

# Obtaining of highly energy-efficient activated carbons based on wood

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**Abstract.** The research work established the distinctive features of the composition and properties of local Paulownia woods - raw materials for the production of highly energy-efficient activated adsorbents. The colloidal, physicochemical properties of the obtained adsorbents from Paulownia wood were revealed. The adsorption properties of the developed adsorbents have been established for deep purification of water-alcohol solutions. In the article, research work was carried out on the wooden stems of a number of trees growing in the territory of Uzbekistan. According to the results of the experimental research, the base of raw materials meeting the requirement of being an adsorbent was researched, and their physico-chemical, colloidal properties were studied. It was found that Pavlovnia wood with high density and porosity can meet the requirement to be an adsorbent. In the study, its porosity, moisture level, ash content, and adsorbent productivity were studied. Based on the obtained results, a series of raw materials that can meet the demand of adsorbent was formed.

## 1 Introduction

As a result of the increase in demand for adsorbents along with the development of the industry, the importance of researching different raw materials bases and developing adsorbents based on them is one of the priority tasks. Obtaining adsorbents based on local raw materials and using them not only for the treatment of industrial wastewater with various complex compositions, but also in the food industry, including the purification of fruit juices and the purification of water-alcohol solutions from toxic substances, including cypress oils, aldehydes, methyl acetate, ethyl acetate, etc. large-scale use is beneficial for the economy of Uzbekistan.

Carbon adsorbents are products of heat treatment of plants and their residues at a high (600-800°C) temperature without an oxygen and airless chamber. Sources for obtaining coal are: bark, crowns, sawdust, shavings and other organs of trees, shells of stones and cake of their fruits, stems, head of legumes and grain plants, as well as weeds. These

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sources have not found their application in the sectors of the national economy. However, they can be processed to obtain a dispersed or granular adsorbent, which can find worthy application in food, pharmaceutical, chemical and other industries, life safety of the population, environmental protection and water protection.

The choice of raw materials and their reserves for the production of adsorbents is an important task. The properties of adsorbents obtained on the basis of coals of various plants, in particular, from Chinara and Yasin, were studied and recommended for industrial wastewater treatment [1-3].

Taking into account the importance of the problem of obtaining activated carbons from local raw materials, and continuing the ongoing research [4-5], we set the task of obtaining carbon-containing sorbents based on Paulownia wood, which also represents the flora of Uzbekistan.

The Paulownia tree largely meets the requirements for the production of adsorbents, which are studied by the authors [6], which is due to its strength, moisture resistance and density.

One of the priority areas for the development of modern technology of adsorption purification from harmful substances is the creation of new, economically cheap and highly effective adsorbents. The need to both discharge wastewater and solve the problem of their reuse, associated with a shortage of fresh water in the republic, determines the requirements for the adsorbents used. For this, the development of new types of adsorbents based on local raw materials [7], as well as their application, is one of the urgent problems for industrial wastewater treatment.

## 2 Materials and methods

Obtaining activated carbon adsorbents was carried out in the following sequence. From a number of raw materials, we studied the chemical compositions and properties, as well as physical characteristics, and selected coals suitable for our purposes [8-9], after which they were subjected to carbonization at a temperature of 300°C to 800°C. For each thermally activated coal samples, the ash content, the water content in the coal by the drying method, and the acetone porosity were determined [10-19]. The composition of carbon-containing adsorbents and activation conditions and other features of carbon raw materials determine their adsorption properties. Among these global tasks, the production and production of adsorbents is no less important. There are not very many coal reserves in the Republic. Therefore, it is necessary to use vegetable raw materials to obtain adsorbents, because, with incomplete combustion in the absence of oxygen, the pores of hydrocarbon raw materials open. These pores can absorb impurities of many gaseous, liquid substances, extracts and solutions. Not all industries can provide themselves with highly efficient adsorbents. All productions buy activated carbons from abroad. Therefore, meeting the needs of industry in activated carbon and other adsorbents of the required high quality is a scientific problem of the modern science of physical and colloidal chemistry.

After drying sawdust wood at a temperature of 140-150°C, their weight is reduced by 1.245-1250 times or 24.5-25.0%. Considering 100 g of freshly cut and dried sawdust as 100%, they have lost free moisture and some volatile elements such as chlorine and iodine. In the composition of the wood of the studied fruit trees, there are 10 studied elements, there are 17-18 more elements that are contained in macro and micro amounts, i.e. boron, rubidium, silicon, lead, molybdenum, chromium, cobalt, nickel, potassium and copper.

Among the studied woods, Paulownia consists of (47.0-49.5% cellulose, 12-15% pentosans, 21-23.5% lignin and 11.8% extractives), 0.6-1.0% ash, 1 0.0% hot water solubles, while local plane tree wood contains 50.5% cellulose, 25.0% pentosans, 23.0% lignin, 0.6% ash and about 1.0% hot water solubles.

The composition of the wood of Birch and Paulownia contains inorganic salts. If we consider the content of such salts as 100%, 40% of them are calcium carbonate and 20% potassium carbonate.

All plants heat-treated at high temperature in airless space form coals. If these woods are heat treated after chemical treatment, then activated carbons are formed.

All plants heat-treated at high temperature in airless space form coals. If these woods are heat treated after chemical treatment, then activated carbons are formed. Washed and dried sawdust was subjected to pyrolysis. During the pyrolysis of wood sawdust with sharp water vapor, a part burned out, and the main part in an amount of about 25-30 % remained, turning into coal. The studied coals (from different trees) had the following yield (carbon composition) after washing with water and drying at 140-150°C: apricot 25.41 %, peach 25.94 %, walnut 25.26 %, cherry 24.61 %, cherry 24.76 %, plane tree 26.08 %, birch 26.40 % and paulown 27.75 %.

### 3 Results and discussion

The influence of heat treatment in a hermetically sealed vessel without access of air and oxygen in a muffle furnace in the temperature range of 300°C-800°C on the physical properties of wood of fruit and non-fruit deciduous trees was studied. It was found that when heated in an airless space in this temperature range, the humidity decreases by 1.0-1.5%; yield of adsorbents by 1-4%; an average yield of 3-5%; strength by 4-6%. The results of the analysis of physical quantities are given in table. 1.

**Table 1.** The results of the analysis of the physical quantities of obtaining adsorbents.

№	Names of wood samples	Activation temperature t, °C	Wood moisture W, %	Ash content, A, %	Output of adsorbents, %	Strength of adsorbents, %
1	Apricot	300	2,75	2,98	29,11	7,43
		400	2,21	3,05	29,11	7,01
		500	1,92	3,28	27,96	8,24
		600	1,43	3,40	26,11	9,03
		700	1,18	3,76	25,01	9,67
		800	1,10	4,05	24,94	10,08
2	Peach	300	2,80	2,96	30,01	8,01
		400	2,32	3,01	29,4	7,63
		500	2,00	3,22	28,5	8,97
		600	1,56	3,37	27,1	10,04
		700	1,34	3,71	25,8	10,69
		800	1,05	4,00	25,02	11,38
3	Walnut (Greek)	300	2,28	3,96	23,75	4,06
		400	2,12	4,18	23,00	4,63
		500	1,98	4,69	22,36	5,78
		600	1,78	5,21	20,80	6,81
		700	1,61	6,09	20,12	8,10
		800	1,50	7,20	19,20	9,45

4	Cherries	300	3,35	3,99	30,08	5,91
		400	2,94	4,10	29,9	6,75
		500	2,26	4,61	29,08	7,48
		600	1,78	5,30	27,7	8,12
		700	1,44	6,43	26,6	8,22
		800	1,15	8,13	26,15	8,31
5	Cherry	300	3,40	4,03	31,46	5,63
		400	2,99	4,15	30,17	6,32
		500	2,35	4,67	29,30	7,19
		600	1,87	5,41	28,10	8,00
		700	1,50	6,23	27,44	8,11
		800	1,10	8,06	27,09	8,20
6	Chinara	300	2,68	6,02	31,45	5,91
		400	2,56	6,12	30,8	6,49
		500	2,40	6,66	30,17	7,28
		600	2,29	7,11	29,06	8,59
		700	2,12	8,00	28,50	8,99
		800	1,95	9,21	28,01	9,86
7	Birch	300	2,58	5,98	31,8	9,00
		400	2,40	6,10	31,12	9,92
		500	2,25	6,56	30,67	10,79
		600	2,06	7,05	30,08	11,43
		700	1,98	8,02	29,10	11,97
		800	1,98	8,89	28,02	12,24
8	Paulownia	300	2,65	5,92	32,30	9,08
		400	2,44	6,05	32,19	10,01
		500	2,28	6,50	31,32	10,86
		600	2,09	6,95	30,63	11,71
		700	2,00	7,86	30,13	12,43
		800	2,00	8,70	30,03	13,24

From Table. 1 it can be seen that the wood of fruit trees has a narrow range of changes in moisture content and ash content, but a wide range of decrease in yield and increase in the strength of the coal adsorbent.

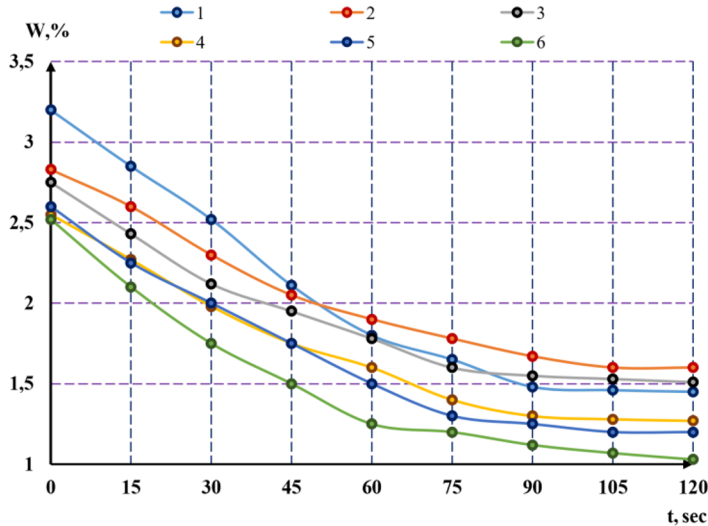
Among the obtained coals, the adsorbent obtained from Paulownia wood has the highest strength and at the same time yield at a temperature of 800°C.

After that, the adsorbent from peach wood, however, at a high temperature above 800°C loses weight.

At a temperature of 850°C and above, most of the activated carbon burns out and the yield strength decreases sharply. The idea was to take advantage of the heat generated by the microwave oven, as wood can also open pores by removing moisture. To do this, we selected samples of adsorbents obtained from wood heat-treated in a temperature regime of 300°C. The results of the experiments are shown in fig. 1 and table. 1.

The temperature range of the microwave oven is 20-120°C. Each after 30 sec. oven temperature becomes 100°C or higher. For the experiments, we used a microwave oven of the South Korean company Samsung, model MW73AR, with an output power of 800–1000 W, with an OM75S magnetron (31).

From fig. 1 shows that the residual moisture is reduced by 1.5-2.0%.



**Fig. 1.** Dependence of humidity on the time of microwave activation of heat-treated wood shavings at a temperature of 300°C.

The study of the effect of thermomagnetic treatment on pore formation showed that the heating temperature of the wood material is not sufficient to open the micropores, and the mesopores located on the surface of the wood do not expand enough and cannot release moisture from the capillary channels. Significant changes in ash content did not occur, so they were not included in the discussion. Mesopore capillary diameters are small in relation to the diameter of water and solution molecules in the wood channels.

It is noticeable that the inverse relationship between the yield of activated carbons and the density (specific gravity) of tree bast, i.e. (3) apricot 772 kg/m<sup>3</sup>, (2) peach 760 kg/m<sup>3</sup>, walnut 680 kg/m<sup>3</sup>, (1) cherry 600 kg/m<sup>3</sup>, (4) plane tree 500 kg/m<sup>3</sup>, (5) birch 650 kg/m<sup>3</sup> and (6) paulownia 320 kg/m<sup>3</sup>. All trees except Chinar and Paulownia contain sugary juices. Therefore, their trunks have high densities.

The pattern between the density and the output of activated carbons can be arranged in the following series:

by density: apricot < peach < walnut < cherry < cherry < birch < plane tree < paulownia;

by output: apricot < peach < walnut < cherry < sweet cherry < birch < plane tree < paulownia.

## 4 Conclusions

As a result of the study of the raw material base suitable for obtaining an adsorbent in Uzbekistan, the initial chemical composition of Paulownia tree waste (branches, rod, shavings) and its physical and chemical properties after activation were studied.

Based on the selected raw materials, the optimal modes for obtaining porous adsorbents (T<sub>pyr.</sub> - 800 ± 50 °C, R-600 ± 50 W, τ-7 min, ν-2450 MHz) of high adsorption efficiency were determined by initial activation of pyrolysis by the usual method, and then using water vapor at a temperature of 800°C±50°C, as well as by activating it with microwave radiation after pyrolysis by an unconventional method.

To determine the suitability of wood materials as raw materials and adsorbents, physico-chemical parameters were performed, i.e. moisture content, ash content, porosity,

pore size and benzene activity determination, particle size distribution, bulk density, strength.

The pattern between the density and the output of activated carbons has been determined and can be arranged in the following row: by density: apricot < peach < cherry < birch < plane tree < paulownia. Output: apricot < peach < cherry < birch < plane tree < paulownia.

## References

1. Levdansky V.A., Levdansky A.V., Kuznetsov B.N. Patent №2352349, A61K 36/185 Method for processing birch bark, 2008102252/15; declared 21.02.2008, publ.20.04.2009.
2. Shchipko M.L., Yangolov O.V., Kuznetsov B.N. Patent No: 2051096 C01B031/08 Method for producing activated carbon, 93034069/26; publ. 12/27/1995 B.I. No. 36.
3. Olontsev V.F. Modern technologies of high-quality carbon adsorbents. Message 2. Technologies based on plant raw materials, Chemical industry. 1998. No. 1. P. 8 - 12.
4. Kononov G.N., Mazitov L.A., Klimov V.O. Thermolysis of ligno-containing raw materials. Scientific works of the Moscow State Forest University. 1994. No. 273. P. 61-65.
5. Pokrovskaya E.N., Nikiforova T.P., Makovsky Yu.A. 1st All-Russian. conf. on polymeric materials of low flammability: Proceedings. report Volgograd. 1995. P. 105-107.
6. Viswanathan, B. Methods of activation and specific applications of carbon materials, Indian Institute of Technology Madras. 2009. 160 p.
7. Juma M. Pyrolysis and combustion of scrap tire, Petroleum & Coal. 2006. 48(1). P. 15-26.
8. Hayashi J., Kazehaya A., Muroyama K., Watkinson A.P. Preparation of activated carbon from lignin by chemical activation, Carbon. 2000, V. 38, Iss.13, P. 1873-1878.
9. Namasivayam C., Sangeetha D. Application of coconut coir pith for the removal of sulfate and other anions from water, Desalination, 2008. V. 219, Iss. 1-3, P. 3-13.
10. Juraevna D. J., Yunusjonovich U. R., Karimovich O. E. Studying on the activated adsorbents derived from waste of a grape seed, Journal of Chemical Technology and Metallurgy, 57, 5, 998-1005, (2022)
11. Rakhimov U.Yu., Jumaeva D.J. Obtaining and investigation of gas vapor of activated adsorbents based on grape seed extract waste, The Scientific Heritage, 2021, N 78-2, P. 17-19.
12. Adel Aljwary, Ziyodulla Yusupov, Rustam Shokirov, Mitigation of load side harmonic distortion in standalone photovoltaic based microgrid, E3S Web of Conferences, 304, 01010 (2021), ICECAE 2021.
13. Hadha Afrisal, Ahmad Didik Setiyadi, Munawar Agus Riyadi, Rifky Ismail, Iwan Setiawan, International Journal on Advanced Science, Engineering and Information Technology, Vol. 12 (2022) No. 6, p. 2258-2265, DOI:10.18517/ijaseit.12.6.16591
14. Jumaeva Dilnoza Juraeva, Rakhmatullayeva Nigora Turgunovna, Shamuratova Makhinbanu Rametullayevna, Bakhronov Khayat Nurovich, Rakhimov Umidjon Yunusjonovich. Differential heat of adsorption of water vapor on an adsorbent obtained on the basis of wood waste, Universum: chemistry and biology, 9-1 (99), (2022).

15. Dilnoza Jumayeva, Izzat Eshmetov, Berdah Jumabaev, Anvarkhodja Agzamkhodjayev Carbon adsorbents on the basis of Brown coal of Angren for cleaning industrial wastewater, *Journal of Chemical Technology and Metallurgy*, 51, 2, 210-214 (2016).
16. Jumaeva D., Eshmetov I., Jumabaev B., Agzamkhodjaev A. Coal adsorbents for sewage treatment, *European Conference on Innovations in Technical and Natural Sciences*, Austria, Viena, P.104-109, (2015).
17. Dilnoza Jumaeva, Olimjon Toirov, Zuhridin Okhunjanov, Umidjon Raximov, Rano Akhrorova. Investigation of the adsorption of nonpolar adsorbate molecules on the illite surface, *Journal of Chemical Technology and Metallurgy*, 58, 2, (2023) 353–359.
18. Dilnoza Jumaeva, Akmal Abdurakhimov, Khodjiakbar Abdurakhimov, Nigora Rakhmatullaeva and Olimjon Toirov, Energy of adsorption of an adsorbent in solving environmental problems, *E3S Web of Conferences* 288, 01082 (2021) SUSE-2021.
19. Dilnoza Jumaeva, Olimjon Toirov, Nigora Rakhmatullaeva Ravshan Akhmedov and Izzat Eshmetov, Energy of adsorption of polar molecules on NaLSX zeolite, *E3S Web of Conferences* 288, 01041 (2021) SUSE-2021.