eichhormia crassipes root | 9.45 | 47 | 1.92 |  | 2.14 | 4.2 |  | 22.27 | A.K.GIRI et al [98] |
| 38 | Banana empty fruit bunch | 5.21 | 15.73 | 78.83 | 41.75 | 5.10 | 1.23 | 0.18 | 51.73 | Sugumaran et al.[153] |
| 39 | Delonix regia fruit pods | 0.22 | 2.80 | 92.03 | 34.22 | 4.50 | 1.94 | 0.42 | 58.91 | Sugumaran et al.[153] |
| 40 | Apple peel | 12.27 | 7.43 | 72.89 | 72.52 | 2.75 | 0.97 | - | 23.75 | R.H. Hesas et al. [102] |
| 41 | Apple pulp | 15.11 | 15.35 | 62.96 | 74.30 | 2.77 | 1.55 | - | 21.37 | R.H. Hesas et al. [102] |
| 42 | Rice stalk | 14.17 | 14.93 | 66.33 | 40.79 | 7.66 | 1.17 | 0.49 | 49.89 | Ai et al.[154] |
| 43 | Silver fir | 14.4 | 78.7 | 0.4 | 51.2 | 6.4 | 0.2 |  | 42.2 | Félix A. Lopez et al [105] |
| 44 | Holm oak | 9.5 | 80.8 | 2.3 | 48 | 5.9 | 0.5 | 0.002 | 45.6 | Félix A. Lopez et al [105] |
| 45 | Stone pine | 9.8 | 82.1 | 0.7 | 50.4 | 6 | 0.3 | 0.01 | 43.3 | Félix A. Lopez et al [105] |
| 46 | Pyrenean oak | 11.1 | 80.5 | 2.4 | 48.5 | 5.9 | 0.5 | 0.01 | 45.1 | Félix A. Lopez et al [105] |
| 47 | Grape stalk | 7 | 63.13 | 8.7 | 41.58 | 4.92 | 1.18 | 0.16 | 52.16 | Işılay Ozdemir et al [110] |
| 48 | Coconut shell | 5.62 | 71.4 | 1.11 | 48.7 | 6.34 | 1.52 | 6.038 | 43.4 | Jibril Mohammed et al [155] |
| 49 | Grape | 4.57 | 17 | 14.23 | 81.76 | 2.71 | 0.99 | 0.1 | 14.45 | Hasan Sayğılı et al [118] |
| 50 | Green coconut shell | 2.983 | 0.902 | 17.208 | 72.04 | 2.96 | 1.16 | 23.79 | 0.046 | D. Das et al. / [113] |
| 51 | Liquefied wood | - | - | - | 93.4 | - | 0.71 | - | 5.63 | Z. Liu et al. [119] |
| 52 | Ampel bamboo | 7.61 | 74.3 | 8.69 | 39.751 | 5.752 | 0 |  |  | M.sucipta et al [156] |
| 53 | Rice husk | 12 | 56.46 | 12.65 | 37.48 | 4.41 | 0.17 | 0.04 | 33.27 | k.promdee et al [157] |
| 54 | Rice straw | 10 | 60.7 | 10.39 | 38.17 | 5.02 | 0.58 | 0.09 | 35.52 | k.promdee et al [157] |
| 55 | Bagasse | 50.73 | 41.98 | 1.43 | 21.33 | 3.06 | 0.12 | 0.03 | 23.29 | k.promdee et al [157] |
| 56 | Wheat straw | 12.81 | 83.08 | 6.63 | 38.34 | 5.47 | 0.6 | 0.37 |  | b.biswas et al [158] |
| 57 | Walnut | 2.57 | 78.04 | 0.64 | 48.34 | 6.16 | 0.69 | 0.03 | 44.78 | F. Karaca et al [159] |
| 58 | Apricot stones | 1.6 | 2.0 | 3.7 | 89.5 | 2.4 | 0.9 | 0.8 | 6.4 | N. Petrov [130] |
| 59 | Cherry stones | 1.6 | 4.2 | 10.0 | 84 | 2.2 | 1 | 0.4 | 12.4 | N. Petrov [130] |
| 60 | Grape seeds | 1.8 | 13.1 | 4.4 | 84.7 | 1.3 | 1.6 | 0.3 | 12.1 | N. Petrov [130] |

From the table it was found that the highest fixed carbon was found from Liquefied wood (93.4%) and lowest ash content was from coconut shell (0.1%). Proper usage of activated carbon requires high fix carbon % and low ash content.

For higher moisture content we need a stronger dehydrating agent. Generally the raw materials that has lower moisture content is chosen for activated carbon production.

The most preferred raw material for activation should have higher carbon content and lower impurities. The carbon content in the raw materials ranges from around 93.4% to 13.27%. The highest carbon percentage found is in liquefied wood. Presence of volatile matter helps in removal of impurities such as oxygen, nitrogen, sulphur and other impurities, so higher the concentration of volatile matter greater is the efficiency of activation and greater is the weight loss. Delonix regia food pods has the highest volatile percentage of 92.8%.

Table 4 lists out the applications of the activated carbon from the various sources.

TABLE 4

|  |  |  |  |
| --- | --- | --- | --- |
| Sl. No. | **Raw Materials** | **Application** | **Reference** |
| 1 | Macadamia nutshells | Phenol Removal | A. Ahmadpour et al. [58] |
| 2 | Viscous rayon | Removal of cobalt and lead | A.C. Pastor et al. [59] |
| 3 | Corn cob agro waste | Application in Electric Double Layer Capacitors(EDLC) | C.F. Chang et al. [60] |
| 4 | Lignin | Removal of 2,4,6-trichlorophenol | J. Hayashi et al. [61] |
| 5 | Gelam wood bark | Removal of phenols and dyes | A.H. Abdullah et al. [63] |
| 6 | Spanish anthracite | Removal of herbicide | D. Lozano-Castello et al. [65] |
| 7 | Bagasse, pericarp of rubber, coconut shell | Removal of iron (III) | Sirichote et al.[160] |
| 8 | Almond husk | Adsorption of Ni (II) from aqueous solution | Hasar2003[161] |
| 9 | Coffee residue | Adsorption of Formaldehyde | V. Boonamnuayvitaya et al. [67] |
| 10 | Peanut shell | Removal of VOC and Heavy metal ions | Q. Cai et al. [68] |
| 11 | Pineapple peel | Methylene Blue adsorption | Q. Cai et al. [68] |
| 12 | Eucalyptus wood | Removal of phenol | Tancredi et al.[162 |
| 13 | Hazelnut shell | Adsorption of Hg (II) | Khalkhali and Omidvari[163] |
| 14 | Babassu shells | Application in Electric Double Layer Capacitors(EDLC) | E. F. Jaguaribe et al. [71] |
| 15 | Sugarcane bagasse | Application in Electric Double Layer Capacitors(EDLC), Removal of dye | E. F. Jaguaribe et al. [71] |
| 16 | Coconut shell | Adsorption of oxalic acid and maleic acid | Rahman et al.[164] |
| 17 | Cassava peels | Application in Electric Double Layer Capacitors(EDLC) | Y. Sudaryanto et al. [73] |
| 18 | Bamboo | Methylene Blue adsorption | B.H. Hameed et al. [72] |
| 19 | Vineyard shoot | Rifampicine removal | Corcho-Corral et al.  [75] |
| 20 | Walnut shells | Used as decolourant | M.L. Mart´in et al. [74] |
| 21 | Coir pith | Removal of metal ions and toxic coloring material | Ash et al.[165] |
| 22 | Olive oil mill residue | Removal of colour from textile wastewater | Pala et al.[166] |
| 23 | Woody birch | Adsorption of Hg (II) | Budinova et al.[76] |
| 24 | Mango pit | Methylene Blue, Hg2+& Cr3+ adsorption | M.P. Elizalde-Gonz´alez et al. [78] |
| 25 | Empty fruit bunch | Phenol removal | Alam et al.[167] |
| 26 | Peanut shell | Adsorption of Pb (II) | Tao and Xiaoqin[168] |
| 27 | Coconut husk | Column filler for gas or liquid treatment | I.A.W. Tan et al. [79] |
| 28 | Sugarcane bagasse | Decolourization of sugar | Qureshi et al.[169] |
| 29 | Coir pith | Removal of 2,4-dichlorophenol (2,4-DCP) | Subha and Namasivayam[134] |
| 30 | Tunisian Olive waste cakes | Adsorption of Heavy metal ions, Herbicides | R. Baccar et al. [80] |
| 31 | Activated sludge | Removal of organic pesticides from industrial waste water | Z. Al-Qodah et al.  [84] |
| 32 | Peach stone | Adsorption of gold | Masiya and Gudyanga[163] |
| 33 | Rice husk | Adsorption of Cu (II) | Yahaya et al.[171] |
| 34 | Groundnut shell | Adsorption of malachite green | Hassan et al.[172] |
| 35 | Hazelnut shell and apricot stone | Adsorption of Cu (II) | Ozcimen and Ersoy-Mericboyu[135] |
| 36 | Groundnut shell | Pesticide (Dichlorvos) removal | Gimba et al.[90] |
| 37 | Eichornia crassipes | Removal of dyes from aqueous solution | Sivaraj et al.[173] |
| 38 | Cattail | Removal of Neutral Red & Malachite Green | Q. Shi et al. [87] |
| 39 | Pomegranate rind (Punica granatum) | Adsorption of Direct red-28 dye | Venckatesh et al.[174] |
| 40 | Coconut shell | Removal of 2,4,6-trichlorophenol | K. Yang et al. [88] |
| 41 | Rice husk | Removal of Cu (II) | Yahaya et al.[175] |
| 42 | Jatropha hull | Methylene Blue adsorption | D. Xin-hui et al. [92] |
| 43 | Rice husk | Malachate Green, Acid yellow & Acid blue adsorption | K.Y. Foo, B.H. Hameed [93] |
| 44 | Bagasse fly ash |  | Chris Salim et al [137] |
| 45 | Sorghum pith | Application in Electric Double Layer Capacitors(EDLC) | S.T. Senthilkumar et al. [94] |
| 46 | Oil palm shell | Methane adsorption | Arami-Niya et al.[176] |
| 47 | Tamarind seed | Uptake of methane for storage | Munusamy et al.[177] |
| 48 | Coffee waste | Adsorption of Zn (II) and Hg (II) from aqueous solution | Giraldo and Moreno-Pirajan.[101]2012 |
| 49 | Coconut shell | Reduction of hexamine cobalt (III) | Sodeinde[178] |
| 50 | Kenaf fiber | Pb (II) removal from waste water | Chowdhury et al.[100] |
| 51 | Eichhornia crassipes root |  | A.K.GIRI et al [98] |
| 52 | Guava peel | Removal of Congo dye red | Singh et al.[179] |
| 53 | Apple peel | Methylene Blue adsorption | R.H. Hesas et al. [102] |
| 54 | Apple pulp | Methylene Blue adsorption | R.H. Hesas et al. [102] |
| 55 | Holm oak |  | Félix A. Lopez et al [105] |
| 56 | Silver fir |  | Félix A. Lopez et al [105] |
| 57 | Stone pine |  | Félix A. Lopez et al [105] |
| 58 | Pyrenean oak |  | Félix A. Lopez et al [105] |
| 59 | BalsamodendronCaudatum Wood Waste | Removal of Reactive Blue 2 & Direct Yellow 28(dye) | B. SivaKumar et al. [104] |
| 60 | Fuel oils waste | Removal of ortho-xylene | A.M. Mohammed et al. [103] |
| 61 | Phenolic resins | Adsorbents in hemoperfusion | D. Li et al. [108] |
| 62 | Sour cherry stone |  | Dilek Angin Fuel [107] |
| 63 | Grape stalk |  | Işılay Ozdemir et al [110] |
| 64 | Reedy grass leaves | Removal of 2,4,6-trichlorophenol | X. Jianzhong et al. [109] |
| 65 | Camellia nut shells | Removal Crystal Violet(dye) from waste water | J. P. Zhang et al. [111] |
| 66 | Foxnut (Euryale forex)  shell | Removal of Volatile Organic Compounds(VOC) | Un UT et al. [112] |
| 67 | Green coconut shell | Methylene Blue adsorption | D. Das et al. [113] |
| 68 | Grape waste | performance in cationic and anionic dyes adsorption | Hasan Sayğılı et al [118] |
| 69 | Holm oak | Removal of organic compound, dye and heavy metal | J. Chang et al.  [114] |
| 70 | Paulownia flower | Removal of dye and Chromium, High performance electrode materials of  Super capacitors | M.N. Mahamad et al.  . [115] |
| 71 | Snail shell waste | Methylene Blue, Heavy Metal ions adsorption | R.H. Gumus et al. [116] |
| 72 | Liquefied wood | Methylene Blue adsorption | Z. Liu et al. [119] |
| 73 | Spent mushroom compost | removal of pollutant in aqueous solution | Şeyda Karadirek et al [122] |
| 74 | Pumkin seed | for removal cationic and anionic dyes from wastewater | İlknur DEMİRAL et al [120] |
| 75 | Sisal fiber waste |  | Uday K. Vaidya et al [121] |
| 76 | Vegetable residue  prickly pear peel  white sapote seed  broccoli stem | elimination of textiles dyes | Alejandra-Alicia Pelaez-Cid et al [123] |
| 77 | Bamboo sawdust | CH4 Selectivity Adsorption from a ch4/n2 system | Hongyan Pan et al 2016 [124] |
| 78 | Sawdust | for heavy metal wastewater | Arunima Nayak et al [125] |
| 79 | Sawdust | Remediation | Arunima Nayak et al [125] |
| 80 | Lignin | use for co2 adsorbent | wenming hao et al [127] |
| 81 | Toilet paper |  | M. Nowrouzi et al [126] |
| 82 | Sunflower pith | Dye removal | Mustafa Baysal et al [143] |
| 83 | Apricot stones | Removal of metal ions(Ni, Mg, As) from water | N. Petrov [130] |
| 84 | Cherry stones | Removal of metal ions(Ni, Mg, As) from water | N. Petrov [130] |
| 85 | Grape seeds | Removal of metal ions(Ni, Mg, As) from water | N. Petrov [130] |

The most common application of activated carbon is the separation and removal of dyes and toxic metal ions.

Depending upon the materials to be absorbed we have to select a specific pore structure of the resulting activating carbon.

Widely used as adsorbents for removal of organic chemicals and metal ions for environment or economic concern from air, gases and potable water.

Used in waste water treatment, Drinking water purification and liquid phase adsorption.

Used for adsorption of metal ions. Sorption of Dye’s to AC which are toxic waste. It extends to purification of sugar syrups, the oil and sugar decolourization, specific application of pharmaceutical and chemical industries.

Treatment of methylene blue(toxic dye)by using AC. Activated carbon electrode preferred in EDLCs.

From the above literary survey, it was found that though a lot of agro-wastes have been used for preparation; dried ridge gourds have not been used. This project was carried out to find out the characterization of the activated carbon prepared from dried ridge gourd. Ridge gourd (scientific name - Luffa) is a genus of tropical and sub-tropical vines in the cucumber family. When the fruit of these species is fully ripened, it is very fibrous. It is then used as a scrubbing sponge (loofah) which is used in everyday applications. This fibrous fruit is the basis of the raw material used. It is grown locally in and around farms and is acquired easily for the project.

**METHOD OF PREPARATION**



Fig-1: Ridge gourd (Dried) Fig-2 : Ridge gourd(dried and cut)

Dried Ridge Gourd was hand-picked from the local farm market and was washed with simple tap water for removal of the dust adhering to it.

After drying in sunlight for 15-20 days the materials were cut in to pieces and kept inside a furnace for about a day at 150⁰C for removal of moisture and other volatile impurities.

It was then crushed with a crusher and sieved to 300-700 µm size range.



The powdered precursor was then chemically activated with ZnCl2 to make the Impregnation Ratio 100%. 500gm of dried precursor was well mixed with a solution that contains 500gm of ZnCl2 in aqueous solution of 3000ml.

Fig 3 : Dried in oven for moistre removal



The slurry mixture was properly mixed and kept for 24 hours for proper soaking of ZnCl2 on its surface.

It was then kept under oven for 24hrs at 100⁰C.

Fig 4: sieved to 300-700

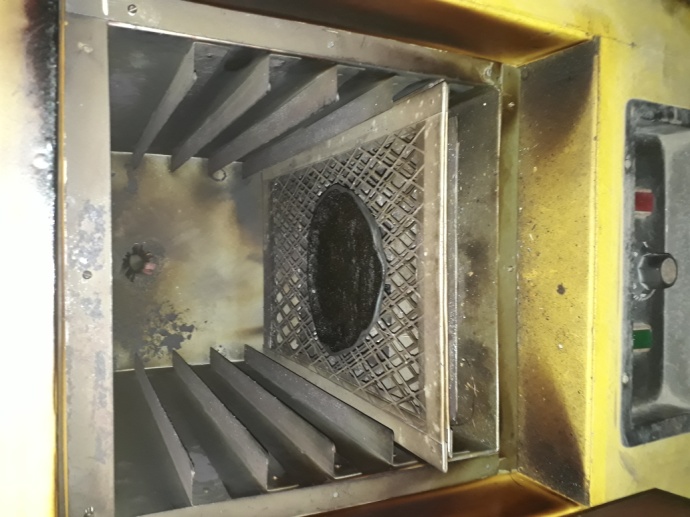
 

Fig 5: preparation before keeping in oven Fig 6: slurry in oven 100°c

**RESULT AND DISCUSSION**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SAMPLE | MOISTURE  (wt. %) | VOLATILE MATTER  (wt. %) | FIXED CARBON  (wt. %) | ASH (wt. %) |
| Before activation | 5.53 | 23.41 | 64.34 | 6.72 |
| Before Carbonization | 4.0 | 32.13 | 52.97 | 10.9 |

Table 5. Proximate analysis of raw precursor and activated carbon

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SAMPLE | C (%) | H (%) | N (%) | S (%) | O (%) |
| Before activation | 43.06 | 6.08 | 1.21 | 0.11 | 49.5 |

Table 6. Ultimate analysis of raw precursor and activated carbon

The sample was analysed after crushing to desired size and before impregnating with ZnCl2 and also after impregnation. The moisture content and fixed carbon % was reduced while volatile matter and ash content increased. Addition of ZnCl2 solution added to the ash content. The ultimate analysis showed that the sample contains high amount of Carbon (43.06%) and Oxygen (49.5%).

Moisture content i.e 5.53 is comparatively very low is comparison to raw material such as grape seed, apple pulp and apple peel which have moisture content in the range (12-15)%. Volatile matter content(23.41%) is also very low in comparison with another raw material. The most important carbon content in the sample around 43.06%, which is moderate in comparison to other raw materials.

FUTURE WORK

The resulted chemical impregnated samples will be then kept inside the muffle furnace after putting it inside galvanized iron pipes.

Materials inside the furnace will be then heated at a heating rate of 10⁰C min-1 till the final carbonization temperature of 650⁰C. A constant flow of nitrogen would be maintained at a rate of 120 cm3 min-1 in STP. The material will be kept inside the furnace for 1hr at 650⁰C. It will then be cooled under constant flow of nitrogen gas till it would completely cool. The dried materials will be washed with 0.5 N HCl for 2-3 times and then washed with warm distilled water to remove different residual organic and mineral matter. Then it will be finally washed with cold water till the solution becomes neutral. Finally the sample will be dried for 24 hours at 100°C inside an oven and packed in an air tight container.

The resulted activated carbon will then be tested to find its BET surface area, Micro pore Volume, Total Pore Volume & Absorption Capacity.

Absorption Capacity would be found by absorbing Methylene Blue Absorption on its surface.

CONCLUSION

The detailed study of preparation, characterization and uses of activated carbon from different waste has been thoroughly investigated. This study gives the idea for upcoming researchers for new development in this field.

The ridge gourd based activated carbon was successfully prepared by chemical activation. Its ultimate and proximate analysis shows a comparable result with the available activated carbon prepared from agricultural waste.

It is concluded that activated carbon can be prepared for every ligno-cellulose material containing carbon. This prepared activated carbon can be used as a good absorbent for various purposes.

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