Journal of Technology & Innovation (JTIN)

DOI: http://doi.org/10.26480/jtin.02.2024.86.90

ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2773-6202 (Online)
CODEN: JTIOCC

RESEARCH ARTICLE

ADSORPTIVE BLEACHING POTENTIAL OF GLUCOSE-SOURCED ACTIVATED CARBON ON PALM AND OLIVE OILS

Christianah Chinenye Aniobi[a*], Oluseye Gbadebo Olasunkanmi[b], Olusola David Ogundele[c], Adebayo Abraham Adaramodu[a], and Sunday Ayodele Alonge[a]

[a]Department of Chemical Sciences, Bamidele Olumilua University of Education, Science and Technology, (BOUESTI), Ikere Ekiti, Nigeria
[b]Department of Chemistry, Federal University of Technology, Akure, Nigeria
[c]Department of Chemical Sciences, Achievers University Owo, Nigeria
**Corresponding Author Email: aniobichigiveth4@gmail.com*

ARTICLE DETAILS

Article History:

Received 12 August 2024
Revised 20 September 2024
Accepted 01 October 2024
Available online 17 November 2024

ABSTRACT

This study explores the adsorptive bleaching potential of glucose-sourced activated carbon on palm and olive oils, exploring its effectiveness in pigment removal across various adsorbent concentrations. Distinct adsorption trends were observed, with higher adsorbent concentrations achieving more efficient bleaching in both oils. For palm oil, a maximum pigment removal of 35.4% was achieved at 3.0 g of adsorbent, while lower concentrations showed reduced efficiency. Olive oil demonstrated a higher bleaching effect, with 64.9% pigment removal at 3.0 g, likely due to its lighter initial color. Adsorption efficiency trends fit well with the Langmuir isotherm model, indicating monolayer adsorption. Langmuir parameters further showed that glucose-sourced activated carbon exhibited a stronger affinity for pigments in palm oil than in olive oil, though effective in both cases. These results highlight glucose-sourced activated carbon as a promising, sustainable adsorbent for industrial oil refining. By utilizing renewable resources, this study aligns with the Sustainable Development Goals (SDGs) 7 (Affordable and Clean Energy) and 12 (Responsible Consumption and Production), emphasizing eco-friendly practices in food processing.

KEYWORDS

Bleaching, activated carbon, glucose, palm oil, goya olive oil

1. INTRODUCTION

Edible oils, such as palm oil and olive oil, play crucial roles in human nutrition and are widely used in cooking, food processing, cosmetics, and pharmaceuticals (Vaisali et al., 2015). Palm oil, a staple in Africa and Southeast Asia, is valued for its high yield and versatility, while olive oil, especially extra virgin olive oil, is prized in Mediterranean diets for its rich flavor and health importance, including its high antioxidants monounsaturated fats content (Boskou, 2006). However, both oils are often characterized by the presence of impurities such as pigments, which can affect their visual appeal, taste, and stability (Monte et al., 2015). These pigments, including carotenoids in palm oil and chlorophyll in olive oil, can degrade over time, leading to off-flavors and reduced shelf life (Guliyev et al., 2018). The refining process for edible oils typically involves several stages, with bleaching being one of the most critical steps. The primary goal of bleaching is to remove these color pigments and other impurities to improve the oil's appearance, flavor, and oxidative stability (Aishat et al., 2015). Conventional bleaching agents, such as bentonite clay and fuller's earth, have been widely used for decades; however, these materials come with several drawbacks. They can be costly, difficult to regenerate, and environmentally hazardous when disposed of (Abdullah et al., 2018). This has driven increasing interest in alternative adsorbents, particularly those that are more sustainable and environmentally friendly (Guliyev et al., 2018).

Activated carbon has emerged as an effective and sustainable alternative for the adsorptive bleaching of edible oils. It is a highly porous substance with a large surface area, making it a good adsorption agent of a wide range of impurities, including pigments, trace metals, and oxidation products (Gupta et al., 2015). Traditionally, activated carbon has been made from materials such as coal, palm kernel shells, wood, but there is growing interest in utilizing renewable and biodegradable sources, such as glucose, to produce activated carbon (Zhang et al., 2004). Glucose-sourced activated carbon can be prepared via pyrolysis, and it has shown promising results in terms of adsorptive capacity and cost-effectiveness (Ioannidou and Zabaniotou, 2007). In edible oil refining, the removal of carotenoids and chlorophyll is a key focus due to their impact on the sensory qualities of the oils. Carotenoids give palm oil its characteristic reddish color, while chlorophyll imparts a greenish hue to olive oil (Boskou, 2006). These pigments not only affect the appearance of the oils but also contribute to their oxidative instability, as they can promote the degradation of the oil under light and heat (Abdullah et al., 2018). Activated carbon, particularly glucose-sourced activated carbon, has been shown to effectively remove these pigments, improving both the oil's appearance and shelf life (Guliyev et al., 2018).

The production of glucose-sourced activated carbon is relatively simple and sustainable. Glucose, a naturally occurring sugar, is pyrolyzed to form activated carbon, which has a high surface area and well-developed pore assembly (Grassi et al., 2022). These properties make it highly efficient in adsorbing color impurities from edible oils (Zhang et al., 2004). Additionally, glucose-derived activated carbon is biodegradable and renewable, making it a more environmentally friendly option compared to traditional clay-based adsorbents, which are non-renewable and can be difficult to dispose of after use (Ioannidou and Zabaniotou, 2007). This aligns with responsible consumption and production (SDG 12) which promotes the adoption of sustainable practices in industrial processes (Schröder et al., 2019).

Quick Response Code	Access this article online	
	Website: www.jtin.com.my	**DOI:** 10.26480/jtin.02.2024.86.90

Cite The Article: Christianah Chinenye Aniobi, Oluseye Gbadebo Olasunkanmi, Olusola David Ogundele, Adebayo Abraham Adaramodu, and Sunday Ayodele Alonge (2024). Adsorptive Bleaching Potential Of Glucose-Sourced Activated Carbon On Palm And Olive Oils. *Journal of Technology & Innovation, 4(2): 86-90.*

Moreover, the application of glucose-derived activated carbon in the bleaching of edible oils reduces the environmental impact of oil refining. Traditional bleaching agents, such as clays, are non-renewable and pose challenges in terms of disposal and regeneration (Abdullah et al., 2018). In contrast, activated carbon can often be regenerated and reused, thus reducing waste and lowering the overall environmental footprint of the refining process (Aishat et al., 2015). This supports SDG 9 (Industry, Innovation, and Infrastructure), which encourages the development of sustainable industrial processes and innovations in materials science (Küfeoğlu, 2022). In recent studies, glucose-derived activated carbon has demonstrated superior performance in removing pigments and other impurities from edible oils compared to conventional bleaching agents (Guliyev et al., 2018). This is particularly important in the refining of palm and olive oils, where the removal of carotenoids and chlorophyll significantly enhances the oil's quality and shelf life (Monte et al., 2015). The adsorptive capacity of glucose-sourced activated carbon is largely attributed to its high porous structure and surface area, which allow it to efficiently trap and remove color impurities (Zhang et al., 2004).

This research aims to assess the adsorptive bleaching potential of glucose-sourced activated carbon in the refining of palm and olive oils (Abdullah et al., 2018). By exploring the feasibility of using glucose-derived activated carbon as an alternative adsorbent, this study seeks to contribute to the development of more sustainable and environmentally friendly refining practices (Ioannidou & Zabaniotou, 2007). The findings will have significant implications for the edible oil industry, where there is a growing demand for greener technologies that align with global sustainability goals (Schröder et al., 2019). This study aligns with Sustainable Development Goals (SDGs), including responsible consumption and production (SDG 12) by promoting the use of renewable, biodegradable materials in the refining process, and climate action (SDG 13) by reducing the environmental impact of oil refining (Sharma & Malaviya, 2023). Additionally, the use of glucose-derived activated carbon supports industry, innovation, and infrastructure (SDG 9), as it represents a sustainable innovation in the production of adsorbents for industrial applications (Vardanega et al., 2022).

2. Materials and Method

2.1 Activation/Carbonization Process

The raw material, glucose (537.87 g), was sourced from Ogbuete Market in Enugu State, Nigeria. It was initially processed to pass through a 3 mm mesh screen, with particles retained on a 1.5 mm sieve. A 200 g portion of glucose was then weighed, to which 100 ml of 35% phosphoric acid was added. The mixture was thoroughly mixed using a glass rod, then left for 24 hours to allow the activation process to continue effectively. Afterward, it was dried at a temperature range of 60–80 °C for 4 hours. The sample was then carbonized in a muffle furnace at approximately 500 °C for two hours. After cooling, it was rinsed with distilled water until the pH of the wash water was neutral or near-neutral. The sample was subsequently crushed, sieved, and dried at 105 °C for 4 hours to prepare it for adsorption testing, then stored in an airtight container for 24 hours (Ahmed, 2017).

2.2 Filtration Process

The glucose solution was serially diluted with double-distilled water, then filtered through filter paper approximately six times to reach the desired pH. Filtration continued until a neutral to mildly acidic pH range (5–6) was attained, verified using a pH meter. The processed activated carbon was then collected and oven-dried at 105 °C for 4 hours to eliminate any remaining moisture (Mulder, 2012).

2.3 Adsorption Process

The adsorption capacity of glucose-derived activated carbon was assessed using a dosage variation method. To examine the effect of dosage on absorbance, six distinct masses of activated carbon (0.5 g, 1.0 g, 1.5 g, 2.0 g, 2.5 g, and 3.0 g) were each added to separate 10 ml samples of effluent solution (Liu et al., 2020).

2.4 Degumming Process

Two oil samples were degummed in a 500 ml volumetric flask using hot water at 100 °C. The process involved using a separating funnel and was repeated until clear water separated from the oil layer, indicating the effective removal of gums (da Silva Araújo et al., 2014).

2.5 Neutralization Process

Approximately 60% degummed palm and Goya olive oils each underwent a 10-minute neutralization process at 800 °C. Following this, 10 ml of 0.1 M NaOH and 6 g of NaCl were added to the oils. Upon the addition of NaOH, the oil began to catalyze, leading to the formation of soap (triglyceride). To remove the soap, hot water was added, and the washing process was repeated until the soap was fully eliminated from the oils (Susik & Ptasznik, 2023).

2.6 Bleaching Process

Activated carbon was employed to decolorize the neutralized oils. A dosage-dependent study was conducted by adding measured amounts (0.5-3.0 g) of activate carbon to 10 ml aliquots of oil. The mixtures were stirred thoroughly then heated at boiling point for 30 minutes. Post heating, the oils were filtered through cotton wool into conical flasks (Laska-Zieja et al., 2020).

2.7 Spectrophotometry Analysis

The absorbance and concentration of the oil samples were measured using a UV spectrophotometer. Prior to analysis, the instrument was warmed up for 30 minutes. Oil samples and a buffer solution were prepared in separate 5 cm cuvettes. The buffer solution was used to set the baseline at 10%, after which the cuvettes containing the oil samples were inserted. To prevent light interference, the cuvettes were covered with waterproof material, which was removed once the baseline was adjusted to 0%. The spectrophotometer's handle was then lifted to display absorbance, and the mode was switched to concentration display. The UV spectrophotometer subsequently recorded the absorbance and concentration of the two oil samples.

2.8 Adsorption Isotherm and Langmuir Equation

Adsorption is the process in which molecules adhere to a surface, while adsorption capacity refers to the amount of adsorbate that an adsorbent can hold. An adsorption isotherm is a graph that represents adsorption equilibrium at a constant temperature. The Langmuir isotherm is a model that describes monolayer adsorption on uniform surfaces. The Langmuir isotherm equation is expressed as ${C_e}/{q_c} = 1.\frac{C_e}{Q^o} + \frac{1}{bQ^o}$, where C_e is the equilibrium concentration (mg/L), (Mg/l), q_c is the percent adsorption, $\frac{1}{bQ^o}$ represents the slope, Q^o is the adsorption capacity, and b is the Langmuir constant.

2.9 Percentage Adsorption of Palm and Goya Olive Oils Using Activated Glucose

Using the formula $qc = 100\ (\frac{C_o - C_e}{C_e})$, where C_o and C_e are adsorption before and after adsorption, the percentage adsorption of the oil by activated glucose was calculated.

3. Results and Discussion

Table 3.1 demonstrations the adsorptive bleaching performance of glucose-sourced activated carbon on palm and olive oils at different concentrations of the adsorbent. The results show distinct trends for both oils, demonstrating the adsorbent's capacity to remove pigments effectively, particularly in olive oil. For palm oil, the absorbance decreases as the weight of the adsorbent increases, indicating improved pigment removal with higher concentrations of glucose-sourced activated carbon. At 3.0 g of adsorbent, the absorbance was 2.81, corresponding to a concentration of 28.10 Mg/l and a percentage adsorption of 35.4%. This shows that a higher concentration of adsorbent leads to more efficient bleaching by removing more pigments from the oil (Adinaveen et al., 2016). As the adsorbent concentration decreases, such as at 0.5 g, the absorbance value rises to 3.96, with a significantly lower percentage adsorption of 9.2%. This reduction in bleaching efficiency indicates that lower adsorbent concentrations are less effective at adsorbing pigments (Syahruddin et al., 2022). In contrast, the adsorptive performance of glucose-sourced activated carbon on olive oil shows a stronger bleaching effect than palm oil. At 3.0 g of adsorbent, the absorbance dropped to 0.25, with a concentration of 25.40 Mg/l and percentage adsorption of 64.9%. The significant pigment removal in olive oil compared to palm oil can be attributed to the lighter initial color of olive oil, which allows for greater adsorption efficiency of the activated carbon (Afshar et al., 2014). Even at the lowest adsorbent concentration of 0.5 g, the absorbance for olive oil was 0.60, with a percentage adsorption of 17.1%, still outperforming palm oil. This suggests that glucose-sourced activated carbon is more effective in adsorbing chlorophyll pigments in olive oil than carotenoids in palm oil (Jalani et al., 2016). The trend observed for both oils shows that increasing the concentration of glucose-sourced activated carbon improves pigment removal, as higher concentrations provide more surface area for adsorption (Alharbi et al., 2022). The results obtained suggests that glucose-sourced activated carbon is an effective bleaching agent, particularly for olive oil, which benefits from the adsorbent's superior affinity for removing pigments. This aligns with studies showing that activated carbon derived from renewable sources has promising adsorptive properties and environmental benefits (Andrade Siqueira et al., 2020). Moreover, the ability to produce activated carbon from glucose, a renewable resource, contributes to the sustainability of the oil refining process (Mussatto et al., 2010).

Table 3.2 present the weight of concentration to percentage adsorption ratio ($^{C_e}/_{q_c}$) which demonstrates the adsorptive bleaching potential of glucose-sourced activated carbon on palm and olive oils. For palm oil, the $^{C_e}/_{q_c}$ values range from 0.050 to 0.089, indicating variable adsorption efficiency. The highest adsorption efficiency was observed at 0.089, suggesting that at this concentration, more pigments were removed, contributing to the effective bleaching of the oil. Lower values, such as 0.050, suggest reduced pigment removal, which may be due to a lower affinity between the adsorbent and specific color-causing compounds in palm oil (Marrakchi et al., 2017). In contrast, the adsorption efficiency for Goya olive oil, represented by $^{C_e}/_{q_c}$ values ranging from 0.030 to 0.046, shows better adsorption performance at lower concentrations. The highest efficiency is observed at 0.046, indicating significant pigment removal at this concentration, which aligns with previous research suggesting that olive oil, having a lighter color than palm oil, allows for more efficient pigment adsorption. The lower values, such as 0.030, suggest a reduction in adsorption efficiency as the concentration decreases, likely due to a decrease in active surface sites of the adsorbent (Mussatto et al., 2010).

Table 3.3 shows the slope, intercept, and Langmuir constant (b) for palm oil and goya olive oil adsorbed by activated glucose. The Langmuir isotherm model is widely used to describe the adsorption process, particularly when dealing with monolayer adsorption on a surface with a finite number of identical sites. In this study, the slope ($\frac{1}{Q^o}$), intercept ($\frac{1}{bQ^o}$), and Langmuir constant (b) values for glucose-sourced activated carbon's adsorptive bleaching potential on palm oil and Goya olive oil are provided. These parameters offer insights into the adsorption capacity and affinity of the adsorbent. For palm oil, the slope ($\frac{1}{Q^o}$) is 0.01, which indicates the inverse of the maximum adsorption capacity, suggesting a relatively higher adsorption capacity compared to olive oil. The intercept ($\frac{1}{bQ^o}$) is 0.048, providing an inverse relationship with the Langmuir constant and adsorption capacity. A higher intercept value is associated with a higher adsorption capacity, meaning that glucose-sourced activated carbon has a significant potential for adsorbing pigments from palm oil (Mussatto et al., 2010). The Langmuir constant (b) of 4.8 for palm oil suggests that the adsorbent has a strong affinity for the pigments present in palm oil. This strong interaction enhances the removal of color-causing compounds, supporting the notion that glucose-sourced activated carbon is effective for bleaching palm oil (Marrakchi et al., 2017).

For Goya olive oil, the slope ($\frac{1}{Q^o}$) is higher at 0.02, indicating a lower maximum adsorption capacity compared to palm oil. This suggests that olive oil requires a lower concentration of activated carbon for effective bleaching. The intercept ($\frac{1}{bQ^o}$) for olive oil is 0.04, slightly lower than palm oil, which correlates with its lower adsorption capacity. Despite the lower intercept, the adsorption of pigments in olive oil is still effective due to the naturally lighter color of olive oil, making it easier to bleach compared to palm oil. The Langmuir constant (b) of 2.0 for olive oil indicates a weaker interaction between the adsorbent and pigments compared to palm oil. However, this still suggests that glucose-sourced activated carbon is an effective adsorbent for removing pigments from olive oil (Mussatto et al., 2010).

The Langmuir adsorption model, defined by the equation $^{C_e}/_{q_c} = 1.\frac{C_e}{Q^o} + \frac{1}{bQ^o}$, provides a theoretical basis to understand the adsorptive bleaching potential of glucose-sourced activated carbon on both palm and olive oils. Figure 3.1 shows adsorbent concentration plotted against percentage adsorption, the data obtained for palm oil shows correlation between the concentration of glucose-sourced activated carbon and the percentage adsorption, with the values gradually increasing with higher adsorbent weight. This suggests that more active sites on the activated carbon become available for pigment removal as the adsorbent concentration increases, promoting a higher adsorption capacity in line with Langmuir theory. The linear nature of the graph indicates that palm oil pigments adhere to the monolayer adsorption mechanism, as predicted by Langmuir (Jalani et al., 2016).

The adsorption values of Goya olive oil also increase with the adsorbent concentration, although the increase is slightly less pronounced than for palm oil. This may be due to the lighter color and different composition of olive oil, which requires fewer adsorption sites for effective bleaching. Additionally, the lower Langmuir constant (b) value for olive oil relative to palm oil suggests a lower affinity of the activated glucose for olive oil pigments. Nonetheless, the trend for olive oil also aligns well with the Langmuir model, confirming that monolayer adsorption is effective for both oils under study (Afshar et al., 2014).

The adsorption capacity (Q°) and affinity (b) derived from the Langmuir plot further validate that glucose-sourced activated carbon is effective for adsorptive bleaching of both palm and olive oils. The findings highlight the material's potential for sustainable applications in the food industry, supporting Sustainable Development Goals (SDGs) related to responsible consumption and production by offering a more eco-friendly bleaching method (Schröder et al., 2019).

Table 3.1: Adsorptive Bleaching Performance of Glucose-sourced Activated Carbon on Palm and Olive Oils at Different Adsorbent Concentrations

Adsorbent Concentration (g)	Palm oil			Goya olive oil		
	Absorbance	Conc. (Mg/l)	% Adsorption	Absorbance	Conc. (Mg/l)	% Adsorption
3.0	2.81	28.10	35.40	0.25	25.40	64.90
2.5	3.10	30.90	28.90	0.21	20.60	71.50
2.0	3.12	30.20	28.30	0.27	26.60	63.30
1.5	3.41	34.10	21.70	0.41	40.90	43.60
1.0	3.49	34.80	19.90	0.54	54.20	25.20
0.5	3.96	39.50	09.20	0.60	60.10	17.10

Table 3.2: Absorbent Concentration/ % Adsorption ($^{C_e}/_{q_c}$)

Activated Glucose	
Palm oil	Goya olive oil
0.085	0.046
0.089	0.035
0.071	0.032
0.069	0.034
0.050	0.040
0.054	0.030

Table 3.3: Slope, Intercept, and Langmuir Constant (b) for Palm Oil and Goya Olive Oil Adsorbed by Activated Glucose

Oil Sample	Slope ($\frac{1}{Q^o}$)	Intercept ($\frac{1}{bQ^o}$)	Langmuir constant (b)
Palm oil	0.01	0.048	4.8
Goya olive oil	0.02	0.04	2.0

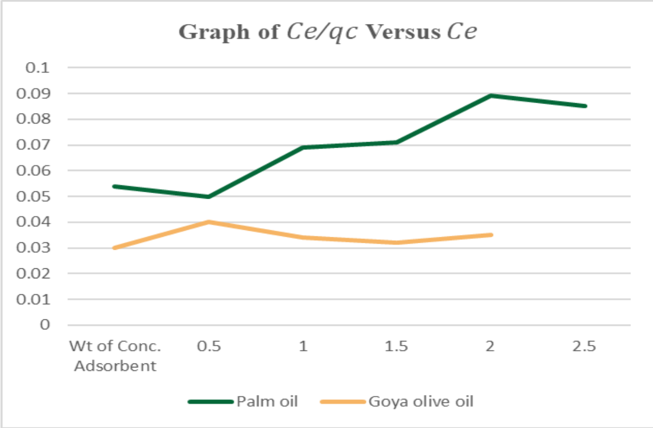

Figure 3.1: Adsorbent Concentration/% Adsorption Versus Concentration for Palm Oil and Goya Olive Oil Adsorbed by Activated Glucose using Langmuir Equation: $C_e/q_c = 1.\frac{C_e}{Q^o} + \frac{1}{bQ^o}$

4. Conclusion

This study confirms that glucose-sourced activated carbon effectively bleaches both palm and olive oils, with efficiency improving as adsorbent concentration increases. The adsorption trends aligned well with the Langmuir model, indicating monolayer adsorption. Palm oil required a higher adsorbent concentration for notable pigment reduction, as shown by its higher Langmuir constant, suggesting a strong affinity between the adsorbent and pigments. Olive oil, being lighter in color, achieved efficient bleaching at lower adsorbent concentrations, which demonstrates the suitability of glucose-sourced activated carbon across various oil types. Beyond its technical effectiveness, this method promotes sustainability by using glucose, a renewable resource for activated carbon production, supporting Sustainable Development Goals (SDGs) related to responsible consumption and production (SDG 12) and affordable, clean energy (SDG 7). By providing an eco-friendly alternative for oil refining, this approach aligns with global goals to minimize environmental impact in industrial processes while ensuring safe and effective food processing practices.

Acknowledgement

The authors gratefully acknowledge Bamidele Olumilua University of Education, Science and Technology (BOUESTI), Ikere Ekiti, Ekiti State, Nigeria, for providing a supportive environment that facilitated this research.

References

Abdullah, N., Tajuddin, M. H., & Yusof, N. (2018). Carbon-based polymer nanocomposites for dye and pigment removal. In *Carbon-based polymer nanocomposites for environmental and energy applications* (pp. 305-329). Elsevier.

Adinaveen, T., Vijaya, J. J., & Kennedy, L. J. (2016). Comparative study of electrical conductivity on activated carbons prepared from various cellulose materials. *Arabian Journal for Science and Engineering*, *41*, 55-65.

Afshar, P. G., Honarvar, M., Gharachorloo, M., Eshratabadi, P., & Bazyar, B. (2014). Bleaching of vegetable oils using press mud obtained from sugar industry. *Eur. J. Exp. Biol*, *4*(1), 677-684.

Ahmed, M. J. (2017). Adsorption of non-steroidal anti-inflammatory drugs from aqueous solution using activated carbons. *Journal of environmental management*, *190*, 274-282.

Aishat, A., Olalekan, S., Arinkoola, A., & Omolola, J. (2015). Effect of activation on clays and carbonaceous materials in vegetable oil bleaching: state of art review. *British Journal of Applied Science & Technology*, *5*(2), 130-141.

Alharbi, H. A., Hameed, B. H., Alotaibi, K. D., Al-Oud, S. S., & Al-Modaihsh, A. S. (2022). Recent methods in the production of activated carbon from date palm residues for the adsorption of textile dyes: A.

Andrade Siqueira, T. C., Zanette da Silva, I., Rubio, A. J., Bergamasco, R., Gasparotto, F., Aparecida de Souza Paccola, E., & Ueda Yamaguchi, N. (2020). Sugarcane bagasse as an efficient biosorbent for methylene blue removal: kinetics, isotherms and thermodynamics. *International Journal of Environmental Research and Public Health*, *17*(2), 526.

Boskou, D. (2006). *Olive oil: chemistry and technology*. AOCS Publishing.

da Silva Araújo, F. D., Araújo, I. C., Costa, I. C. G., de Moura, C. V. R., Chaves, M. H., & Araújo, E. C. E. (2014). Study of degumming process and evaluation of oxidative stability of methyl and ethyl biodiesel of Jatropha curcas L. oil from three different Brazilian states. *Renewable Energy*, *71*, 495-501.

Grassi, P., Lunardi, P., Foletto, E. L., Dotto, G. L., Lima, E. C., & Jahn, S. L. (2022). Production of sugar-derived carbons by different routes and their applications for dye removal in water. *Chemical Engineering Research and Design*, *182*, 237-245.

Guliyev, N., Ibrahimov, H., Alekperov, J., Amirov, F., & Ibrahimova, Z. (2018). Investigation of activated carbon obtained from the liquid products of pyrolysis in sunflower oil bleaching process. *International Journal of Industrial Chemistry*, *9*(3), 277-284.

Gupta, V. K., Nayak, A., Bhushan, B., & Agarwal, S. (2015). A critical analysis on the efficiency of activated carbons from low-cost precursors for heavy metals remediation. *Critical Reviews in Environmental Science and Technology*, *45*(6), 613-668.

Ioannidou, O., & Zabaniotou, A. (2007). Agricultural residues as precursors for activated carbon production—A review. *Renewable and sustainable energy reviews*, *11*(9), 1966-2005.

Jalani, N. F., Aziz, A. A., Wahab, N. A., Hassan, W. H. W., & Zainal, N. H. (2016). Application of palm kernel shell activated carbon for the removal of pollutant and color in palm oil mill effluent treatment. *Journal of Earth, Environment and Health Sciences*, *2*(1), 15-20.

Küfeoğlu, S. (2022). SDG-9: industry, innovation and infrastructure. In *Emerging Technologies: Value Creation for Sustainable Development* (pp. 349-369). Springer.

Laska-Zieja, B., Marcinkowski, D., Golimowski, W., Niedbala, G. & Wojciechowska, E. (2020). Low-cost investment with high quality performance. Bleaching earths for phosphorous reduction in the low-temperature bleaching process of rapeseed oil. Foods, 9(5), 603.

Liu, X., Xu, X., Dong, X., & Park, J. (2020). Competitive adsorption of heavy metal ions from aqueous solutions onto activated carbon and agricultural waste materials. *Pol. J. Environ. Stud*, *29*(1), 749-761.

Marrakchi, F., Bouaziz, M., & Hameed, B. (2017). Activated carbon–clay composite as an effective adsorbent from the spent bleaching sorbent of olive pomace oil: Process optimization and adsorption of acid blue 29 and methylene blue. *Chemical Engineering Research and Design*, *128*, 221-230.

Monte, M. L., Monte, M. L., Pohndorf, R. S., Crexi, V. T., & Pinto, L. A. (2015). Bleaching with blends of bleaching earth and activated carbon reduces color and oxidation products of carp oil. *European journal of lipid science and technology*, *117*(6), 829-836.

Mulder, M. (2012). *Basic principles of membrane technology*. Springer science & business media.

Mussatto, S. I., Fernandes, M., Rocha, G. J., Órfão, J. J., Teixeira, J. A., & Roberto, I. C. (2010). Production, characterization and application of activated carbon from brewer's spent grain lignin. *Bioresource Technology*, *101*(7), 2450-2457.

Schröder, P., Antonarakis, A. S., Brauer, J., Conteh, A., Kohsaka, R., Uchiyama, Y., & Pacheco, P. (2019). SDG 12: responsible consumption and production–Potential Benefits and impacts on forests and livelihoods. *Sustainable development goals: their impacts on forests and people*, 386-418.

Sharma, R., & Malaviya, P. (2023). Ecosystem services and climate action from a circular bioeconomy perspective. *Renewable and sustainable energy reviews*, *175*, 113164.

Susik, J. & Pta sznik, S. (2023). The first stage of refining of post-fermentation corn oil with a high content of free fatty acids and phytosteroids-Comparison of neutralization by an ion-exchange resin without solvent and base neutralization Food Research International, 164, 112302.

Syahruddin, S., Yuliati, L., Widhiyanuriyawan, D., & Wardana, I. (2022). The role of activated carbon nanoparticles on hydro-degumming non-edible vegetable oils. *Alexandria Engineering Journal*, *61*(6), 4729-4739.

Vaisali, C., Charanyaa, S., Belur, P. D., & Regupathi, I. (2015). Refining of edible oils: a critical appraisal of current and potential technologies. *International Journal of Food Science & Technology*, *50*(1), 13-23.

Vardanega, R., Osorio-Tobón, J. F., & Duba, K. (2022). Contributions of supercritical fluid extraction to sustainable development goal 9 in South America: industry, innovation, and infrastructure. *The Journal of Supercritical Fluids*, *188*, 105681.

Zhang, T., Walawender, W. P., Fan, L., Fan, M., Daugaard, D., & Brown, R. (2004). Preparation of activated carbon from forest and agricultural residues through CO2 activation. *Chemical Engineering Journal*, *105*(1-2), 53-59.