Journal Homepage: http://ijcpe.uobaghdad.edu.iq
Iraqi Journal of Chemical and Petroleum Engineering
Vol. 26 No. 2 (June 2025) 47 – 56
EISSN: 2618-0707, PISSN: 1997-4884

Preparation and characterization of adsorptive carbonized corncob for elimination of sulfur from sulfurized n-hexane

Yousuf Oday [a], Haider A. Al-Jendeel [a, *], Zaid Nidhal Shareef [b]

a Department of Chemical Engineering, College of Engineering, University of Baghdad, Aljadria, Baghdad, 10071, Iraq
b Curtin University, Chemical Engineering Department, Australia

Abstract

The present study is conducted to investigate the adsorption desulfurization process for eliminating sulfur from a simulated fuel within a sulfur content range similar to what exists in typical naphtha streams. The model oil, n-hexane, was sulfurized with dibenzothiophene (DBT), which is the most complex form of sulfur constituents in fuels. Corncob, a natural biomass waste material, was utilized to accomplish the adsorption remedy of sulfur.

The carbonization process took place at 500 °C. FTIR, SEM, XRD, AFM, and BET-surface area facilitated a comprehensive characterization of carbonized corncob (CC) adsorbent. The results showed that the corncob sample has homogeneous surfaces and relatively analogous active positions. The CC adsorbent was utilized to adsorb sulfur in its DBT configuration from the sulfurized fuel (n-hexane). Certain adsorption factors of temperature, contacting time, and adsorbent dosage were examined to select the most appropriate adsorption conditions. After that, the chosen conditions were employed to adsorb various sulfur concentrations. For the same initial concentration of sulfur of 400 ppm, the removal attained 75% at favorable parameters of 60°C, 30 min, and 3g $L^{-1,}$ respectively. The efficiency of sulfur removal was substantially augmented with the reduction of the initial sulfur content. Thus, it attained more than 79 % when the original concentration of sulfur in the n-hexane was maintained in the range of 100 ppm. The results perfectly coincided with the Langmuir model of adsorption isotherms. The thermodynamics of the desulfurization adsorption process reflected that the adsorption is associated with an endothermic event. The estimated standard enthalpy changes were 6.34 kJ mol^{-1}. The adsorption was spontaneous over the employed temperature range of 30 – 60°C.

Keywords: Corncob; Adsorption desulfurization; Sulfur removal; Sulfurized n-hexane; Light-cut products.

Received on 05/09/2024, Received in Revised Form on 29/11/2024, Accepted on 29/11/2024, Published on 30/06/2025

https://doi.org/10.31699/IJCPE.2025.2.5

1- Introduction

Crude oil is the most abundant hydrocarbon fuel with a diversity of sulfur compounds. The sulfur ingredients vary from the simple sulfur form (S) to the highly complex constituent of dibenzothiophene ($C_{12}H_8S$). These varieties are eventually dispersed in different petroleum products through refining stages. The total sulfur content in crude oil is around 0.1 – 5 % wt [1]. The dibenzothiophene (DPT) compound and its group of thiophenes form 70% of the overall sulfur content in crude oil [2]. Over refining and combustion, these species are mainly released as gases of SO_2 and H_2S. These gases seriously damage the environmental system [3]. To eliminate sulfur from the different petroleum products, two stages of hydrodesulfurization and sulfur recovery are required. Commercializing these techniques is associated with high cost and energy consumption issues. Employing HDS to treat crude oil streams is inefficient for the removal of certain sulfur constituents. Thus, alternate desulfurization approaches are essential for curing crude oil and light products [4].

Adsorption has been introduced as a low-cost and energy-effective desulfurization technique, particularly when using sustainable and waste substances [5]. Activated carbon extracted from natural wastes such as corncobs can be an effective adsorbent material [6,7].

Finding cheap materials, such as corn waste, to remove sulfur from petroleum compounds contributes to reducing pollution and saving a large amount of energy needed to remove these wastes by other methods. Adsorption for sulfur treatments using corn waste serves to valorize agricultural waste and save energy [8, 9]. Corncobs are favorable for preparing active carbon due to their porous framework and sufficient effective area. Many industries successfully applied activated carbon that is produced from corncob as an adsorbents [10, 11]. Significantly, it is an attractive feedstock that has been experimented with to synthesize active adsorbents for desulfurization purposes [7, 12]. Producing activated carbon from corncob for such applications is carried out via carbonization of raw substance at 500 – 900 °C and then applying physical or chemical activation processes, which increase surface activity [12, 13]. The physical activation path includes introducing the carbonized corncob (CC) to an oxidizing environment (normally oxygen or steam) at a high

---

*Corresponding Author: Email: haider.aljendeel@coeng.uobaghdad.edu.iq

temperature of 600 – 1200°C [14]. Chemical activation occurs through the use of chemicals such as strong/weak acids, strong alkalis, and salts. Practically, the chemical is favorable as it is performed at a smaller temperature magnitude and less activation time [14, 15].

The elimination of sulfur substances strongly depends on the utilized method, in which sulfur compounds should be completely captured [16]. The high surface chemistry of corncob-based activated carbon should enhance its adsorption properties, especially for desulfurization [17-19]. Recently, the adsorption of sulfur using carbonized corncob that is activated by 2.0 M HCl acid resulted in sulfur removal by around 83% [7].

The current study focused on using the carbonized corncob (CC) sample as an adsorbent, avoiding further treatment with acidic or alkali reagents. Corresponding parameters were examined, such as comprising temperature, contacting time, the dosage of adsorbent material, and initial sulfur concentration. The thermodynamics of the adsorption process were also estimated to identify the calorimetric events and spontaneity of the adsorption stage.

2- Methodology

2.1. Material

In the present work, corncobs were the adsorbent substance exploited to adsorb sulfur. It was obtained from a domestic vegetable storehouse in Diyala. A pure sample of hexane (99%) was used as a model oil. It is commercially supplied by CDH Chemicals Company, while dibenzothiophen (DBT) was delivered from Sigma-Aldrich.

2.2. Methods

The experiments have involved three steps: (1) preparation of the corncob powder, (2) carbonization and characterization of the corncob sample, and (3) employing the carbonized corncob in the elimination of sulfur from the sulfurized hexane.

2.2.1. Pretreatments of the corncob sample

In this step, the corncob pieces were turned into fine powder before the thermal treatment for carbonization purposes. The corncob powder was extracted after cleaning and removing out seeds. In the beginning, the corns were first cleaned carefully. The clean cobs were then exposed to the sunlight for 72 hours in the average ambient temperature of 38 °C. The dried cobs were then fragmented into tiny pieces of different sizes that were 2 cm^3 on average. Additional heating was essential, and it was electrically implemented at 75 °C with a heating time of 6 h. The drying process occurred with periodic excitement after each heating course of one hour. After that, these pieces were pulverized and sieved over a 600 µm sieve. The powder was then collected to execute the carbonization stage [15].

2.2.2. Carbonization of the carbon sample

A sufficient quantity of the corncob sample (200 g) was equally divided, carefully loaded in crucibles, and introduced to a muffle furnace for only 0.1 h with a controlled temperature of
500 ºC to obtain the carbonized sample. After cooling down, the resulting carbon was maintained in a tight package to be ready for sulfur desulfurization experiments from the simulated oil. The samples with thermal treatment are assigned as thermally carbonized corncob and remarked as (CC).

To characterize the carbonized corncob (CC), measurements of surface area, surface morphology, microstructure, and crystallography were achieved using Brunauer, Emmett, and Teller (BET) technique, scanning electron microscopy (SEM), Atomic Force Microscope (AFM), Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction (XRD) respectively.

2.2.3. Desulfurization experiments

The desulfurization experiments were performed for the desulfurization of simulated fuel (n- hexane) using the adsorptive desulfurization approach. The utilized adsorbent substance used in this process was the thermally carbonized corncob (CC) sample. The experimental setting is as shown in Fig. 1.

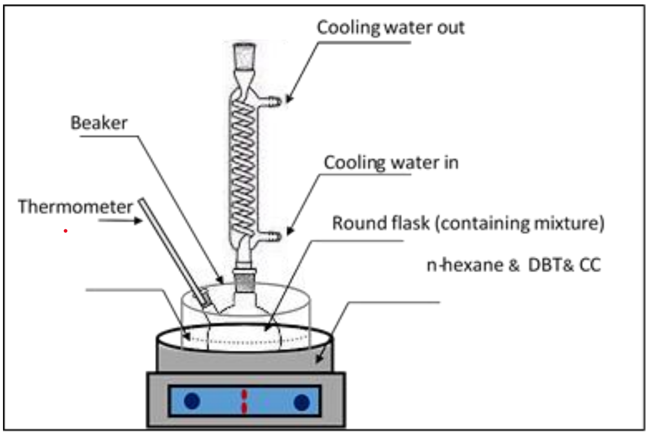


Fig. 1. Experimental arrangement of sulfur adsorption from the model fuel (n-hexane) employing the (CC) sample as an adsorbent

The simulated oil of 3 L was adequately prepared by liquefying the dibenzothiophene with simulated fuel [20]. The initial sulfur amount was determined to be 400 ppm. The dissolving step continued for 25 min, and it was carried out at a temperature of 60 °C. In each run, 50 mL of the contaminated hexane was mixed with the CC sample.

The dependency of the sulfur removal efficiency on the dosages of CC adsorbent, quantities of dibenzothiophene, time, and temperature was investigated. The experimental extents of doses were 1 – 5 g L^{-1}, while the range of initial sulfur concentration was between 100 and 400 ppm. The applied stirring time varied from 5 to 35 min, and the temperature was changed from 30 to 50 °C. After filtration, the liquid was introduced to measure sulfur concentration. The calculated error of the performed experiments was about 2%.

2.3. Adsorption isotherm

As the most common adsorption models, Langmuir and Freundlich's isotherms were normally used to describe the spreading of species in solid and liquid phases in saturation [21, 22]. Utilizing these simulations enables significant insight into the adsorption and its corresponding requirements for the designation of sulfur reduction techniques [23]. In the present research, carbonized corncob (CC) was employed to remove sulfur from liquid mixtures. The adsorption data were examined with the aid of these models. Langmuir's approach [24] can describe the accumulation of sulfur in a monolayer form on homogeneous surfaces, and it is mathematically presented by Eq. 1 [25, 26].

$$\frac{Ce}{qe}=\frac{Ce}{qm}+\frac{1}{K_Lqm} \qquad (1)$$

Nevertheless, Freundlich covers the adsorption behavior of sorbate by solids of heterogeneous adsorbing surfaces [27]. Eq. 2 represents the linear form of this adsorption style [26, 28].

$$lnq_e = lnK_F + \frac{1}{2}lnC_e \qquad (2)$$

Where *qm* represents the maximum theoretical adsorption capacity in which the CC surface is covered completely with sulfur (mg·g^{-1}), *Ce* denotes the sulfur concentration at equilibrium (mg L^{-1}), *qe* refers to the equilibrium adsorbed sulfur in mg g^{-1}, and *KL* symbolizes an energy factor. *KF* and n represent constants that are related to the intensity of adsorption.

2.4. Adsorption thermodynamics

The thermodynamic parameters of DBT adsorption onto the carbonized corncob (CC samples) were estimated from sets of experimental data obtained at different temperatures with an interval of 10 °C (30, 40, 50, and 60 °C), while the other parameters were kept constant. The enthalpy (ΔH°), entropy (ΔS°), and Gibbs energy (ΔG°) were calculated by using Van't Hoff equations (Eqs. 3, 4, and 5) [26, 28, 29]. *Kd* in Eq. 3 is a dimensionless factor, and it is known as the equilibrium constant [30, 31].

$$K_d = \frac{q_e}{C_e} \qquad (3)$$

$$lnKd = \frac{\Delta S^\circ}{R} - \frac{\Delta H^\circ}{RT} \qquad (4)$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad (5)$$

3- Results and discussions

3.1. Characterization of carbonized corncob (CC)

3.1.1. Surface area (BET) and pore volume

The produced carbonized corncob (CC) had a BET surface area of about 137 m^2 g^{-1} with a pore volume of 0.09 cm³ g^{-1}. Further carbonization at a higher temperature and longer heating time did not significantly affect the surface area and pore volume. In a prior study, carbonization of the corncob sample at 800 °C for around 2 h provided a surface area of 160 m² g^{-1} and a pore volume of 0.1 cm³ g-1 [15]. However, energy consumption should be considered when using such high temperatures [32].

3.1.2. XRD analysis

The crystallographic analysis of the CC sample produced from corncob via thermal treatment is presented in Fig. 2.

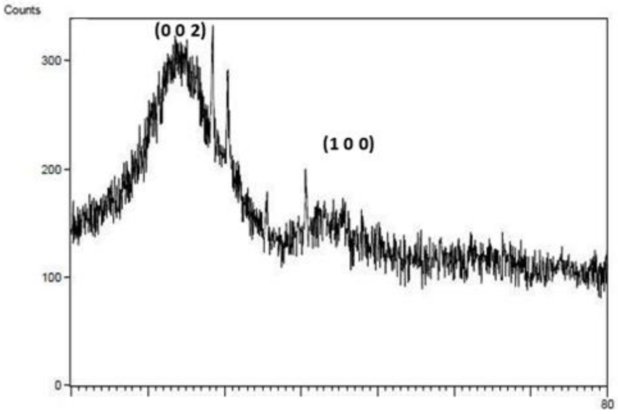


Fig. 2. XRD spectrum of CC sample

Fig. 2 shows broadening background diffractions, indicating that the CC sample predominantly has amorphous structures [33]. The presented wide peaks at 2θ of 24.5° and 43.5° magnitudes characterize minor remains of crystalline corncob. The appearance of the tiny, pointed peaks at 28°, 30.5°, 35.5°, and 40° is probably associated with the presence of some unknown impurities.

Bragg-Scherer's equations facilitated estimation of the D-spacing of the characteristic peak d002 = 0.36 nm. Compared with the literature of using different acid and alkali activation techniques after thermal treatment at above 780 °C [14], the obtained d002 values were in the range of 0.34 – 0.35 nm. This reflects that the d002 of the CC sample is slightly higher than the reported ranges, assigning less surface area [34]. Considering the avoidance of using multi-thermal treatment courses at high temperatures (780 – 800 °C before, through, and after activation) as applied in these studies, the obtained surface area in the current work could be efficient as an adsorbent agent.

3.1.3. FR-IR analysis

The FT-IR spectrum of CC samples is shown in Fig. 3. The FTIR spectrum reflects a broad band between 3480 and 3100 $\text{cm}^{-1,}$ which mainly corresponds to the stretching form of O–H bonds that may overlap with stretching vibration modes of N–H bonds [35]. At around 2928 cm^{-1}, C–H band has likely existed as an indicator for the appearance of alkyl groups. The stretching vibrations of carbonyl bands are present at the wavelength of 1612 cm^{-1}, while the normal C–O groups are close to 1108 cm^{-1}. The 2346 cm^{-1} band is more likely associated with the appearance of some impurities [32]. The previously reported FTIR data of corncob monitored locations at 900, 1040, and 1630 cm^{-1} for cellulose [15], whereas at 850, 1420, 1500, and 1600 cm^{-1}, aromatic ingredients were detected [15, 36]. In the existing study, the carbonization process has led to the presence of other bands, which are mainly related to several carbon assemblies [17].

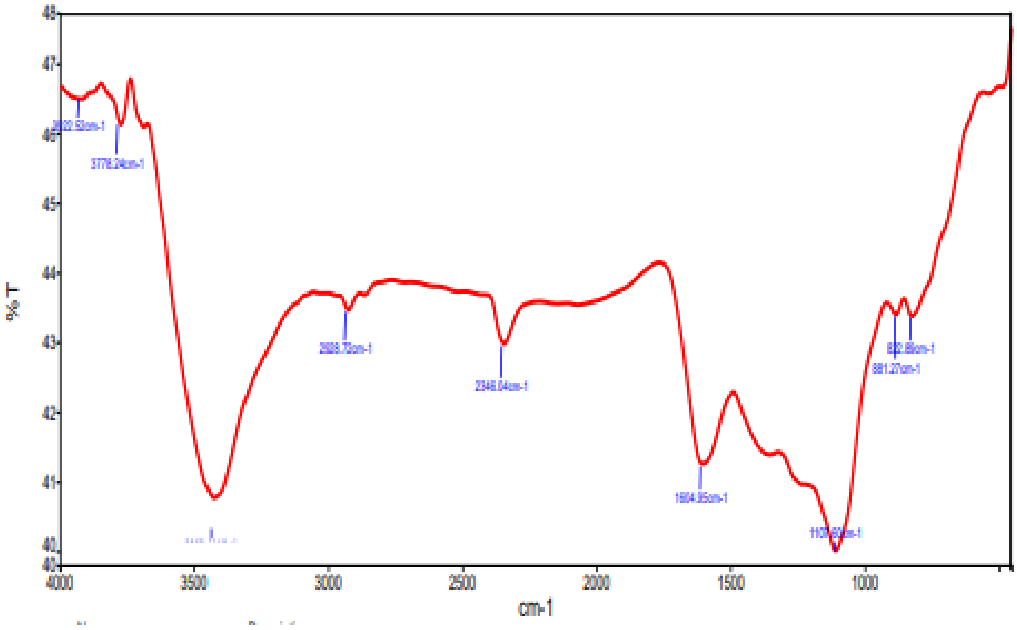
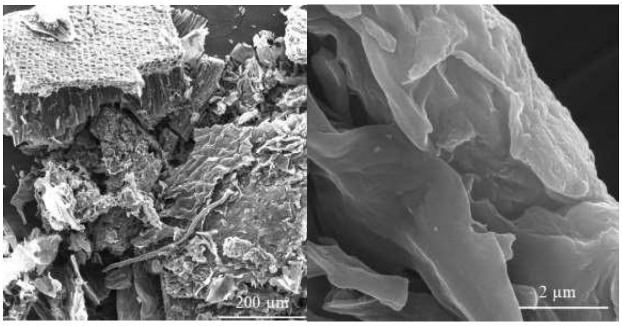


Fig. 3. FT-IR spectrum of CC sample

3.1.4. SEM analysis

The morphological analysis of the carbonized corncob (CC) sample is presented in Fig. 4.



(a) (b)

Fig. 4. SEM data of the CC sample (a) scale of 200 µm, and (b) scale of 2 µm

It is clear to observe that the thermally treated corncob (CC) sample has a honeycomb layers-like morphology (Fig. 4a). Each layer seems to be constructed just like a networking lattice. The interior of the networking frame contains forked channels. More focus on the interior sections presents a formation of layers that have been folded around each other (Fig. 4b). These observations are almost similar over many sites of the monitored section. Such morphology could provide the required surface area for adsorbed DBT.

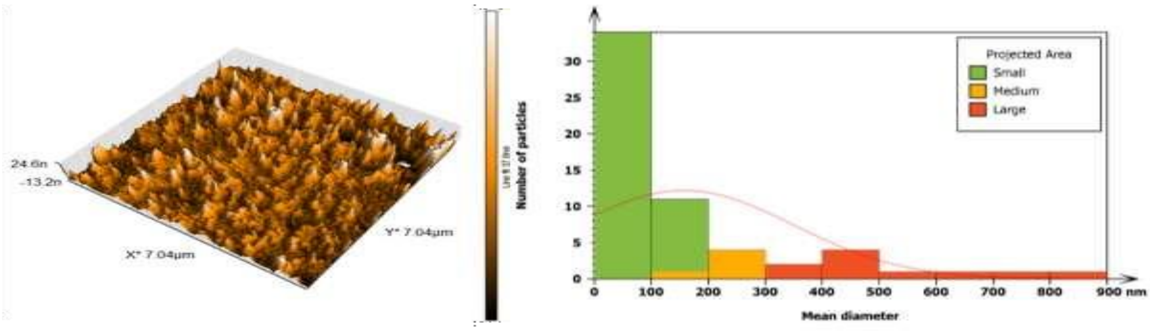
The EDS measurements facilitated the determination of the elemental content of the carbonized sample, particularly the carbon content. The data showed that the CC sample consists of carbon, oxygen, silicon, and potassium with weight percentages as listed in Table 1.

Table 1. Elemental contents of the CC sample

Element	C	O	K	Si
W%	64.10	25.26	5.794.84	4.84

3.1.5. AFM analysis of CC sample

The three-dimensional (3D) surface morphology and particle analysis of the CC sample were determined by atomic force microscopy (AFM). The monitored data is shown in Fig. 5.



(a) (b)

Fig. 5. AFM analysis of the CC samples (a) 3D surface analysis, and (b) particle analysis

The 3D surface image of the CC sample (Fig. 5a) shows that its particles have a hills and valleys shape. The hills appear like they have been sculpted. Also, they are relatively small. The valleys themselves have tiny peaks in their configurations. Together with the smallness of the principal hills from their background could be the reason for the partially homogeneous shape of the surface of the CC grains. The mean height of peaks is between 30 – 40 nm, which could contribute to smothering the surfaces of particles of the CC sample.

The particle analysis (Fig. 5b) indicates that most of the particles are set in a small size range of diameters. The distribution of particle diameters is reflected in Table 2.

Table 2. Particle diameter analysis of the CC sample

Particle	Percentage (%)	Diameter (nm)
Small	74	66
Medium	8.5	249
Large	17.5	534

3.2. Adsorption of sulfur

The best conditions for better adsorption of sulfur were determined by sets of experiments using the carbonized corncob sample (CC). These conditions were regulated according to the removed amount of sulfur from the simulated fuel (n-hexane). The efficiency of sulfur reduction was varied with time, temperature, and the dosage of adsorbent. The optimum conditions were selected and eventually applied to examine the variation of sulfur removal with the initial concentration (ppm) of sulfur in the model fuel.

3.2.1. Influences of time

Variation of the DBT removal with contact time in the range of 0.0 – 35 min with an interval of 5 min is presented in Fig. 6.

The data in Fig. 6 shows that the adsorption increases with time. The efficiency of removal is around 66% after only 5 min. Slight increases were observed to attain approximately 72.5% as the time became 20 min. After 10 min, the elimination of sulfur reaches 73%. No increase was monitored after 30 min. A specific adsorption time for the elimination of sulfur via carbonized corncob is not available in the previous works. However, the time to attain the saturation with such efficiency by just 30 min is relatively short, which was adequate to adsorb sulfur species on CC surfaces and maybe the deeper sites. The best adsorption time was chosen to be 30 min.

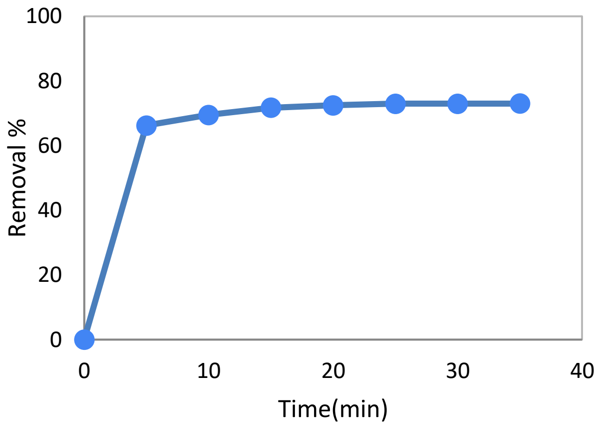


Fig. 6. Variation of sulfur elimination in different periods via using the CC sample at constant temperature, adsorption dosage, and sulfur initial content of 40 °C, 3 g L^{-1}, and 400 ppm, respectively

3.2.2. Influences of temperature

The dependency of sulfur removal on temperature in the range of 30 – 70 °C is depicted in Fig. 7.

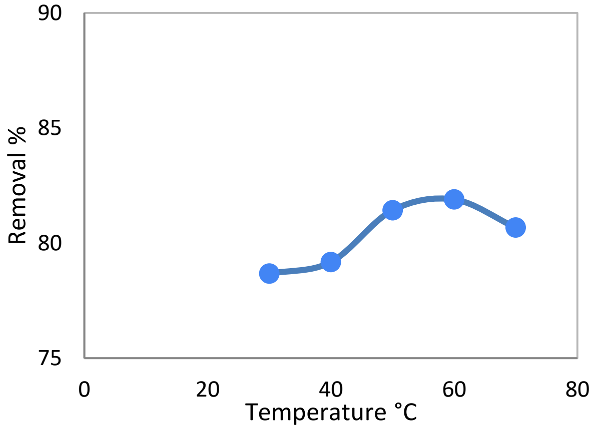


Fig. 7. Variation of DBT removal percent with temperature (°C) using CC sample at constant time, adoption dosage, and sulfur initial content of 30 min, 3 g L^{-1}, and 400 ppm, respectively

It can be shown that when the temperature is 30 °C, the efficiency of sulfur reduction is about 72%, while it reaches 73% after increasing the temperature by 10 °C. The sulfur removal is increased to 78% when the temperature is 60 °C. After that, it reduces to around 76% with increasing temperature. The current observations present that sulfur elimination on the CC sample is superior at elevated temperatures of below 70 °C, which could refer to the occurrence of endothermic events and the formation of strong forces between sulfur and CC particles at these temperatures [37,38]. The optimum temperature of 60 °C was picked as the preferred degree.

3.2.3. Influences of adsorbent dosage

The extent of adsorbent dosage of the CC sample was 1 – 5 g L^{-1}. Fig. 8 presents data on sulfur elimination at this range.

From Fig. 8, the removal percentage of sulfur is approximately 76.9% at the dosage of 1 g L^{-1}, and it gradually increases to around 78.9% is observed when the CC dose attains 3 g L^{-1}. Further increasing of dosage does not cause any improvement in the removal efficiency. The value of 3 g L^{-1} appears as the proper amount.

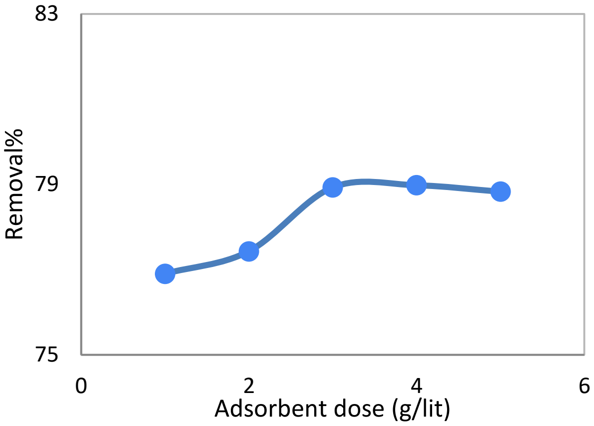


Fig. 8. Variation of DBT removal with adsorbent dose (g L^{-1}) via using CC sample at constant time, temperature, and initial sulfur content of 30 min, 40 °C, and 400 ppm, respectively

3.2.4. Influences of initial sulfur content

Table 3 displays the results of sulfur elimination by CC material at various initial quantities of sulfur. The employed range of sulfur was 100 to 400 ppm. The optimum parameters obtained above were utilized in this set of experiments.

Table 3. Examination of the best conditions of time, temperature, and adsorbent dose using the CC sample as adsorbent material

Time (min)	Temp. (°C)	Adsorbent dose (g L-1)	Initial sulfur Conc. (ppm)	Removal of sulfur (%)
30	60	3	100	79.4 ± 1.59
30	60	3	200	78.3 ± 1.57
30	60	3	300	76.6 ± 1.53
30	60	3	400	75.0 ± 1.50

Table 3 indicates that the removal of sulfur is improved with a decrease in its initial concentration in the simulated fuel. The removal is around 79.5% at a sulfur content of 100 ppm, and it drops to 75% when the concentration becomes 400 ppm. This is similar to the highest removal obtained by determining the best conditions. Unfortunately, there is no data to compare with regarding the use of carbonized corncob to adsorb sulfur compounds from fuels.

Compared with previously reported data for sulfur elimination from naphtha, which has carbon atoms and sulfur amount almost similar to the model fuel, elimination of sulfur has not exceeded 68 or 80% [39, 40]. A more recent publication reported a removal magnitude of around 83% of sulfur from sulfurized n-hexane using corncob-acid activated carbon [7]. This reveals that the CC sample is a talented, not expensive, and energy-effective substance for adsorbing crude oil's undesired sulfur contents.

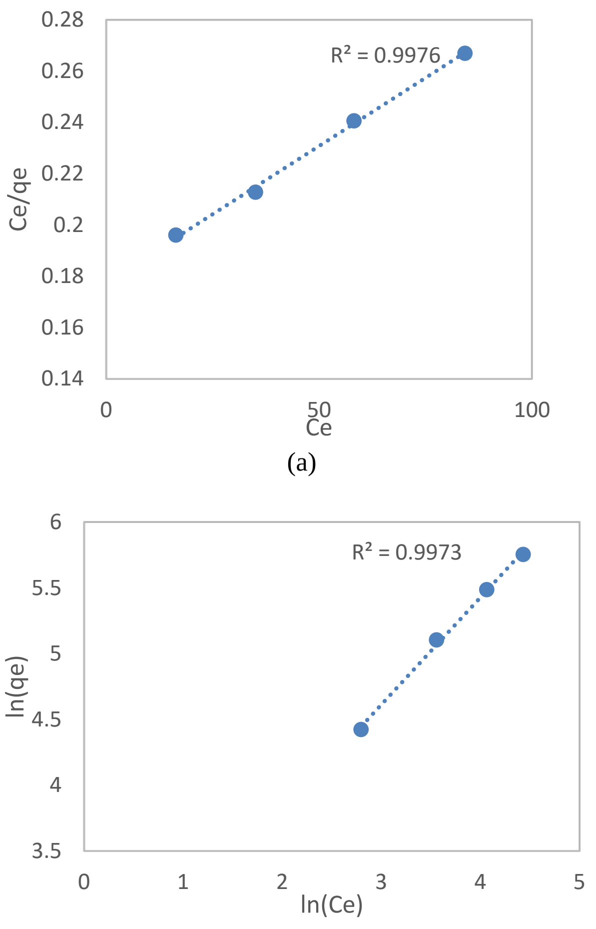
3.3. Adsorption isotherm

The adsorption performance with particular adsorption models was examined. These models have been widely used to illustrate the spreading of sulfur particles in a mixture of solid and liquid [41]. Plotting of qe (mg.g^{-1}) versus the Ce (mg.L^{-1}) enables obtaining the data of equilibrium adsorption using the required mathematical relations (section 2.3). Fig. 9 a and Fig. 9b present Langmuir and Freundlich simulations, respectively. The linking isotherm factors are presented in Table 4.

From Fig. 9, and Table 4, the Langmuir model can represent the experimental data better than the Frendlich style for adsorption of DBT onto the CC sample. This is obtained through comparison of the fitting correlation factor (R^2) of 0.9776 and 0.9773 of these two models, respectively. Fitting the data with the Langmuir model means that the CC sample relatively has homogenous surfaces and uniform adsorption sites. This is consistent with the results obtained from the above characterization sections, particularly the data obtained from SEM and AFM.

3.4. Adsorption thermodynamics

To investigate the findings obtained in previous sections regarding the temperature-enhancing adsorption and the spontaneity of the entire process, the equations of 3, 4, and 5 were applied, employing four temperatures up to the optimal degree of 60 °C (i.e., 30, 40, 50, and 60° C). The parameters in equation 3.4 were obtained by plotting the adsorption coefficient logarithm (ln Kd) and the temperature reciprocal (1/T).



(a)

(b)

Fig. 9. Sulfur adsorption data using CC sample based on (a) Langmuir, (b) Freundlich relations

Table 4. Factors of both Langmuir and Freundlich’s scenarios for sulfur adsorption by (CC) adsorbent at 60 °C

Model	**Factor**	**Magnitude**
Langmuir	KL	0.0062
	R^2	0.9776
Freundlich	KF	8.7916
	n	1.2297
	R^2	0.9773

Thermodynamics of DBT adsorption onto the CC sample obtained from the linearization of four scattered points are shown in Fig. 10. The corresponding parameters were calculated and listed in Table 5.

Table 5 shows that the removal of sulfur by CC material is associated with an endothermic event with a small enthalpy change of about 6.34 kJ mol^{-1}. It also shows that the desulfurization is spontaneous at the tested temperatures, and the spontaneity increases gradually up to the optimal temperature of 60 °C. The average ΔG° value is around -3.56 kJ mol^{-1}.

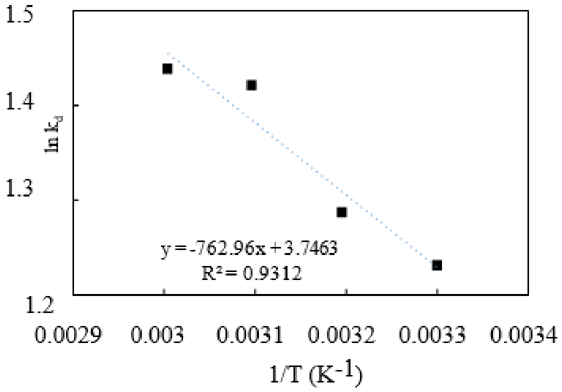


Fig. 10. Plotting the adsorption coefficient (ln Kd) logarithm and the temperature (1/T) reciprocal to obtain the thermodynamic parameters for the DBT adsorption onto the CC sample

Table 5. Thermodynamic parameters values for the adsorption of dibenzothiophene (DBT) onto the CC sample

Temperatures (K)	Kd	ΔH° kJ mol^{-1}	ΔS° J mol^{-1} K^{-}	ΔG° kJ mol^{-1}
303	3.42	6.34	31.15	-3.09
313	3.62			-3.41
323	4.14			-3.72
333	4.21			-4.03

4- Conclusions

The current study confirms the ability of corncob in its carbonized form to be a promising low- cost adsorbent substance for the elimination of sulfur species from light-cut oil products, and as experimented, from sulfurized n-hexane. The applied treatment of carbonization contributed to an effective adsorption area and porous framework of homogeneous active pores. The elimination of sulfur reached about 79.5% via the desired parameters of temperature, time, and the dosage of adsorbent. At equilibrium, the isotherm model of Langmuir fitted considerably with the obtained data in the present work. Thermodynamically, the adsorption process was associated with an endothermic event with a small enthalpy change of around 6.34 kJ mol^{-1}, and it was spontaneous over the tested temperature window of 30 -60 °C. The data indicated that a carbonized corncob sample (CC) is an effective adsorbent for the elimination of sulfur from fuels.

References

[1] A. Qasim, H. H. Alwan,"Enhancement of light Naphtha quality using calcite adsorbent from eggshells by adsorptive desulfurization", *South African Journal of Chemical Engineering*, Volume 46, 196-204, 2023. https://doi.org/10.1016/j.sajce.2023.08.007

[2] I. V. Babich, J. A. Moulijn, "Science and technology of novel processes for deep desulfurization of oil refinery streams: a review," *Fuel*, Volume 82, 607-631, 2003. https://doi.org/10.1016/S0016-2361(02)00324-1

[3] A.T. Nawaf, B. A. Abdulmajeed, “Design of oscillatory helical baffled reactor and dual functional mesoporous catalyst for oxidative desulfurization of real diesel fuel”, *Chemical Engineering Research and Design*, Vol. 209, pp.193-209, 2024. https://doi.org/10.1016/j.cherd.2024.07.032

[4] I. Mohammed, H. H. Alwan, A. N. Ghanim, "Using Box-Behnken experimental design for optimization of gas oil desulfurization by electrochemical oxidation technique," *IOP Conference Series: Materials Science and Engineering*, Volume 928, 2nd International Scientific Conference of Al-Ayen University (ISCAU-2020), 15-16 July 2020, Thi-Qar, Iraq, 022158, 2020. http://doi.org/10.1088/1757-899X/928/2/022158

[5] A. Qasim and H. H. Alwan, “Adsorptive Desulfurization of Iraqi Light Naphtha Using Calcite and Modified Calcite”, *Iraqi Journal of Chemical and Petroleum Engineering*, 25(1), pp. 83–93, 2024, https://doi.org/10.31699/IJCPE.2024.1.8

[6] S. M. Al-Jubouri, H. A. Al-Jendeel, S. A. Rashid, S. Al-Batty, "Green synthesis of porous carbon cross-linked Y zeolite nanocrystals material and its performance for adsorptive removal of a methyl violet dye from water," *Microporous and Mesoporous Materials*, Volume 356, 112587, 2023. https://doi.org/10.1016/j.micromeso.2023.112587

[7] Y. Oday, H. A. Aljendeel, "Synthesis and Characterization of Acidic Activated Carbon from Corncobs for Adsorption Desulfurization of Simulated Crude Oil," *Journal of Ecological Engineering*, Volume 25, Issue 8, 2024. https://doi.org/10.12911/22998993/189895

[8] M. O. Azeez, S. A. Ganiyu, "Review of biomass derived-activated carbon for production of clean fuels by adsorptive desulfurization: Insights into processes, modifications, properties, and performances," *Arabian Journal of Chemistry*, 105182, 2023. https://doi.org/10.1016/j.arabjc.2023.105182

[9] P. González-García, "Activated carbon from lignocellulosics precursors: A review of the synthesis methods, characterization techniques, and applications," *Renewable and Sustainable Energy Reviews*, Volume 82, 1393-1414, 2018. https://doi.org/10.1016/j.rser.2017.06.118

[10] X. He, X. Chen, X. Wang, L. Jiang, "Optimization of activated carbon production from corn cob using response surface methodology," *Frontiers in Environmental Science*, Volume 11, 1105408, 2023. https://doi.org/10.3389/fenvs.2023.1105408

[11]S. Fauzia, H. Aziz, D. Dahlan, R. Zein, "Study of equilibrium, kinetic, and thermodynamics for removal of Pb (II) in aqueous solution using Sago bark (Metroxylon sago)," *AIP Conference Proceedings*, Volume 2023, Issue 1, October 2018. https://doi.org/10.1063/1.5064078

[12]S. A. Obaid, "Langmuir, Freundlich, and Tamkin adsorption isotherms and kinetics for the removal of artichoke tournefortii straw from agricultural waste," *Journal of Physics: Conference Series*, Volume 1664, Issue 1, p. 012011, November 2020. https://doi.org/10.1088/1742-6596/1664/1/012011

[13]N. Muttil, S. Jagadeesan, A. Chanda, M. Duke, S. K. Singh, "Production, types, and applications of activated carbon derived from waste tires: an overview," *Applied Sciences*, Volume 13, Issue 1, 257, 2023. https://doi.org/10.3390/app13010257

[14]G. K. Jabaar, H. A. Al-Jendeel, and Y. A. Alsheikh, “Desulphurization of Simulated Oil Using SAPO-11 with CNT’s as Adsorbent: A Kinetic Study”, *IJCPE*, vol. 24, no. 3, pp. 69–77, Sep. 2023. https://doi.org/10.31699/IJCPE.2023.3.7

[15]A. C. Lua, T. Yang, "Effect of activation temperature on the textural and chemical properties of potassium hydroxide activated carbon prepared from the pistachio-nut shell," *Journal of Colloid and Interface Science*, Volume 274, Issue 2, 594-601, 2004. https://doi.org/10.1016/j.jcis.2004.02.051

[16]S. H. Ammar & S. A. Jaafar “adsorption kinetic and isotherms studies of thiophene removal from Model Fuel on activated carbon supported copper oxide”. *Iraqi journal of chemical and petroleum engineering* vol.18 no.2, pp. 83-93, 2017. https://doi.org/10.31699/IJCPE.2017.2.7

[17]N. M. Abdullah, H. Q. Hussien, and R. R. Jalil . “heavy naphtha desulfurization by ozone generated via the DBD plasma reactor” *Iraqi Journal of Chemical and Petroleum Engineering*, vol.25 no. 2 pp.131-137, 2024. https://doi.org/10.31699/IJCPE.2024.2.12

[18]C. Song, "An overview of new approaches to deep desulfurization for ultra-clean gasoline, diesel fuel, and jet fuel," *Catalysis Today*, Volume 86, Issues 1-4, 211-263, 2003. https://doi.org/10.1016/S0920-5861(03)00412-7

[19]G. K. Jabaar, H. A. Al-Jendeel, Y. A. Alsheikh, "Desulphurization of Simulated Oil Using SAPO-11 with CNT's as Adsorbent: A Kinetic Study," *Iraqi Journal of Chemical and Petroleum Engineering*, Volume 24, Issue 3, 69-77, 2023. https://doi.org/10.31699/IJCPE.2023.3.7

[20]M. H. K. Darvanjooghi, M. N. Esfahany, S. H. Esmaeili-Faraj, "Investigation of the effects of nanoparticle size on CO_2 absorption by silica-water nanofluid," *Separation and Purification Technology*, Volume 195, 208-215, 2018. https://doi.org/10.1016/j.seppur.2017.11.032

[21]N. Gaur, K. Narasimhulu, Y. PydiSetty, "Recent advances in the bio-remediation of persistent organic pollutants and its effect on the environment," *Journal of Cleaner Production*, Volume 198, 1602-1631, 2018. https://doi.org/10.1016/j.jclepro.2018.07.124

[22]T. F. Akinhanmi, E. A. Ofudje, A. I. Adeogun, P. Aina, I. M. Joseph, "Orange peel as a low-cost adsorbent in the elimination of Cd (II) ion: kinetics, isotherm, thermodynamic and optimization evaluations," *Bioresources and Bioprocessing*, Volume 7, 1-16, 2020. https://doi.org/10.1186/s40643-020-00320-y

[23]H. Aljendeel, E. Borhan, and M. J. Al-Ani, “Kinetic Study of Transesterification Reaction of Edible Oil Using Heterogenous Catalyst”, *Iraqi Journal of Chemical and Petroleum Engineering*, vol. 23, no. 3, pp. 11–16, Sep. 2022, http://doi.org/10.31699/IJCPE.2022.3.2

[24]M. H. Alhassani, S. M. Al-Jubouri, H. A. Al-Jendeel, "Stabilization of phenol trapped by agricultural waste: a study of the influence of ambient temperature on the adsorbed phenol," *Desalination and Water Treatment*, Volume 187, 266-276, 2020. https://doi.org/10.5004/dwt.2020.26398

[25]H. A. Al-Jendeel, H. A. Rasheed, N. S. Ahmedzeki, M. H. Alhassani, "Dual Application of Al-Kheriat of Removal of Arsenic from Aqueous Solution and Acting as Rodenticide," *Journal of Ecological Engineering*, Volume 24, Issue 4, 2023. https://doi.org/10.12911/22998993/159335

[26]M. S. Jabbar and R. T. A. Alrubaye, “Adsorption Isotherms and Isosteric Heat of Adsorption of Metal Organic Frameworks as Gas Storage for Liquefied Petroleum Gas Vehicle in Iraq”, *Iraqi Journal of Chemical and Petroleum Engineering,*, vol. 23, no. 3, pp. 25–34, Sep. 2022, https://doi.org/10.31699/IJCPE.2022.3.4

[27]S. M. Al-Jubouri, et al., "Antibiotics adsorption from contaminated water by composites of ZSM-5 zeolite nanocrystals coated carbon," *Journal of Water Process Engineering*, Volume 47, 102745, 2022. https://doi.org/10.1016/j.jwpe.2022.102745

[28]M. T. Amin, A. A. Alazba, M. Shafiq, "Nonspontaneous and multilayer adsorption of malachite green dye by Acacia nilotica waste with dominance of physisorption," *Water Science and Technology*, Volume 76, Issue 7, 1805-1815, 2017. https://doi.org/10.2166/wst.2017.415

[29]G. Liu, J. Ma, X. Li, Q. Qin, "Adsorption of bisphenol A from aqueous solution onto activated carbons with different modification treatments," *Journal of Hazardous Materials*, Volume 164, Issues 2-3, 1275-1280, 2009. https://doi.org/10.1016/j.jhazmat.2008.09.046

[30]É. C. Lima, M. H. Dehghani, A. Guleria, F. Sher, R. R. Karri, G. L. Dotto, H. N. Tran, "Adsorption: fundamental aspects and applications of adsorption for effluent treatment," in *Green Technologies for the Defluoridation of Water*, Elsevier, pp. 41-88, 2021. https://doi.org/10.1016/B978-0-323-85768-0.00004-X

[31]A. H. Jawad, S. A. Mohammed, M. S. Mastuli, M. F. Abdullah, "Carbonization of corn (Zea mays) cob agricultural residue by one-step activation with sulfuric acid for methylene blue adsorption," *Desalination and Water Treatment*, Volume 118, Issue 3, 342-351, 2018. https://doi.org/10.5004/dwt.2018.22601

[32]P. Barpanda, G. Fanchini, G. G. Amatucci, "Structure, surface morphology, and electrochemical properties of brominated activated carbons," *Carbon*, Volume 49, Issue 7, 2538-2548, 2011. https://doi.org/10.1016/j.carbon.2011.01.053

[33]M. J. Prauchner, V. M. Pasa, N. D. Molhallem, C. Otani, S. Otani, L. C. Pardini, "Structural evolution of Eucalyptus tar pitch-based carbons during carbonization," *Biomass and Bioenergy*, Volume 28, Issue 1, 53-61, 2005. https://doi.org/10.1016/j.biombioe.2004.05.004

[34]H. Lata, V. K. Garg, R. K. Gupta, "Removal of a basic dye from aqueous solution by adsorption using Parthenium hysterophorus: an agricultural waste," *Dyes and Pigments*, Volume 74, Issue 3, 653-658, 2007. https://doi.org/10.1016/j.dyepig.2006.07.002

[35]H. A.K. Al-jandeel, “Removal of Phenolic Compounds from Aqueous Solution by Using Agricultural Waste (Al-Khriet)”, *IJCPE*, vol. 14, no. 3, pp. 55–62, Sep. 2013. https://doi.org/10.31699/IJCPE.2013.3.6

[36]W. T. Tsai, C. W. Lai, K. J. Hsien, "Adsorption kinetics of herbicide parquet from aqueous solution onto activated bleaching earth," *Chemosphere*, Volume 55, Issue 6, 829-837, 2004. https://doi.org/10.1016/j.chemosphere.2003.11.023

[37]A. E. Ofomaja, "Sorption dynamics and isotherm studies of methylene blue uptake onto palm kernel fiber," *Chemical Engineering Journal*, Volume 126, 35-43, 2007. https://doi.org/10.1016/j.cej.2006.08.022

[38]Q. A. Mahmood, B. A. Abdulmajeed, R. Haldhar, "Oxidative Desulfurization of Simulated Diesel Fuel by Synthesized Tin Oxide Nano-Catalysts Supported on Reduced Graphene Oxide," *Iraqi Journal of Chemical and Petroleum Engineering*, Volume 24, Issue 4, 83-90, 2023. https://doi.org/10.31699/IJCPE.2023.4.8

[39]N. S. AhmedZeki, S. M. Ali, and S. R. Al-Karkhi “investigation desulfurization method using air and zinc oxide/ activated carbon composite”. *Iraqi journal of chemical and petroleum engineering*, vol.18 no.1, pp. 37-46, 2017. https://doi.org/10.31699/IJCPE.2017.1.3

[40]M. V. Lopez-Ramon, F. Stoeckli, C. Moreno-Castilla, F. Carrasco-Marin, "On the characterization of acidic and basic surface sites on carbons by various techniques," *Carbon*, Volume 37, Issue 8, 1215-1221, 1999. https://doi.org/10.1016/S0008-6223(98)00317-0

تحضير وتوصيف كوز الذرة المتفحم الماز لإزالة الكبريت من ن–هكسان المكبرت

يوسف عدي [١]، حيدر عبد الكريم رشيد [١، *]، زيد نضال شريف [٢]

١ قسم الهندسة الكيمياوية، كلية الهندسة، جامعة بغداد، بغداد، العراق
٢ جامعة كيرتن، قسم الهندسة الكيمياوية، استراليا

الخلاصة

أجريت الدراسة الحالية للتحقيق في عملية إزالة الكبريت بالامتزاز من وقود محاكي ضمن محتوى الكبريت في نطاق مماثل لما يوجد في تيارات النفتا النموذجية. تم كبرته نموذج من ن–هكسان باستخدام ثنائي بنزوتيوفين (DBT)، وهو الشكل الأكثر تعقيدًا لمكونات الكبريت في الوقود. تم استخدام كوز الذرة، وهي مادة نفايات حيوية طبيعية، لإنجاز معالجة الكبريت بالامتزاز. تم استخدام المعالجة الحرارية في غياب الأكسجين لتوليف عينة كوز الذرة المتفحمة (CC). تم تحقيق مراحل معالجة أولية مختلفة تتضمن تنظيف كوز الذرة وتفتيته وتجفيفه قبل خطوة الكربنة للحصول على مسحوق ناعم من كوز الذرة. تمت عملية الكربنة عند ٥٠٠ درجة مئوية. أعطت فحوصات FTIR و SEMو XRDو AFMو BETتوصيفًا شاملاً لممتز CC. أظهرت النتائج أن عينة كوز الذرة لها أسطح متجانسة ومواضع نشطة متماثلة نسبيًا. تم استخدام مادة الامتزاز CC لامتزاز الكبريت في تكوين DBT الخاص به من الوقود (n–hexane). تم فحص بعض عوامل الامتزاز لدرجة الحرارة ووقت التلامس وجرعة المادة المازة لاختيار أكثر ظروف الامتزاز ملاءمة. بعد ذلك، تم استخدام الظروف المختارة لامتزاز تركيزات مختلفة من الكبريت. لنفس التركيز الأولي للكبريت ٤٠٠ جزء في المليون، بلغت الإزالة ٧٥٪ عند ٦٠ درجة مئوية و ٣٠ دقيقة و ٣ جرام /لتر على التوالي. تم زيادة كفاءة إزالة الكبريت بشكل كبير مع تقليل محتوى الكبريت الأولي. وبالتالي، فقد بلغت أكثر من ٧٩٪ عندما تم الحفاظ على التركيز الأصلي للكبريت في n–hexane في نطاق ١٠٠ جزء في المليون. تطابقت النتائج تمامًا مع نموذجLangmuir . عكست الديناميكا الحرارية لعملية الامتزاز بإزالة الكبريت أن عملية الامتزاز ترتبط بحدث ماص للحرارة، ويحدث في نطاق صغير من تغير المحتوى الحراري. كانت التغيرات المقدرة في المحتوى الحراري القياسي ٦,٣٤ كيلوجول/ مول. كان الامتزاز تلقائيًا على مدى نطاق درجة الحرارة المستخدمة من ٣٠ إلى ٦٠ درجة مئوية. تسلط نتائج هذا العمل الضوء على أن عينة كوز الذرة المتفحمة (CC) هي مادة قابلة للتحقيق لامتصاص الكبريت من المنتجات البترولية الخفيفة، ومن المحتمل أن يتم توجيهها إلى امتزاز صديق للبيئة وفعال من حيث التكلفة.

الكلمات الدالة: كوز الذرة، إزالة الكبريت بالامتزاز، إزالة الكبريت، ن–هكسان مُكبرت، منتجات المقطع الخفيف.