Petroleum and Coal

Article **Open Access**

Application of Renewable Biosorbent Material in Water Treatment from Oil Pollution

Mohamed A. Ayad[1,], Mostafa E. Aboul-Fetouh[1], Soad Z. Mohamed[2], Renee I. Abdallah[2], Tarek M. Aboul-Fotouh[1]*

[1] *Mining and Petroleum Engineering Department, Faculty of Engineering, Al-Azhar University, Nasr City, Cairo, Egypt*
[2] *Egyptian Petroleum Research Institute (EPRI), Nasr City, Cairo, Egypt*

Received July 24, 2023; Accepted October 17, 2023

Abstract

Biosorbent chicken feathers can effectively sorb oil from seawater, making them a promising alternative to synthetic sorbents, so it is imperative that plentiful, problematic, and disruptive waste feathers are decontaminated. This study aims to evaluate and optimize the chemical treatment of waste chicken feathers (white chicken feathers (WCF) and baladi chicken feathers (BCF)) and explore their potential as a renewable biomaterial for the pollution of seawater from oil spills. Scanning electron microscopy, infrared spectroscopy, and X-ray diffraction are used for feather characterization; hydrogen peroxide (H_2O_2) and sodium dodecyl sulfate (SDS) are used for chemical modification due to lipids or grease covering the feather's surface having a negative effect on the oil sorption process. Chemical agents are used to remove them. At maximum lipid removal efficiency, the optimum type and concentration of chemical modifications for lipid removal from feathers are Sodium Dodecyl sulfate (SDS), with a concentration of 1.5 g/l, which has the highest lipid removal percentage at 58%, while hydrogen peroxide (H_2O_2) is 47%. SEM-EDX analysis indicates that BCF was more efficient than WCF. In addition, FTIR spectra confirm that lipids and proteins are presented and observed to have absorption properties. XRD diffraction shows the crystallinity index of a BCF was 30% and that of a WCF was 50%, and a BCF has a higher amorphous content. 1 g of WCF has an oil sorption efficiency of 93.3% at 10 min. contact time and 88.3% during an experiment beginning, while 1 g of BCF has a sorption efficiency of 97% at 10 min. contact time and 93% during an experiment beginning. At 50 ml of oil feed used, the maximum sorption efficiency was 67.7% (33.9 ml) and 75.4% (37.7 ml) of WCF and BCF, respectively. The oil sorption capacity values increased with the oil quantity used but decreased the sorption efficiency. Finally, these two feather types, WCF and BCF, achieved promising initial results compared to other sorbents, and their application in the petroleum industry will achieve a huge breakthrough in the field of the environment to reduce water pollution and save huge amounts of money due to the cheapness of feather material.

Keywords: *Sorption; Oil pollution; Chicken feathers; Chemical modification; SEM-EDX; Sodium dodecyl sulfate.*

1. Introduction

Nature offers an almost limitless supply of high-performance materials, but these materials need to be rigorously studied to be used as the basis of innovative technology and practical raw materials [1-2].

Feathers from chickens are an example of this. One of the most sophisticated keratin structures to be seen in vertebrates, feathers are highly organized, hierarchically branching structures. Keratin is regarded as these materials' main structural component. In addition to providing the capacity to fly, feathers are crucial for controlling body temperature and providing physical and chemical protection [3-4]. Feathers are distinctive integumentary appendages that perform a range of diverse roles and are one of the characteristics that distinguish contemporary birds from other species [5-6].

In poultry processing plants, contaminants such as oil, dirt, burrs (dried vegetables), woody pieces, and mineral elements contaminate chicken feathers [7-9]. The feathers commonly lie as dirty that include numerous foreign substances, such as offal, diluted blood, grease, skin, many biological organisms, fatty and waxy materials. Freshly gathered feathers may include a range of microorganisms since chickens are warm-blooded [10].

Approximately 91% of chicken feathers contain protein (keratin), 1% are lipids, and 8% are water [11-12]. The average amount of lipid per gramme of chicken feathers was 9.0 ± 3.0 mg. The estimated total fat content of chicken feathers is 1.53% [13]. A chicken feather's amino acid sequence is highly similar to that of other feathers and has a lot in common with reptile keratins from claws. Table 1 shows that the sequence mostly comprises cystine, glutamine, proline, and serine. Serine (16%) is the most prevalent amino acid, and the OH group in each serine residue aids in the absorption of moisture from the air by chicken feathers [10].

Table 1. The amino acid composition of chicken feather keratin fiber.

Functional groups	Amino acid	Content, %wt.
Positively charged	Arginine	4.30
Negatively charged	Aspartic acid	6.00
	Glutamine	7.62
Hydrophobic	Tyrosine	1.00
	Leucine	2.62
	Isoleucine	3.32
	Valine	1.61
	Cystine	8.85
	Alanine	3.44
	Phenylalanine	0.86
	Methionine	1.02
Hygroscopic	Threonine	4.00
	Serine	16.0
Special	Proline	12.0

Chicken feathers should be cleaned and chemically treated to remove impurities, eliminate microbes, and enable beneficiation of the feathers. A variety of processes are available to improve the physical, chemical, and mechanical properties of chicken feathers. Cleaning (decontamination) of the chicken feathers using detergents removes the accumulation of surface contaminants that have resulted from nature, slaughtering, transportation, and storage. Chemical treatment of feathers involves the use of chemicals in cleaning activities, primarily to remove grease and fat (lipids). Decontamination and chemical treatment can be achieved by dissolution in solvents, mechanical detachments, evaporation, or chemical degradation [14-15].

The Soxhlet extraction technique is employed for the extraction and separation of chemical constituents in the material, such as medicinal plants, feathers, etc. Furthermore, the Soxhlet extraction method requires simple and inexpensive equipment that is easy to operate [16]. The most common solvent used to extract oils from plant sources is n-hexane, which has a boiling point range of about 63–69°C and is an excellent oil solvent for oil solubility and simplicity of recovery [17]. Water quality is enhanced, more oil is recovered, aquatic biota is protected, and the ecosystem is protected as a result of treating oil spills in impacted waters [10]. Crude oil, diesel, and kerosene spills are harmful to the environment [18]. Due to the presence of amino acids, the fiber of chicken feathers is both extremely hydrophobic and somewhat hygroscopic [1]. When utilizing 150 mL of technical oil, chicken feathers have a very high capacity for the adsorption of liquid oils at a rapid uptake time of 10 minutes up to 16.21 g of oil per gram of chicken feather [2].

2. Materials and methods

Therefore, this research was done to develop and characterize two unstudied feather types, white (WCF) and baladi chicken feathers (BCF), optimize and determine the efficiency of the removal of lipids by SDS and H_2O_2 that can be used as cleaning agents, as well as use these feathers in the petroleum industry as sorbent materials, and infer the significance of WCF and BCF in sorption processes and their potential applications for addressing environmental pollution and improving sorption capacity as compared to literature.

Baladi and white chicken feathers were obtained from a chicken slaughterhouse, where they were heaped as solid waste material. Chemicals (hydrogen peroxide H_2O_2 and sodium dodecyl sulfate) were used.

2.1. Feather waste preparation

Chicken feathers (CF) were used as feather waste, and they were obtained from a local slaughterhouse poultry processing plant located in Cairo, Egypt. As feathers are a type of sample that is not homogeneous and is exposed to various environmental factors, micro- and macro-pollution, and dust, they need to be properly prepared prior to analysis. Firstly, feathers are typically immersed in a detergent solution, then washed and rinsed thoroughly with tap water to remove the detergent, then soaked in distilled water after that and dried at room temperature for storing. The samples were dried in an oven dryer at 105°C for 24 hours before being cut into small filaments 3 cm long with scissors. This material was treated in a Soxhlet apparatus for the optimal time with hexane to remove fatty material, followed by evaporation of the residual solvent. The dry feathers were stored at room temperature in closed containers and used for experiments [19-21].

2.2. Chemically modified treatment

Chemical treatment can occur due to the chemical nature of the surface that is contaminated by a chemical agent exposed to the contaminant on the surface [14-15]. Common chemical cleaning agents that are used include hydrogen peroxide (H_2O_2) and sodium dodecyl sulfate (SDS) [10]. An anionic or non-ionic surfactant was used to clean the feathers without affecting their texture. A combination of bleaching and extraction will form high-quality keratin from waste feathers [22].

SDS is mostly used in laundry detergents with a variety of cleaning uses [23]. Because of its capacity to form foam, cut through grease, and suspend dirt particles in such a way that they can be readily washed away, SDS is a very efficient surfactant used in any operation involving the removal of greasy stains and residues [24-25].

2.3. Moisture content

The moisture evolution temperature of chicken feather fibers and quill fractions occurs in the range of 100–110°C. Each oven-dried sample was dried at 110°C+5°C until its change in weight was weighed to the nearest 0.1 mg as compared to the original weight of the sample that was stored at room temperature (23°C) [13].

To achieve a constant mass, the Baladi and White feather samples were dried at 105°C. The moisture content was calculated by using equation (1). Which was expressed on a dry basis. Analyses were run in triplicate [26].

$$moisture\ content = \frac{W1-W2}{W1}\ ;\ \%wt. \qquad (1)$$

where: W_1= original mass in grams of sample; W_2= Oven dry mass in grams of sample.

2.4. Soxhlet extraction

The samples of dried materials were removed from the refrigerator and kept at room temperature (28°C) for 30 minutes to gently release the water vapor from the samples. The Soxhlet extraction processes using n-hexane (99% assay) as the extraction solvent were carried out to investigate the percentage and the quality of the extraction. A round bottom extraction flask and sample were weighted, then the solvent was poured into the flask, which was placed on the heating mantle, and a thimble filter containing the sample was placed in the extractor [27].

Due to the low selectivity of ethanol for oil extraction, the optimization of the extraction time was only carried out for n-hexane extraction. Following that, lipid monomers were extracted in hexane, and the total volume was decreased to a final hexane volume of 200 µl [28].

After the extraction process, the round bottom extraction flask containing solvent was placed on a rotary evaporator to release the solvent, and the extraction flask containing lipid was weighed. The percentage of lipid extraction was calculated by using equation (2) [28].

$$lipid\ extraction = \frac{W2-W1}{G};\ \%\,wt. \quad (2)$$

where: W_1 = mass in grams of round bottom extraction flask; W_2 = mass in grams of extraction flask containing lipid; G= mass in grams of sample.

2.5. Characterization of feathers

SEM analysis using a scanning electron microscope was used to examine the morphology of all types of feathers. For one test, dried chicken feathers were ground into powder using a mechanical blender ball mill machine.

2.5.1. Scanning electron microscope (SEM)

SEM analysis was used to determine the porosity and surface texture of the sorbent and characterize its surface morphology. Chicken feathers have hollow structures of knots and hooks [29-30].

The effects of decontamination and chemical treatments on the morphology and elemental composition of feathers were studied. Also, bactericidal effectiveness was further analyzed using scanning electron microscope (SEM) analysis as well as elemental profile analysis using energy dispersive spectroscopy (EDX) [10].

The presence of elements such as Na, Mg, Si, Fe, and Cu can enhance adsorption through the following mechanisms: biosorption, ion exchange, chelation, co-ordination, and complexation reactions [31-33].

2.5.2. Fourier transform infrared spectroscopy (FTIR)

The functional groups in chicken feathers were detected using a Fourier transform infrared (FTIR) spectrophotometer. An attenuated total reflectance (ATR) attached FTIR spectrometer was used in the wavenumber range of 400–4000 cm^{-1} and at 30 scans [34]. The FTIR spectrum was taken in transmittance mode. The scanning range can be set from 4,000 to 650 cm^{-1}, with a precision of 0.8 cm^{-1} [35]. FTIR confirmed the presence of an amino and a carboxyl group in the sample; the two groups confirm the presence of amino acids. As a result, the final product confirmed the presence of true keratin proteins with no foreign materials [36].

Infrared spectroscopy FTIR investigation was used as an effective chemical bond identification tool to assess the structural changes in proteins. FTIR spectra of chicken feather parts show characteristic absorption bands assigned mainly to the peptide bonds (CONH) [37].

2.5.3. X-ray diffraction (XRD)

Phillips analytical diffractometer was used to obtain the x-ray diffraction patterns of the chicken feathers. The scanning region of the diffraction angle (2ϴ) was from 4° to 90° [38].

Crystallinity refers to the degree of structural order in a solid. In a crystal, the atoms or molecules are arranged in a regular, periodic manner [39]. Crystallinity makes a material strong, but it also makes it brittle. A completely crystalline polymer would be too brittle to be used as plastic. The amorphous regions give the polymer toughness, that is, the ability to bend without breaking [40].

The crystallinity index (Ic) was determined using equation (3) [41].

$$Crystallinity\ index, \% = \frac{I_{9^o}-I_{14^o}}{I_{9^o}} * 100 \quad (3)$$

where: I_{9^o}= maximum diffraction intensity with 2θ at 9°; I_{14^o} = minimum diffraction intensity with 2θ at 14°.

3. Results and discussion

3.1. Moisture content

The moisture content was measured on BFC after storage at room temperature (23°C). Moisture content for BF was around 6%–8%; however, for white feathers, it was around 7%–10%.

The moisture content of the white was at 8.7%, which is higher than for the BF at 7.6%. The moisture content values for both feather types are very low, indicating that the sample was homogeneous. The ability of chicken feathers and fractions to absorb moisture from the environment has important implications.

However, the average moisture content of the chicken feathers did not exceed 10%; this implies that the material could be safely stored for long periods of time with no concerns of deterioration. Moisture contents of 6%–10% indicate that chicken feathers are hygroscopic. The hygroscopicity of BFC increases.

3.2. Determination of lipid content for a complete feather sample

1 g of Baladi or White chicken feathers were used for each trial of extraction lipid percent determination, so Figure 1 shows the lipid content of BF ranged from 0.82–1.12%, while in White feathers it ranged from 1.13–1.24%. This implies that the percentage of lipids in white is greater than in BF. The average lipid content of NF is 1.005% and 1.19% for BFC.

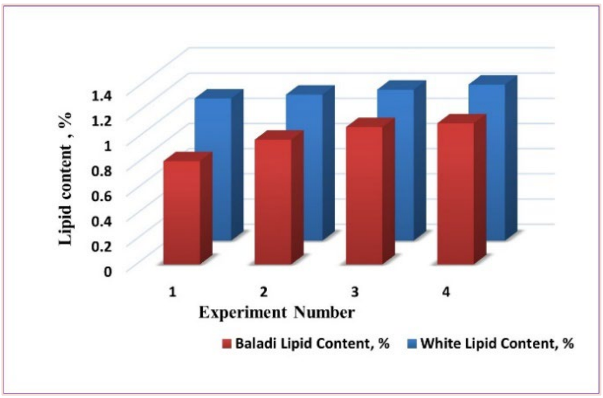

Figure 1. Lipid Content for a complete feather sample.

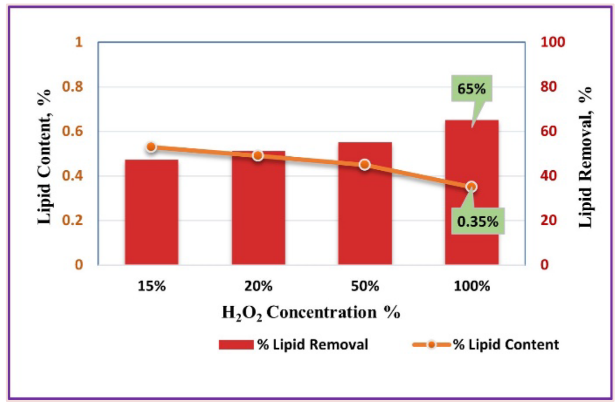

Figure 2. Lipid content and removal percentages of a chemically modified BF with H_2O_2.

3.2.1. Determination of lipid content for a chemically modified feather with hydrogen peroxide (H_2O_2)

The optimal concentration of hydrogen peroxide for chemical modification of feathers was discovered. The optimum point is at the lowest residue of lipid content after treatment and, accordingly, at the highest value of the lipid removal percentage. As a result, the reference percentage of lipids in BWF is 1.005% and 1.19%, respectively.

Figure 2 illustrates the lipid content and removal percentages of a chemically modified Baladi feather treated with hydrogen peroxide (H_2O_2) at different concentrations. It was found that the percentage of lipid content decreases and the percentage removed increases with H_2O_2 concentration, with the lowest value of the lipid content at 100% H_2O_2 concentration being 0.35%. Therefore, it has the highest lipid removal percentage at 65%.

Similarly, in WF after treatment, the lipid removal percentage is shown in Figure 3, with the lowest value of the lipid content at 100% H_2O_2 concentration being 0.63%. Therefore, it has the highest lipid removal percentage at 47%.

3.2.2. Determination of lipid content for a chemically modified feather with sodium dodecyl sulfate (SDS)

The optimum concentration of sodium dodecyl sulfate (SDS) for chemical modification of feathers was obtained at the lowest residue of lipid content and at the highest value of the lipid removal percentage after the treatment process.

Figure 4 shows the lipid content and removal percentages of a chemically modified Baladi feather treated with SDS at different concentrations. The percentage of lipid content decreased, and the percentage removed increased with SDS concentration until at a concentration of 1.5 g of SDS/1L of water in which the lowest value of the lipid content of 0.26%. Therefore, it has the highest lipid removal percentage at 74%. With concentrations above 1.5 g/L, the results are reversed, and at a concentration of 2 g of SDS per 1 L of water, the rate of lipid content removal decreases.

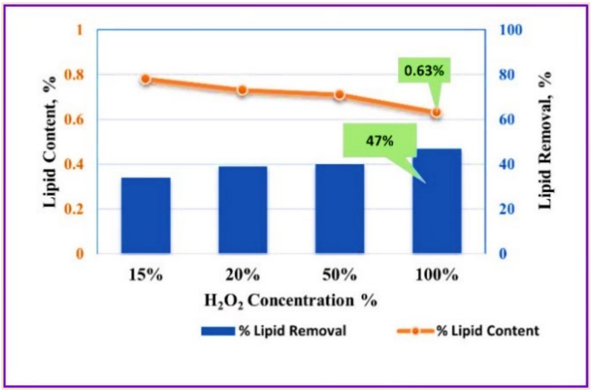

Figure 3. Lipid content and removal percentages of a chemically modified white feather with hydrogen peroxide (H_2O_2).

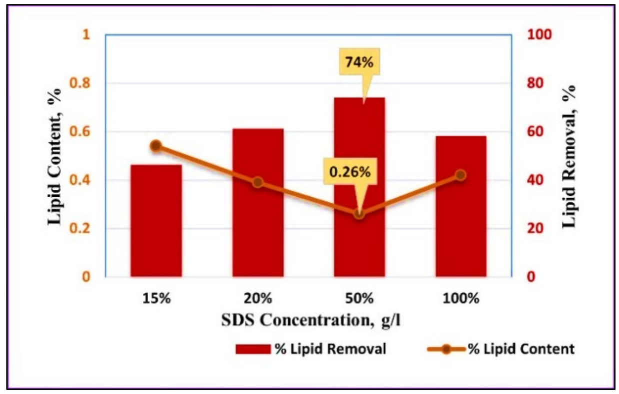

Figure 4. Lipid content and removal percentages of a chemically modified BF with SDS.

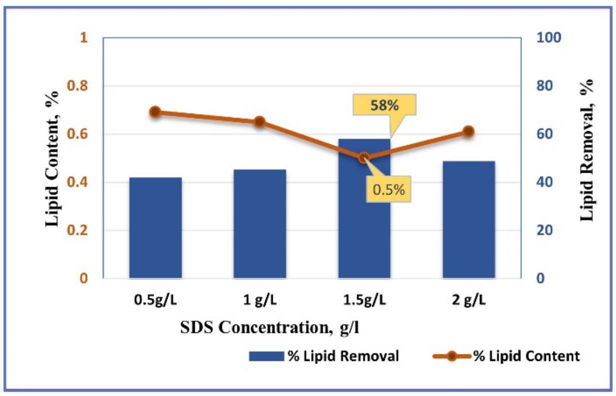

Figure 5. Lipid content and removal percentages of a chemically modified white feather with SDS.

Similarly, in white feathers after chemical modification, the lipid removal percentage is shown in Figure 5, with the lowest value of the lipid content at 1.5 g/L SDS concentration being 0.5%. Therefore, it has the highest lipid removal percentage at 58%. Also, the rate of lipid content removal decreased as the SDS concentration increased above 1.5 g/L and reached 2 g/L.

3.3. Baladi and white chicken feathers characterization

The results of the scanning electron microscope clearly showed the surface texture and morphological characteristics of feathers; the FTIR spectrophotometer investigated the functional groups; and the XRD diffractometer recorded the intensity peaks.

3.3.1. SEM-EDX data analysis

Figures 6 & 7 display SEM-EDX data for baladi and white feathers respectively, there are not many impurities with fatty substances on feather surfaces due to the feathers cleaning process to remove contaminants from dust, blood, and other dirt, but these impurities are less in the Baladi than the White feathers. The sulfur element percentage in baladi is less than in white feathers, Likewise, the unwanted elements in white are more than in baladi feathers.

Figure 8 shows the SEM structure of chemically modified chicken feathers for Baladi and White treated with hydrogen peroxide (H_2O_2) and sodium dodecyl sulfate (SDS). There were no significant differences in the images among the samples, and no damage occurred to the samples after chemical treatment.

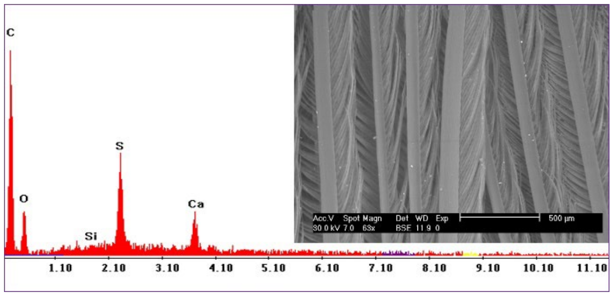

Figure 6. SEM-EDX images and elemental profiles for decontaminated Baladi chicken feathers.

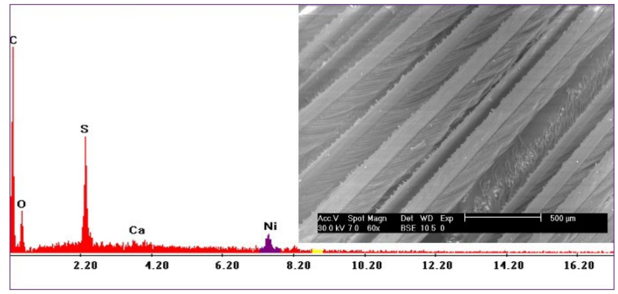

Figure 7. SEM-EDX images and elemental profiles for decontaminated White chicken feathers.

As shown in Figure 9, EDX analysis of the elemental profiles of the samples revealed that the carbon content of Baladi feathers treated with SDS was higher than that of those treated with H_2O_2, but that the carbon content of white feathers was lower due to the presence of some impurities that affected the treatment process.

For example, the presence of nickel element in a large percentage in the white feather sample before treatment, where the percentage was 3.37 wt.%, but after treatment with SDS, the feather sample was free of the element, but after treatment with H_2O_2, a small percentage of the element remains, confirming the efficiency and effectiveness of the SDS.

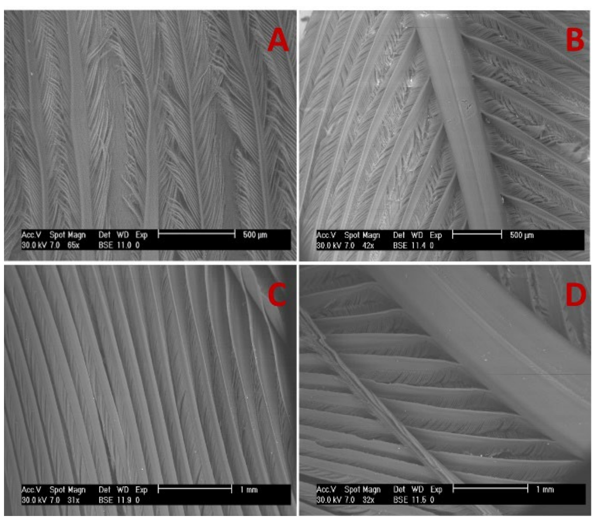

Figure 8. The SEM structure of chemically modified chicken feathers: (A) Baladi and (B) White feathers treated with H_2O_2, (C) Baladi and (D) White feathers treated with SDS.

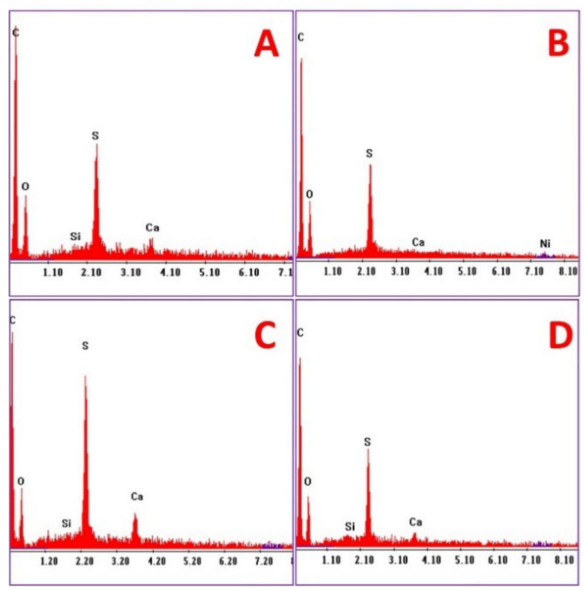

Figure 9. EDX images of the elemental profile of chemically modified chicken feathers: (A) Baladi and (B) White feathers treated with H_2O_2, (C) Baladi and (D) White feathers treated with SDS.

3.3.2. FTIR spectroscopy data

Figure 10 showed the FTIR spectra of Baladi and White chicken feathers. In the FTIR spectra of BF, peptide bonds were observed in the region from 600 to 1300 cm^{-1}, whose absorption band peaks of 685 and 1236 cm^{-1} were attributed to the stretching vibrations of N-H and O-H bonds.

The presence of C-O and N-H bonds, which were confirmed at wavelengths of 1078 and 685 cm^{-1} respectively, indicate that carboxyl and amino groups and the contents of amino acids were presented, so it is confirmed that protein is present.

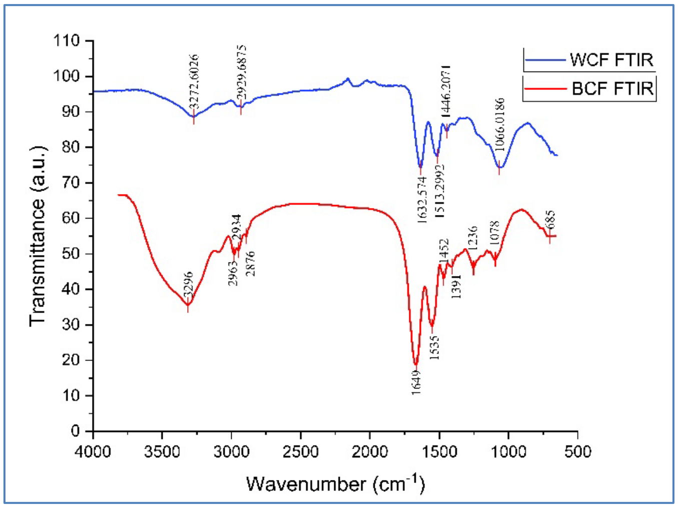

Figure 10. FTIR spectra of Baladi and White chicken feathers.

The stretching of long-chain hydrocarbons (alkyl, alkene, alkane, and alkyne) was measured at 1452, 1500-1700, 2800-3000, and 3296 cm^{-1}. These signals can be attributed to groups of amino acids and lipids. Similarly, the FTIR spectra of white feathers confirmed amino acids, proteins, and lipids, but with lower absorption band peaks. However, the FTIR of the baladi had more peak points, which combined made them have better absorption properties than white feathers.

3.3.3. XRD diffraction data

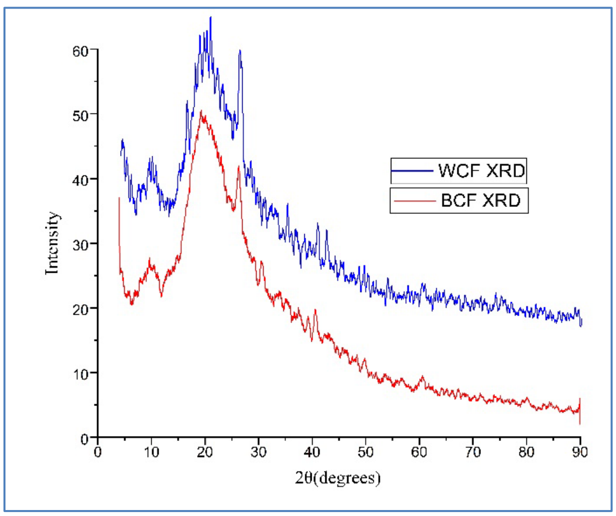

Figure 11. XRD Patterns of baladi and white chicken feathers.

The XRD pattern of the baladi and white chicken feathers was presented in Figure 11. The XRD results confirmed that the Baladi chicken feathers reveal a single broad peak at 26^{o}, which is the most intense in the crystalline pattern, whereas the White chicken feathers reveal three peaks at 19^{o}, 24^{o}, and 40^{o}. It was observed for the White chicken feather with different peaks and accordingly different intensity values, but the Baladi had one peak, which indicates a reduction in crystallinity.

The crystallinity index of a baladi chicken feather is 30%, according to the previously mentioned equation, whereas the crystallinity index of a white is 50%. The decrease in crystallinity could improve the extraction and dissolubility of the feather keratins.

3.4. Chicken feathers as a sorbent for oil spills

Using feathers in the oil sorption process in the petroleum industry has an effective result in oil spill cleanup. Whether used as a powder, fiber, or intact feather without grinding, the duration of oil-feather contact, as well as the best type between WCF and BCF, can be studied, and the desired results can be deduced.

As shown in Figure 12, the oil sorption capacity was 17.65 mL per 1g of WCF at the beginning of contact time, which means in the first seconds, through a slight gradual increase with the contact time, it reached 18.65 ml per 1g of WCF at 10 minutes. Figure 13 exhibited the oil sorption efficiency increases with contact time, so it was 88.3% at the beginning and reached 93.3% at 10 minutes, and this indicates that with contact time increasing, the rate of sorption increases, but the difference rate is slight. Therefore, from an environmental and safety point of view, it is preferable to conduct operations at the beginning for the speedy disposal of pollution harmful to the marine environment.

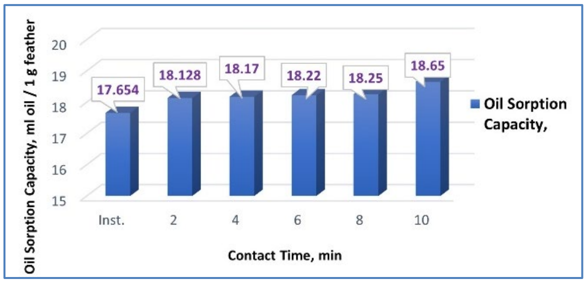

Figure 12. Optimization of oil-white chicken feather contact time.

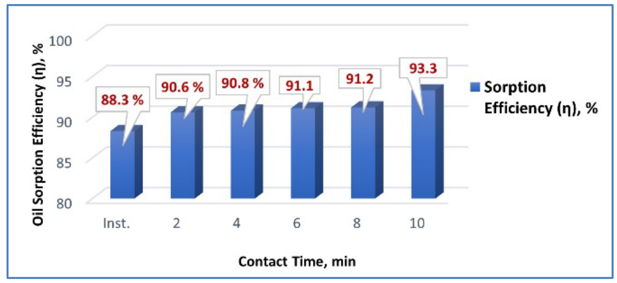

Figure 13. Oil sorption efficiency of white chicken feather vs. contact time.

3.5. Sorption capacity of fiber or powder size of WCF

As shown in Figures 14 and 15, oil was sorbed by powder (size: < 1mm) and fiber (size: 5mm to 1cm) applied at any rpm rotation speed to accelerate the sorption process and ensure that the total amount was sorbed. In addition, intact feathers were used to sorb oil at different quantities to prove the effectiveness of feathers as a sorbent, and Figure 16 revealed that at a constant oil spill quantity, the oil sorption capacity decreased as the chicken feather size decreased and the amount of feather required to recover all the oil increased. So, the sorption process for intact feathers without cutting or pulverizing was 1g per 20 ml, 3.5g per 20 ml for fiber, and 5.5g per 20 ml of oil for powder. It was noticed that with this large amount of powder consumed, it gathered, formed a slurry with the oil, and was recovered, leaving no trace of the oil.

Figure 14. Chicken feathers fiber and powder size as a sorbent

Figure 15. Intact chicken feathers as a sorbent

In Figure 17, at a constant sorbent quantity of 1 g, the oil sorption efficiency of WCF decreased with an increased oil volume, which was 83.3% at 20 mL and 67.7% at 50 mL, and if the oil volume increased again, the sorption efficiency decreased due to the stability of the feather quantity and the increase in the amount of oil spill. For the BCF had a sorption efficiency of 93% at 20 mL of oil volume and 75.4% at 50 ml of oil spill and the sorption efficiency decreased as in the white feathers at the same rate as shown in Figure 18.

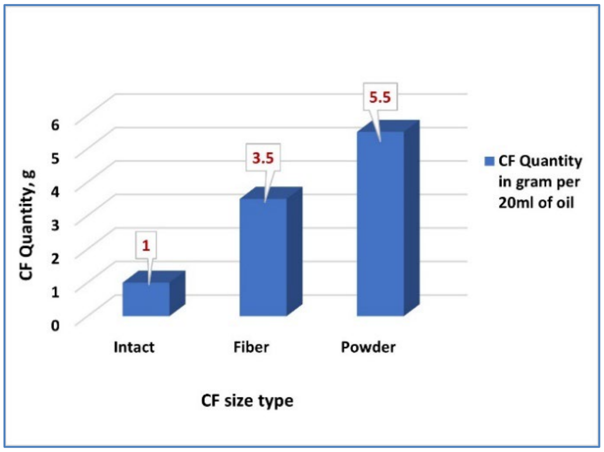

Figure 16. Oil sorption capacity of chicken feathers at different sizes

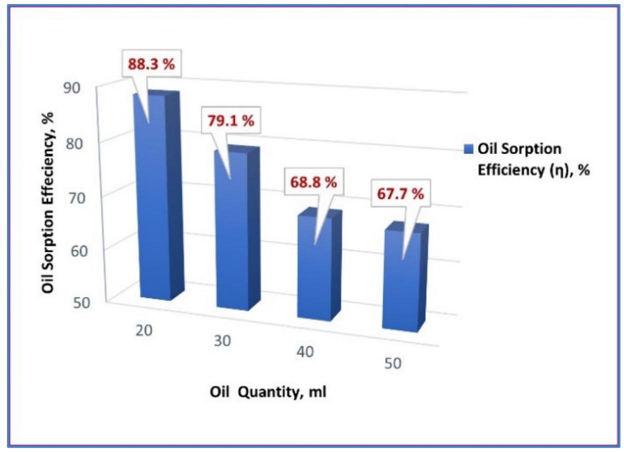

Figure 17. Oil sorption efficiency for 1g of white chicken feather

As shown in Figure 19, Compared to BCF, the rate of oil sorption efficiency is greater than that of WCF, but with the stability of the feather quantity at 1g and the increase in the amount of oil, the sorption efficiency was 67.7% of WCF and 75.4% of BCF indicated that the BCF is better than WCF due to the preferability of BCF in sorption capacity.

From the foregoing, it became clear that the feathers have great effectiveness in treating and absorbing any quantities of oil and are also much better than other types mentioned in previous studies, as the efficiency did not exceed 16 grams of oil(about 18 mL) per gram of feathers, and 150 mL of oil was used, but here, using 50 ml, the absorption rate exceeded 37 ml with an efficiency of 75%, and this is an achievement. It is possible to delve deeper into case studies to make the most of feathers as a sorbent material for removing oil pollution. Table 2 summarizes the optimization of the sorption process conditions.

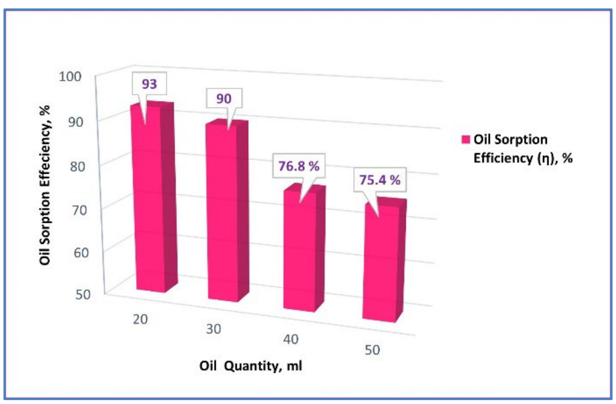

Figure 18. Oil Sorption efficiency for 1g of Baladi Chicken Feather

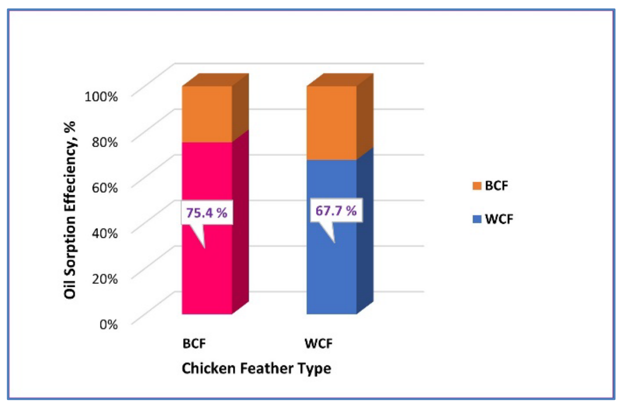

Figure 19. The sorption capacity of BCF vs. WCF at 50 ml of oil

Table 2. Specifications of different categories for the sorption process.

Category	Sensitivity	Reason
Chemical treatment	Sodium dodecyl sulfate	highest lipid removal percentage at 74% with concentrations above 1.5 g/L
Oil feather contact time	At the beginning	respect to the environmental overview
	At 10 minutes	respect to the maximum sorption capacity
Feather size	Intact then fiber then powder	respect to sorption capacity per 1 gram
	Powder then intact then fiber	respect to clean-up efficiency
Feather type	Baladi chicken feather	lower lipid content and a high oil sorption capacity

4. Conclusion

WBF have lower moisture content, requiring higher moisture content for better yield and quality. To determine the optimal treatment, tests with various chemicals are conducted. Sodium dodecyl sulfate is the optimal chemical modification for lipid removal from feathers at 1.5 g/L, achieving maximum removal efficiency. SEM-EDX analysis shows BF are more efficient than white feathers, with varying functional groups and absorption properties. FTIR spectra reveal lipids and proteins, while XRD diffraction reveals a lower crystallinity index in BF.

The oil sorption efficiency of 1 g of BCF was found to be 93.3% at 10 minutes of contact time and 88.3% at the start of the experiment. The highest sorption effectiveness was 75.4% (37.7 mL) with 50 mL of oil feed. As more oil was used, the oil sorption capacity values increased but the sorption effectiveness decreased.

The application of chicken feathers as a sorbent material for oil spill removal in the petroleum industry was highly appreciated for the great results, so it is recommended later to do further in-depth research into the oil biosorption processes.

References

[1] Saravanan K, and Dhurai B. Exploration on the amino acid content and morphological structure in chicken feather fiber. Journal of Textile and Apparel, Technology and Management, 2012; 7(3): 1-6.

[2] Tesfaye T, Sithole B, and Ramjugernath D. Valorisation of waste chicken feathers: Green oil sorbent. Int J Chem Sci., 2018; 16(3): 282.

[3] McGovern V. Recycling poultry feathers: more bang for the cluck. Environmental Health Perspectives, 2000; 108(8): A366-A369.

[4] Yu M, Wu P, Widelitz RB, and Chuong CM. The morphogenesis of feathers. Nature, 2002; 420: 308-312.

[5] Zeisler-Diehl V, Al-Khutabi E, Kirfel G, Schreiber L, van Echten-Deckert G, and Herzog V. Detection of endogenous lipids in chicken feathers distinct from preen gland constituents. Protoplasma, 2020; 257: 1709-1724.

[6] Saino N, Romano M, Rubolini D, Teplitsky C, Ambrosini R, Caprioli M, and Wakamatsu K. Sexual dimorphism in melanin pigmentation, feather coloration and its heritability in the barn swallow (Hirundo rustica). PLoS One, 2013; 8(2): e58024.

[7] Cunningham F. The microbiology of poultry meat products. Elsevier, 2012.

[8] Pourjavaheri F, Mohaddes F, Shanks RA, Czajka M, and Gupta A. Effects of different purification methods on chicken feather keratin. In Advanced Materials Research, 2014; 941: 1184-1187.

[9] Tseng FC. Biofibre production from chicken feather. PhD Thesis, University of Waikato, 2011.

[10] Tesfaye T, Sithole B, and Ramjugernath D. Valorisation of waste chicken feathers: optimisation of decontamination and pre-treatment with bleaching agents using response surface methodology. Sustainable Chemistry and Pharmacy, 2018; 8: 21-37.

[11] Zainudin NF, Lee KT, Kamaruddin AH, Bhatia S, and Mohamed AR. Study of adsorbent prepared from oil palm ash (OPA) for flue gas desulfurization. Separation and Purification Technology, 2005; 45(1): 50-60.

[12] Lederer R. Integument, feathers, and molt. Ornithology: The Science of Birds, 2005; 6(23): 05.

[13] Kock JW. Physical and mechanical properties of chicken feather materials. PhD Thesis, Georgia Institute of Technology, 2006.

[14] Bateup BO. Optimization of the Aqueous Scouring Process in Symposium on Wool Scouring and Worsted Carding: New Approaches. CSIRO Division of Textile Industry, 8-16; 1986.

[15] Hurren CJ, Zhang M, Liu X, and Wang X. A study of ultrasonic scouring of greasy Australian wool. 2006; 493-497.

[16] De Castro ML, and Garcıa-Ayuso LE. Soxhlet extraction of solid materials: an outdated technique with a promising innovative future. Analytica chimica acta, 1998; 369(1-2): 1-10.

[17] Mamidipally PK, and Liu SX. First approach on rice bran oil extraction using limonene. European Journal of Lipid Science and Technology, 2004; 106(2): 122-125.

[18] Cervantes-González E, Rojas-Avelizapa LI, Cruz-Camarillo R, Rojas-Avelizapa NG, and García-Mena J. Feather waste as petroleum sorbent: a study of its structural biodegradation. In Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy, 2010; 13(1): 7.

[19] Chevion S, Berry EM, Kitrossky N, and Kohen R. Evaluation of plasma low molecular weight antioxidant capacity by cyclic voltammetry. Free Radical Biology and Medicine, 1997; 22(3): 411-421.
[20] Behrooz RD, Esmaili-Sari A, Ghasempouri SM, Bahramifar N, and Covaci A. Organochlorine pesticide and polychlorinated biphenyl residues in feathers of birds from different trophic levels of South-West Iran. Environment International, 2009; 35 (2): 285-290.
[21] Pourjavaheri F, Shanks R, Czajka M, and Gupta A. Purification methods for chicken feather keratin. In Proceedings of the 5th International Conference on Advance Polymeric Materials, 2013; 5: 1-4.
[22] Smulders E, Rähse W, Rybinski W, Steber J, Sung E, and Wiebel F. Laundry detergents. Weinheim, 2002; p. 52.
[23] Niraula TP, Bhattarai A, Chatterjee SK, and Biratnagar N. Sodium dodecyl sulphate: A very useful Surfactant for Scientific Investigations. J. Knowl. Innov, 2014; 2: 111-113.
[24] Devesa-Rey R, Vecino X, Barral MT, Cruz JM, and Moldes AB. Study of the sorption of biosurfactants from Lactobacillus pentosus on sediments. World Academy of Science, Engineering and Technology, 2011; 79: 187-189.
[25] Ferreira-Dias S, Valente DG, and Abreu JM. Comparison between ethanol and hexane for oil extraction from Quercus suber L. fruits. Grasas y Aceites, 2003; 54(4): 378-383.
[26] Ahmad A, Alkarkhi AF, Hena S, and Khim LH. Extraction, separation and identification of chemical ingredients of Elephantopus scaber L. using factorial design of experiment. International Journal of Chemistry, 2009; 1(1): 36.
[27] Baales J, Zeisler-Diehl VV, and Schreiber L. Analysis of Extracellular Cell Wall Lipids: Wax Wax, Cutin Cutin, and Suberin Suberin in Leaves, Roots, Fruits, and Seeds Seeds. In Plant Lipids: Methods and Protocols, 2021; 275-293.
[28] Belarmino DD, Ladchumananandasivam R, Belarmino LD, Pimentel JR, daRocha BG, Galv AO, and deAndrade SM. Physical and morphological structure of chicken feathers (keratin biofiber) in natural, chemically and thermally modified forms. Materials Sciences and Applications, 2012; 3(12): 7.
[29] Ifelebuegu AO, and Chinonyere P. Oil spill clean-up from sea water using waste chicken feathers. In Proceedings of the 4th international conference on advances in applied science and environmental technology, 2016; 5: 61-64.
[30] Ahalya N, Ramachandra TV, and Kanamadi RD. Biosorption of heavy metals. Res. J. Chem. Environ, 2003; 7(4): 71-79.
[31] Miessler GL, and Tarr DA. Coordination chemistry IV: reactions and mechanisms. Inorganic Chemistry, 1999; 5: 437-474.
[32] Lancashire RJ. Stability, Chelation and the Chelate Effect.2015 .
[33] Ali MF, Hossain MS, Moin TS, Ahmed S, and Chowdhury AS. Utilization of Waste Chicken Feather for the Production of Eco-Friendly and Sustainable Composite. Cleaner Engineering and Technology, 2021; 4: 100190.
[34] Zhou LT, Yang G, Yang XX, Cao ZJ, and Zhou MH. Preparation of regenerated keratin sponge from waste feathers by a simple method and its potential use for oil adsorption. Environmental Science and Pollution Research, 2014; 21: 5730-5736.
[35] Gupta A, Kamarudin NB, Kee CYG, and Yunus R. Extraction of keratin protein from chicken feather. Journal of Chemistry and Chemical Engineering, 2012; 6(8): 732.
[36] Eslahi N, Dadashian F, and Nejad NH. An investigation on keratin extraction from wool and feather waste by enzymatic hydrolysis. Preparative Biochemistry and Biotechnology, 2013; 43(7): 624-648.
[37] Nwadiogbu JO, Ajiwe VI, and Okoye P. Removal of crude oil from aqueous medium by sorption on hydrophobic corncobs: Equilibrium and kinetic studies. Journal of Taibah University for Science, 2016; 10(1): 56-63.
[38] Xu W, Ke G, Wu J, and Wang X. Modification of wool fiber using steam explosion. European Polymer Journal, 2006; 42(9): 2168-2173.
[39] Tesfaye T, Sithole B, Ramjugernath D, and Chunilall V. Valorisation of chicken feathers: Characterisation of chemical properties. Waste Management, 2017; 68: 626-635.
[40] Long JJ, Cui CL, Wang L, Xu HM, Yu ZJ, and Bi XP. Effect of treatment pressure on wool fiber in supercritical carbon dioxide fluid. Journal of Cleaner Production, 2013; 43: 52-58.
[41] Ma B, Qiao X, Hou X, and Yang Y. Pure keratin membrane and fibers from chicken feather. International journal of biological macromolecules, 2016; 89: 614-621.

To whom correspondence should be addressed: Mohamed A. Ayad, Mining and Petroleum Engineering Department, Faculty of Engineering, Al-Azhar University, Nasr City, Cairo, Egypt; e-mail: mohamedayad@azhar.edu.eg