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DETERMINATION OF THE ADSORPTION AND PHYSICOCHEMICAL PROPERTIES OF ACTIVATED CARBON DERIVED FROM PEACH PITS.

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Annotation: This study investigates the adsorption efficiency and physicochemical properties of activated carbon synthesized from peach pit shells (ShFK) through pyrolysis and steam activation at 850°C. The surface area, pore volume, iodine number, and benzene adsorption capacity of the prepared carbon were comprehensively analyzed and compared with those of the industrially known AG-3 grade activated carbon. Experimental data indicate that ShFK activated carbon exhibits a high adsorption capacity (up to 1.85 g/100 g for benzene), low ash content, and significant surface functionality, including –OH, –CHO, and –COOH groups, confirmed via IR and SEM analyses.
Furthermore, ShFK was successfully employed to purify monoethanolamine (MDEA) solutions, achieving an increase in amine concentration from 40% to 52%, while reducing mechanical impurities below the permissible level. The presence of thermostable salts was also effectively lowered, demonstrating ShFK's superior performance over AG-3 in MDEA regeneration. The results validate the potential of peach pit-derived carbon as a cost-effective, sustainable, and high-performance adsorbent for industrial applications.
Key words: Activated carbon, peach pits, adsorption capacity, physicochemical properties, MDEA purification, surface area, SEM analysis.

Introduction: Until now, activated carbon has been imported into Uzbekistan from abroad. It has been widely used in the process of extracting metals from hydrometallurgical solutions, as well as in the purification of lubricating oils and fuels from sulfur-containing compounds, in the removal of mercaptans from aviation kerosene, in the purification of water from various heavy salts, and as a filter in protective gases. Moreover, activated carbon finds extensive applications in the pharmaceutical industry.

Activated carbon obtained from the shell of fruit tree pits was tested in experimental trials for its effectiveness in extracting metals from hydrometallurgical solutions. The results of the research were compared with the properties of the well-known AG-3 grade activated carbon [7, 8]. Since the activated carbon was derived specifically from peach pits, it was designated as **ShFK**. Its physicochemical properties were studied in accordance with the requirements of the existing technical standards.

Literature review: Activated carbon is a widely used adsorbent due to its high surface area, porous structure, and ability to remove a variety of pollutants from liquids and gases. Traditional sources of activated carbon include coal, wood, and coconut shells; however, recent research has increasingly focused on the valorization of agricultural waste such as fruit pits as cost-effective and sustainable alternatives [1,2].

Several studies have demonstrated that activated carbon derived from fruit-based biomass—such as apricot, peach, and olive pits—can possess comparable or even superior adsorption properties compared to commercial adsorbents [3,4]. Pyrolysis followed by chemical or steam activation has been shown to yield materials with high surface area and well-developed pore networks, which are critical for effective adsorption processes [5].

In particular, the regeneration and purification of amine solutions like monoethanolamine (MDEA) used in gas treatment and chemical processing require efficient adsorbents to remove heat-stable salts and mechanical impurities [6]. Conventional AG-3 activated carbon is widely used for such purposes; however, alternative materials derived from local biomass may offer economic and environmental advantages.

Recent comparative analyses suggest that peach pit-based activated carbon not only exhibits favorable physical characteristics such as pore volume and surface functionality, but also achieves high adsorption capacity for organic and inorganic impurities [7]. Infrared (IR) spectroscopy and scanning electron microscopy (SEM) have further confirmed the presence of oxygen-containing functional groups and microstructural integrity in these materials [8].

Therefore, the current study builds upon previous works to further investigate the adsorption behavior and physicochemical performance of activated carbon synthesized from peach pits, particularly in the context of MDEA purification and its comparison with AG-3 commercial carbon.

Methodology: The adsorption capacity of ShFK was determined using the cryoscopic method [9,10]. This method allows for the evaluation of both the selectivity and the dynamic capacity of the adsorbents by analyzing the change in concentration of the chromatographic solution passing through the adsorbent and the corresponding decrease in the crystallization temperature of the solution.

The analysis is conducted as follows: a 2% standard organic solution is passed through a glass column filled with 10 g of the adsorbent (particle size 0.25–0.50 mm, pre-dehydrated) in cyclohexane until saturation is achieved, that is, until the crystallization temperature of the filtrate (t_3) equals that of the initial standard solution (t_2). The filtration rate is set at 1 drop per second, which corresponds to a flow rate of 0.4 volumes per hour. The crystallization temperatures of the pure cyclohexane (t_1) and the standard solution (t_2) are measured in advance. Then the crystallization temperature of the filtrate (t_3) is determined.

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The filtrate is collected in 12.85 mL portions (equivalent to 10 g of solution). In each portion, the crystallization temperature (t_3) is measured. The amount of adsorbed substance (in mol.%) is then calculated using the following formula:

$$A = \frac{t_3 - t_2}{t_1 - t_2} * 100\%$$

The molar percentage of the adsorbed substance is calculated using the following formula:

$$P = \frac{A/100 * M}{(1 - A/100) * 84{,}16 + A/100 * M} * 10$$

M – the molecular weight of the substance;
84.16 – the molecular weight of cyclohexane.

The amount of adsorbed substance is calculated in grams for each portion and then normalized to 100 grams of adsorbent. This method is both fast and accurate. It is designed for the preparation of model sorbent solutions using cyclohexane as a highly pure solvent [7].

Activated carbon is obtained by carbonizing the shell of fruit pits at a temperature range of 400–500°C. The raw material is heated at various temperatures, and in each case, a constant mass of 1000 g is used. The yield of the product obtained at each temperature is shown in Table 1.

The carbonized raw material is then impregnated with a 4% $ZnCl_2$ solution for 20 hours. After saturation with $ZnCl_2$, it is dried until approximately 15% moisture remains. The material is subsequently activated with steam at 800–850°C. The final product is shaped into granules according to the requirements for its intended application.

The experimental results are presented in Tables.

Results: The experimental results are presented in Tables 1 and 2.

Table 1. Conditions of the Carbon Production Process and Its Properties:

Temperature, °C	**Weight After Carboniza-tion, g**	**Hardness, g/dm³**	**Surface Area, m²/g**	**Ash Content, %**	**Benzene Adsorption Capacity, g/100 g**
400	613	524	211	4,8	0,24
500	521	557	225	5,0	0,46
600	405	562	234	5,1	0,52
700	276	596	475	5,2	0,87
800	253	623	513	5,5	1,18

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Table 2. Adsorption Properties of Activated Carbon Derived from Fruit Pits:

Temperature, °C	**Carbonization Time, minutes**	**Burn-off Rate, %**	**Hardness, g/dm³**	**Surface Area, m²/g**	**Ash Content, %**	**Benzene Adsorption Capacity, g/100 g**
800	60	29	577	805	9,5	1,45
850	120	27	570	890	8,5	1,87

According to the experimental results presented in Table 2, activated carbon obtained from fruit pit shells, carbonized under an oxygen-free environment at 450–550°C and activated with steam at an average temperature of 850°C for 2 hours, demonstrated an increase in benzene adsorption capacity up to 1.85 g. Simultaneously, an expansion in the pore structure was observed. The data in the table clearly show that an increase in adsorption capacity is associated with a decrease in ash content. It is well known that the expansion of pores contributes to enhanced adsorption efficiency.

Certain properties of the activated carbon derived from fruit pits — designated as ShFK — were compared with those of the well-known AG-3 grade activated carbon. These comparative results are presented in Table 3.

Table 3. Comparative Analysis of the Properties of Activated Carbon and AG-3:

Parameter	Activated Carbon	
	AG-3	ShFK
Hardness, g/dm³	450	512
Pore Volume, cm³/g	0,8-1,0	0,87-1,03
Micropore Volume, cm³/g	0,24-0,28	0,30-0,35
Adsorption Activity for C_6H_6, g/100 g	1,23	1,87
Iodine Adsorption Capacity, %	43	75
Hardness, %	75	75-78
Ash Content, %	14-16	4-5
Surface Area, m²/g	1016,8	1025,8

Table 3 presents a comparison of the main properties of ShFK activated carbon with those of AG-3 activated carbon. According to the obtained results, the newly synthesized activated

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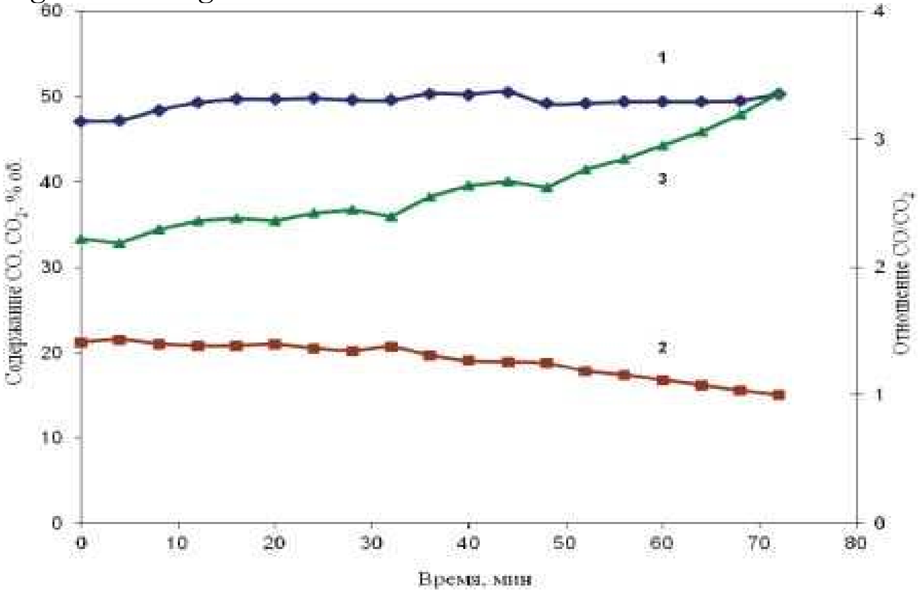
carbon (ShFK) demonstrated improved adsorption capacity, a higher amount of retained ash, greater pore volume and surface area, as well as increased bulk density.

The effectiveness of the prepared ShFK carbon in purifying MDEA (methyldiethanolamine), used in production, from toxic components was also investigated. In the purification experiment, when monoethanolamine solution was treated with ShFK activated carbon, its concentration increased from 40% to 52%. In contrast, purification with AG-3 activated carbon showed a slight decrease in the carbon efficiency indicator.

Figure 1. Changes in CO and CO_2 Content in Saturated MDEA over Time:



During the purification of MDEA using activated carbon prepared at 850°C, the saturation behavior of CO and CO_2 adsorption over time was observed. Within 70 minutes, 200 g of ShFK activated carbon was able to purify approximately 8–9 liters of MDEA solution. Although the adsorption efficiency gradually decreased, the carbon remained effective for purifying up to 10–15 liters of solution.

In the purified MDEA solution, the amount of thermostable salts was found to be 2.80 wt%, which exceeds the permissible concentration by 1%. However, in solutions purified with AG-3 and ShFK activated carbons, the concentrations were 0.83% and 0.81%, respectively—within the acceptable limits.

The initial, unpurified amine solution contained a high level of mechanical impurities—1068 mg/L, while the maximum permissible concentration is 500 mg/L. After purification with AG-3, the level dropped to 488 mg/L, and with ShFK it was further reduced to 479 mg/L, indicating that ShFK performed even better than AG-3. A high level of mechanical impurities can lead to excessive foaming and operational instability during processing.

Table 4. Physicochemical Properties of MDEA Purified with ShFK Activated Carbon:

№	Properties	Sample of Used MDEA	Purified with AG-3 Activated Carbon	Purified with ShFK Activated Carbon
1	Amine Concentration, wt.%	40	39	52

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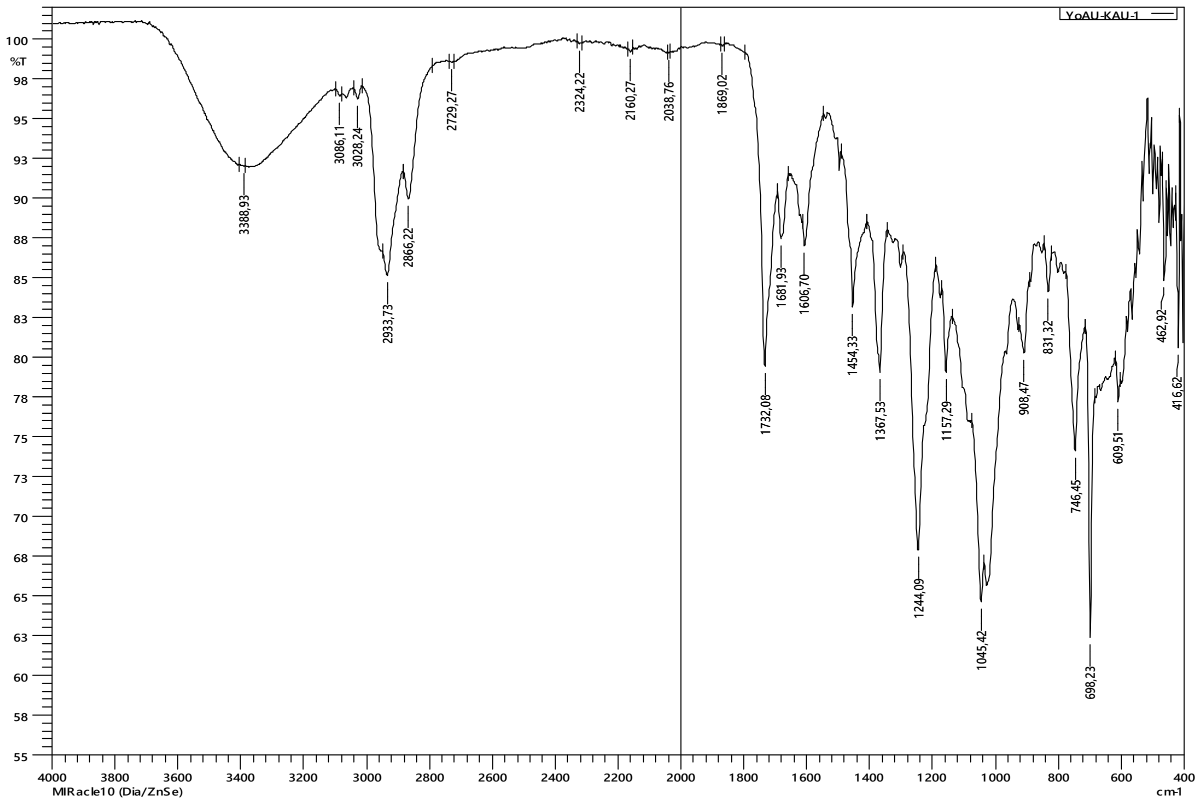
2	pH	10,80	10,40	10,40
3	Density, g/cm³	1,092	1,085	1,122
4	Salt Content, %	2,80	0,83	0,81
5	Content of Mechanical Impurities, mg/L	1068	488	479
6	Foam Height, mm	16	16	15
7	Foaming Time, sec	20	8	8

Figure 2. IR Spectrum Analysis of the Fruit Pit:



The elemental composition and internal structure of ShFK activated carbon adsorbents obtained by pyrolyzing the shell of fruit pits are shown in Figure 3 using scanning electron microscopy (SEM). Based on the SEM images of the carbon samples derived from the fruit pit shells, it was observed that the elemental composition remained almost unchanged. However, the sample carbonized at 850°C exhibited the presence of surface functional groups such as –OH, –CHO, and –COOH, indicating chemical activation on the surface.

Figure 3. Microscopic Image of Carbon Obtained from Fruit Pits:

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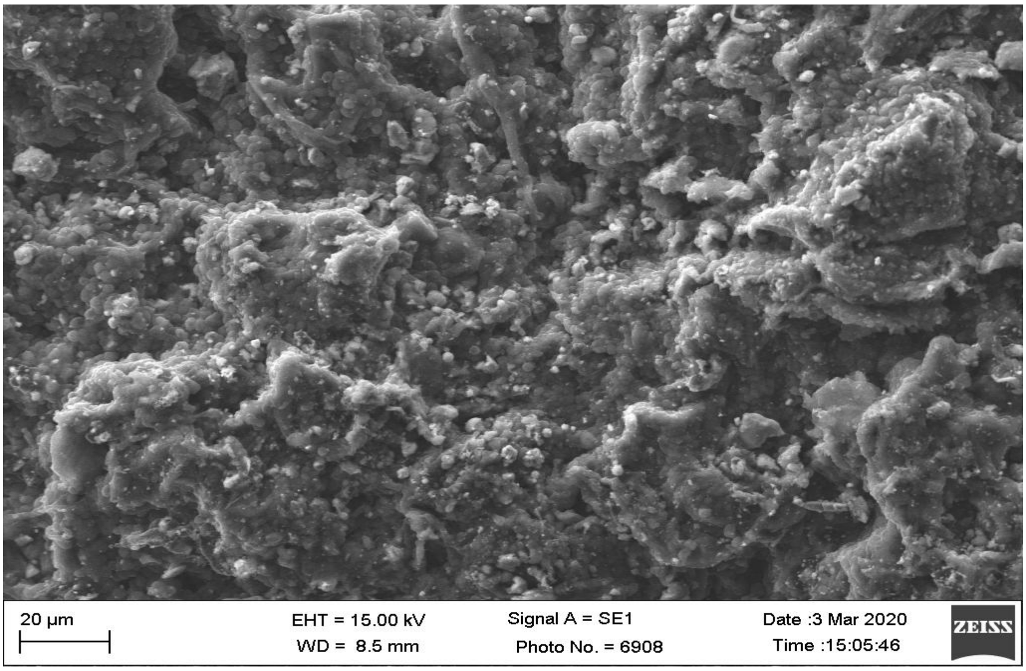

Figure 4. Elemental Analysis of the Carbon Sample:

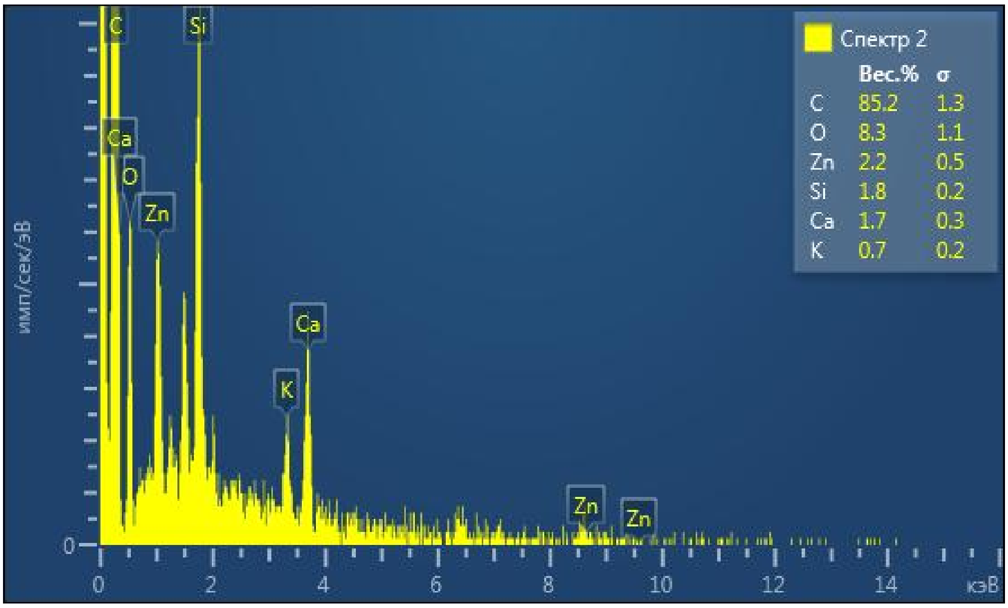

Table 5. Quantitative Elemental Composition of the Carbon Sample:

Element	Weight %	Capacity, wt.%
C	85.19	1.26
O	8.27	1.11
Si	1.84	0.23

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K	0.74	0.20
Ca	1.75	0.26
Zn	2.21	0.46
Total:	100.00	

Discussion: The experimental results clearly demonstrate the high potential of peach pit-derived activated carbon (ShFK) as an effective adsorbent for various industrial applications. The material exhibited a well-developed porous structure with a high surface area (m^2/g) and significant micropore volume (cm^3/g), comparable or even superior to that of commercial AG-3 activated carbon. The benzene adsorption capacity reached up to 1.85 g/100 g, indicating strong interaction with organic molecules and confirming the effectiveness of the activation process at 850°C.

Infrared spectroscopy (IR) and scanning electron microscopy (SEM) analyses provided further insight into the surface chemistry and microstructure of the synthesized carbon. The presence of functional groups such as –OH, –CHO, and –COOH on the carbon surface suggests enhanced chemical reactivity and affinity toward polar compounds, which likely contributed to the observed adsorption efficiency.

The application of ShFK in the purification of monoethanolamine (MDEA) demonstrated its practical relevance. When used in the regeneration process, ShFK increased the concentration of MDEA from 40% to 52%, outperforming AG-3 in terms of adsorption of contaminants. Furthermore, the amount of thermostable salts in the treated solution decreased to 0.81 wt%, remaining within the permissible limits and indicating effective decontamination. Mechanical impurities were reduced from 1068 mg/L to 479 mg/L, which is below the threshold value of 500 mg/L and slightly better than the result obtained with AG-3 (488 mg/L).

Additionally, the lower ash content and improved foam behavior (lower foam height and foaming time) in MDEA solutions treated with ShFK suggest that the carbon is not only effective in adsorption but also contributes to process stability by reducing foaming tendencies.

Overall, these findings confirm that activated carbon synthesized from peach pit shells is a viable and sustainable alternative to commercial adsorbents. Its performance in both adsorption capacity and chemical regeneration highlights its potential for broader application in industrial separation and purification processes.

Conclusion: The research has demonstrated that activated carbon synthesized from peach pit shells (ShFK) possesses promising adsorption and physicochemical properties, making it a strong candidate for industrial purification applications. The carbonization and steam activation process at 850°C resulted in a material with high surface area, well-developed pore structure, and functional surface groups essential for effective adsorption.

Comparative analysis with commercial AG-3 activated carbon revealed that ShFK not only matches but in some aspects exceeds AG-3's performance. Specifically, ShFK achieved higher benzene adsorption capacity, lower ash content, and better removal efficiency of mechanical impurities and thermostable salts in MDEA solutions. The increase of amine concentration from 40% to 52% and the reduction of mechanical impurities to 479 mg/L highlight its operational effectiveness in real-world applications.

The findings support the use of agricultural waste—such as fruit pit shells—as an economically and environmentally sustainable raw material for producing high-quality activated carbon. The

successful regeneration of MDEA using ShFK also points to its potential role in chemical processing industries, offering both cost and performance advantages over conventional materials.
Future studies should further explore the regeneration cycles, scaling possibilities, and broader applicability of ShFK-based carbons across other chemical systems and wastewater treatment processes.

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