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Synthesis of zinc chloride activated eco-friendly nano-adsorbent (activated carbon) from food waste for removal of pollutant from biodiesel wash water

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ABSTRACT

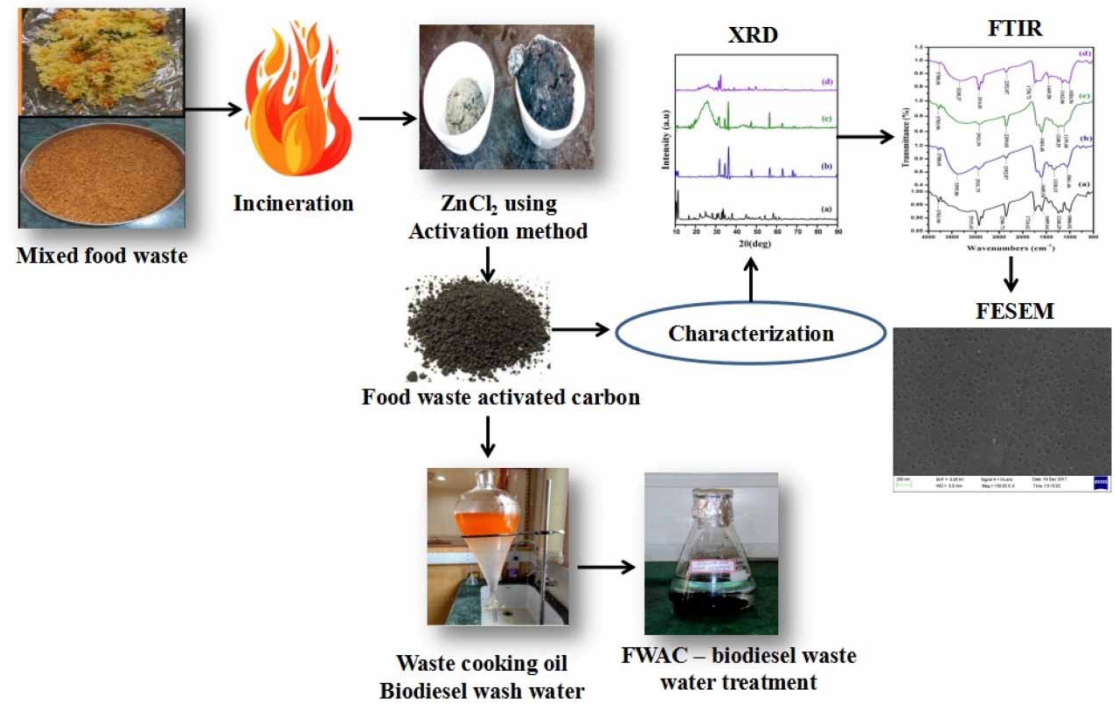
Food waste has been a complex component added to municipal solid waste, making it a major reason for the evolution of greenhouse gases, foul odour and a dwelling habitat for insects and microbes. Diversion of the mixed food waste (unsegregated) to useful materials (activated carbon) would have immense industrial significance. In this study, rice, vegetables, oil and spice (WCVR); mixed fruit peels including banana peel, pomegranate peel, orange peel and lemon peel (MFPW); plain rice (WCR) and mixed food waste (rice, dhal, vegetables, fruits, meat and bones) (MFW) were used. Food waste samples were heated at a temperature of 350 °C for 3 h in an incinerator and then activated with zinc chloride for 2 h in a muffle furnace maintained at 500–600 °C temperature. Zinc chloride activated carbon was characterized through X-ray diffraction, field emission scanning electron microscopy and fourier transform infrared spectroscopy. WCR carbon was the best-activated carbon, yielding nanomaterials with $2\theta = 25.81$, 31.76, 34.41 and 56.54, which was in accordance with the JCPDS card number. The MFW activated carbon reduced the biodiesel wash water pH from 10 to 6.5 making it suitable for recycling. Turbidity was reduced by 98.41%, chemical oxygen demand by 41.33%, oil and grease by 99.05% for MFW carbon.

Key words: activated carbon, biodiesel wash water, food waste, nanomaterial, turbidity

HIGHLIGHTS

- Biodiesel washwater was generated enormously during biodiesel synthesis.
- Food waste was converted to activated carbon (AC) and activated with zinc chloride.
- Synthesized AC had high intensity peaks at 31.9°, 34.5° and 36.5°.
- 0.5 g AC reduced turbidity, COD, oil and grease by 98.41, 41.33 and 99.05%.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Food waste generation was around 1.4 billion tons per year in developing countries (Girotto *et al.* 2015; Kosheleva *et al.* 2019; Tucho & Okoth 2020). This may be attributed to the lack of awareness of the value of food, food security, poverty and societal wellbeing. Food waste when mixed with municipal solid waste results in stale odours from the waste dump yards contributing to secondary pollution. Food waste is rich in carbon-based materials, which can be processed through appropriate techniques for value-added products recovery (Joshi 2002; Pandey *et al.* 2016). Many investigators have processed food waste through anaerobic digestion to synthesize biogas (CO_2, CH_4), a green fuel for rural livelihoods (Cho *et al.* 1995). Although biogas production is the most popular utility for food waste, excess availability of food waste, lack of popularization of biogas application as a replacement to conventional cooking fuels and need for location-specific biogas plant installations in proximity to where the food waste is generated, needs private interest and remains a challenge that has led to the idea of developing a mechanism to divert a percentage of food waste to activated carbon. In larger communities (apartments, hostels, mansions, industries, etc), the food waste can be reduced through connected home techniques via smart mobile applications by providing ideas towards inventory management and cooking skills (Tavill 2020).

Food waste is converted to activated carbon via pyrolysis, hydrothermal carbonization, etc. This has emerged as a hot topic in the current scenario among environmental researchers working on industrial wastewater remediation. Food waste-based activated carbon possesses numerous advantages like less cost, enormous resource availability, etc. The best activated agent for the potential of activated carbon produced to adsorb various adsorbates from aqueous solutions are electrocoagulation (Chavalparit & Ongwandee 2009), coagulation, adsorption (Pitakpoolsil & Hunsom 2013), biological processes and microbial fuel cell systems. Adsorption is one of the most effective methods used for the treatment of wastewater from different sources (Halim *et al.* 2012; Bashir *et al.* 2015; Azmi *et al.* 2016). The use of activated carbon (AC) as an adsorbent was considered as one of the most efficient technologies for the removal of colorants, organic pollutants, chemical oxygen demand (COD), and heavy metals (Li *et al.* 2009). Activated carbon is highly porous in nature and has a wide range of practical applications because of its versatile adsorption capacity (Dabwan *et al.* 2015). Researchers around the globe have utilized bamboo, peach stones, grass, wood, agricultural wastes like coir pith, peanut hull, rice husk, palm trees, palm

stones, fruit peel, sugar beet pulp, grain sorghum, wheat husk and industrial wastes for the synthesis of activated carbon (Yalcın & Sevinc 2000; Ramakrishnan & Namasivayam 2009; Abdul-Hameed & Al-Juboury 2020a, 2020b).

Activated carbon (AC) from materials has been preferably synthesized by chemical (Kumar & Jena 2016; Tran *et al.* 2018) or physical methods over recent years (Guan *et al.* 2013; Enaime *et al.* 2017). Chemical activation of carbonaceous material with $ZnCl_2$ has resulted in 70% of adsorption capacity compared with activated carbon produced using other agents (Mahamad *et al.* 2015). Surface and structural analyses of activated carbon is the most important and essential property to be analyzed to decide its commercial applications (Dizbay-Onat *et al.* 2018; Inbaraj *et al.* 2021). Several researchers have attempted to use homogeneous food waste generated from processing raw materials, to be diverted for activated carbon synthesis (Dhandapani *et al.* 2020; Yang *et al.* 2021). This reported study was taken up to investigate the effect of four different food waste samples generated routinely into $ZnCl_2$ incorporated activated carbon for the treatment of biodiesel wash water, to evaluate its efficiency for the removal of turbidity and reduction of pH.

Water scarcity and treatment regimes in various sectors including biodiesel production, dying industries, electroplating, etc., are emerging from research around the globe (Baldev *et al.* 2018; MubarakAli 2019). Transesterification processes generate a huge amount of wash water (wastewater) during the biodiesel production owing to the wet washing step (Chung *et al.* 2019; Poornapushpakala *et al.* 2021). Biodiesel wash water will be alkaline in nature with pH above 9 (Mustafa & Asmatulu 2020). Wash water reuse will reduce the dependence of biodiesel industries on freshwater resources and will decrease the amount spent on freshwater requirements during wet washing.

The study was extended further to synthesize a heterogeneous food waste $ZnCl_2$ activated carbon, to eliminate the process of segregation of food waste into homogeneous food waste samples, thereby reducing the investment of time and money on segregation. Food waste activated carbon is reported as a novel adsorbent efficient in treating highly turbid, strongly alkaline wastewater including biodiesel wash water. Also, this will be a first-time attempted mechanism in which mixed food waste (MFW) of maximum heterogeneity generated, can be diverted indigenously towards activated carbon synthesis, contributing to a sustainable approach for recycling food waste which would otherwise become an added source of organic pollution when dumped on landfills.

2. EXPERIMENTAL METHODS

2.1. Materials and chemicals

Food waste was collected from the Sathyabama Institute of Science and Technology Chennai, Tamil Nadu, India that has a mess hall, catering to about 12,000 people every day and hence is identified as a potential source for food waste collection. Zinc chloride ($ZnCl_2$) with purity >98% was purchased from Fisher Scientific Mumbai and an incinerator (model A1500 150* 100 * 96 cm Italy) was used.

2.2. Collection of food waste and analysis

Four different food wastes namely rice, vegetables, oil and spice (WCVR); mixed fruit peels including banana peel, pomegranate peel, orange peel and lemon peel (MFPW); plain rice (WCR) and mixed food waste containing rice, dhal, vegetables, fruits, meat and bones (MFW) were collected in plastic buckets and subjected to proximate studies as per ASTM International D3,173–3,175 test standards.

2.3. Preparation of activated carbon from food waste

The collected food waste samples were dried for 8 h in sunlight to remove moisture and subsequently oven dried at 105 °C for 4–5 h to remove remaining bound moisture. The waste samples were heated at 350 °C for a time of 3 h in an incinerator (model A1500 150* 100 * 96 cm Italy) to convert the dried food waste into carbon. Furthermore, the dried carbonaceous food waste samples were size reduced using a ball mill (SPEX 8000M-230 dual mixer mill, 230 V/50 Hz USA) for 15 min and sieved through a 40-mesh screen. The synthesized carbon powder was doped in 1 N $ZnCl_2$ solution in the ratio 1 g:2 mL for 2 h at 80 °C (Saqib *et al.* 2018). The $ZnCl_2$-doped carbon samples were further activated at 500–600 °C in a muffle furnace for 2 h. The activated samples were size reduced with a pestle and mortar to produce fine activated carbon. The activated carbon samples were then washed with distilled water to reduce the pH to neutral. The washed activated carbon samples were dried in a hot air oven at 110 °C for 2 h and crushed to produce the activated carbon. The procedure was carried out for all four food waste samples collected.

2.4. Characterization of food waste carbon

The $ZnCl_2$ activated carbon samples obtained from food waste samples WCVR, MFPW, WCR and MFW were characterized for their crystalline or amorphous nature, surface morphology and presence of functional groups using X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM) and Fourier transform-infrared spectroscopy studies. The XRD technique was used to examine the crystalline and non-crystalline nature of the material. XRD was performed using an analytical D/Max-2500 X-ray diffractometer equipped with Cu-Kα radiation (1.5406 Å) operating at 40 kV, 50 mA in the 2θ range of 20°–80° with scanning rate of 0.02 S^{-1}. Thus, phase analysis and the nature of activated carbon were confirmed using XRD. FESEM images were taken to investigate the surface morphology of the activated carbon using an SEM: Carl Zeiss (SUPRA 55, Germany) by field emission scanning electron microscopy. Furthermore, the surface carbon–oxygen functional groups present in samples were identified by performing FTIR measurements using the KBr method by FTIR – Fourier transform infrared spectroscopy (ALPHA FTIR Spectrometer, Bruker). FTIR studies were carried out between 4,000 and 500 cm^{-1} for all the samples.

2.5. Preparation of biodiesel wash water from waste cooking oil

Here, 50 L waste cooking oil (WCO) was collected from the mess hall facility at Sathyabama Institute of Science and Technology, Tamil Nadu, India. The free fatty acid (FFA) content of the collected WCO was tested as per ASTM D664. The FFA content was determined using a sodium hydroxide (NaOH) titration method. The WCO was transesterified using methanol 1:3 molar ratio and NaOH as a catalyst for a time of 90 min in a 100 L capacity biodiesel pilot plant established at the Centre for Waste Management, Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India. Biodiesel was separated from the byproduct (crude glycerol) after a settling time of 8 h at room temperature. Later the biodiesel was collected and subjected to wet washing (Ranjan *et al.* 2018):

$$\text{Tryiglyceride} + \text{Methanol} \rightarrow \text{Glycerol} + \text{Biodiesel} \quad (1)$$

The collected biodiesel was washed with hot water at 60–80 °C for 15 min. Due to density difference, the washed biodiesel remained at the top allowing the wash water to settle at the bottom. The collected wash water was tested for its pH and the washing cycle was repeated until the pH of wash water collected became neutral (Nirmala *et al.* 2020). Depending on the quality of the WCO used as the raw material, the number of washing cycles varied from 3 to 5. Wash water generated during each cycle of washing was collected and used for adsorption studies.

2.6. Adsorption studies

Here, 0.5 g of $ZnCl_2$ activated carbon was added to 100 mL of biodiesel wash water and agitated in a stoppered conical flask at constant speed of 120 rpm for 2 h. The mixture was filtered using a Whatman filter paper (110 mm). Wash waters after treatment with food waste activated carbon from all four samples (WCVR, MFPW, WCR and MFW) were analyzed as per standards (Wong *et al.* 2018) and their properties (pH, turbidity, COD, oil and grease) were determined.

3. RESULTS AND DISCUSSION

3.1. Proximate analysis

The proximate analysis of the food waste samples are represented in Table 1. It was observed that the fixed carbon percentages of all samples fell between 22 and 32 comparable with the previously reported literature (Bashir *et al.* 2018) and were found to be suitable for activated carbon synthesis. It was observed that food waste with no rice content, comprising of only fruit peels (B) has a higher percentage fixed carbon, while for other samples fixed carbon was found to increase with increasing cooked rice percentage. The moisture content, ash content and volatile matter of the samples WCVR, MFPW, WCR, MFW were also comparable to the proximate composition (Sayğılı *et al.* 2015). The samples WCVR, MFPW, WCR and MFW had 65.91%, 53.44%, 60.92% and 54.21% moisture content, 0.026%, 5.01%, 1.56% and 13.42% ash content, and 10.9%, 10.20%, 10.35% and 9.74% volatile content, respectively.

Table 1 | Comparison of proximate analysis of collected food waste with previously published literature

Sample	Moisture content (%)	Ash content (%)	Volatile mater (%)	Fixed carbon (%)	References
WCVR	65.91	0.026	10.19	23.86	In this study
MFPW	53.44	5.01	10.20	31.346	
WCR	60.92	1.56	10.35	27.17	
MFW	54.21	13.42	9.74	22.62	
Food waste	60.9	1.61	80.9	11.4	Chen *et al.* (2019a)
Food waste	74	1.15		24.85	Chen *et al.* (2019b)
Food waste	76.5	6.4	79.1	14.5	Saqib *et al.* (2018)
Kitchen waste	60–85	3.5–5.5	–	18–30	Chang *et al.* (2006)

WCVR, Kitchen waste (rice, vegetables, oil and spice); MFPW, Mixed fruit peels; WCR, Mess hall waste (plain rice); MFW, Mixed food waste (rice, dhal, vegetables, fruits, meat and bones).

3.2. Structural and surface characterization

3.2.1. X-ray diffraction (XRD) measurements

The X-ray diffraction technique was used to interpret the influence of $ZnCl_2$ treatment on activating food waste carbon. Carbon powder was prepared for XRD analysis by grinding the required amount at 80 °C for 2 h. The typical broad diffraction peak was obtained at 22.3° and 42° corresponding to (002) and (101) planes respectively. This indicated the presence of dominant amorphous phase (Figure 1). It is also noted that the XRD pattern of waste cooked rice (WCR) (Chingombe *et al.* 2005) showed a high intensity peak (002) with increased broadening without any secondary peaks which indicated that the carbon atoms existed in highly distorted manner compared with the other samples (Rajbhandari *et al.* 2012; Danish *et al.* 2018).

The diffraction pattern (Figure 2) of the $ZnCl_2$ treated activated carbon samples confirmed the formation of ZnO which has absorbed on to the carbon surface after $ZnCl_2$ treatment. The appearance of high intensity peaks at 31.9°, 34.5° and 36.5° indicate the crystalline hexagonal phase of ZnO (JCPDS# 36-1451) as all the samples were dried at 600 °C in an air atmosphere. The addition of $ZnCl_2$ significantly affected the amorphous nature of the carbon phase as it can be seen that the intensity had changed for all the samples (Zięzio *et al.* 2020). Interestingly, the amorphous carbon peak had completely disappeared for cooked vegetable rice (WCVR) and the mixed fruit peel waste (MFPW) sample, whereas the amorphous peak still appeared for the WCR

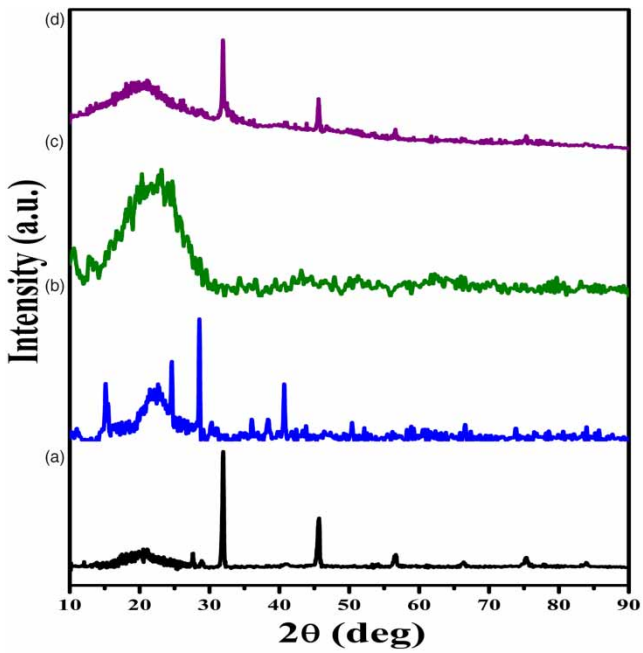


Figure 1 | XRD patterns of carbonaceous food waste samples before activation of WCVR (a), MFPW (b), WCR (c) and MFW (d).

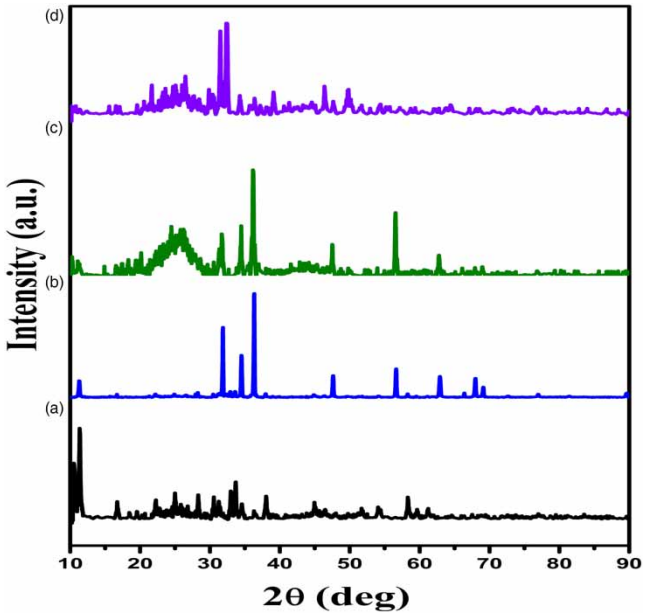


Figure 2 | XRDs pattern of carbonaceous food waste samples after activation of WCVR (a), MFPW (b), WCR (c) and MFW (d).

and mixed food waste sample (MFW). The results strongly revealed that the $ZnCl_2$ activation had stabilized the amorphous carbon phase in the WCR and mixed food waste sample (MFW). It was evident that the crystalline nature of carbon had improved in the $ZnCl_2$ activated WCR sample compared with the untreated sample as reduced peak broadening is observed.

3.2.2. Field emission scanning electron microscopy (FESEM)

The surface morphology for adsorbents obtained from different food waste materials varied significantly. Specifically $ZnCl_2$ activated adsorbent synthesized from rice was observed to have a mesoporous surface (Rajbhandari *et al.* 2012; Mokhtar *et al.* 2013) which is very important from the water treatment point of view and can handle wide ranges of pollutants including heavy metals, surfactants and high molecular weight organic pollutant (Mokhtar *et al.* 2013). $ZnCl_2$ activation enhanced the stability and mesoporosity of the carbonaceous material and depicted the changes in surface morphology of carbonaceous samples after $ZnCl_2$ activation (Figures 3 and 4). The activation process brought changes in the surface of the adsorbents. From the results, it is evident that $ZnCl_2$ activation has been effective on waste rice as uniform pore (mesoporous) distribution was observed (Bae *et al.* 2014). Also, the FESEM data have been analyzed further and it was observed that the food waste-based activated carbon was 44.87 nm in size and the activated carbon synthesized from other food waste materials also had particles of size less than 100 nm, leading to the conclusion that the food waste carbonaceous materials yield nanoparticles upon $ZnCl_2$ activation.

3.2.3. FTIR spectroscopy

Some important functional groups were identified in the synthesized activated carbon samples by FTIR spectroscopy as shown in Figure 5. It is evident that the peaks at 1,006.02 cm^{-1}, 1,026.56 cm^{-1} are responsible for C-O stretching and 2,346.71 cm^{-1}, 2,352.87 cm^{-1}, 2,359.03 cm^{-1} and 3,783.90 cm^{-1}, 3,788.01 cm^{-1} for O-H stretching in esters (Yagmur *et al.* 2008). The peaks 1,061.46 cm^{-1}, 1,320.15 cm^{-1}, 1,248.29 cm^{-1}, 1,139.48 cm^{-1} and 1,162.06 cm^{-1} correspond to the C-N stretching in aliphatic amines and the peaks at 3,395 $cm^{-1}$and 3,338 cm^{-1} indicate the broad vibrational band caused by N-H stretching. The peak at 1,724.62 cm^{-1} corresponds to the C = O stretching in ketones. The peaks at 2,915.43 cm^{-1}, 2,921.75 cm^{-1} and 2,931.85 cm^{-1} indicate the C-H stretching in alkanes. The 1,603.48 cm^{-1}, 1,609.64 cm^{-1}, 1,605.54 cm^{-1} peaks indicate the C = C stretching in alkenes and the peak at 1,449.50 cm^{-1} indicates the C = C stretching in aromatic compounds (Saka 2012; Jaria *et al.* 2019) (Figure 6). Indication of the decomposition of alkane and ester functional groups as the peaks in the spectral range around ~2,300 cm^{-1}–3,000 cm^{-1} is not evident for all the samples (WCVR, MFPW, WCR, MFW). Most of the frequencies attributed to the activated carbon were absent and were mainly due to the existence of volatile organic compounds at an activation temperature in the range of 500–600 °C. However, the observation of transmission peaks of $ZnCl_2$ treated samples in the range ~ 1,000 cm^{-1}–3,500 cm^{-1} may be attributed to the activated carbon samples attached to the surface groups bearing

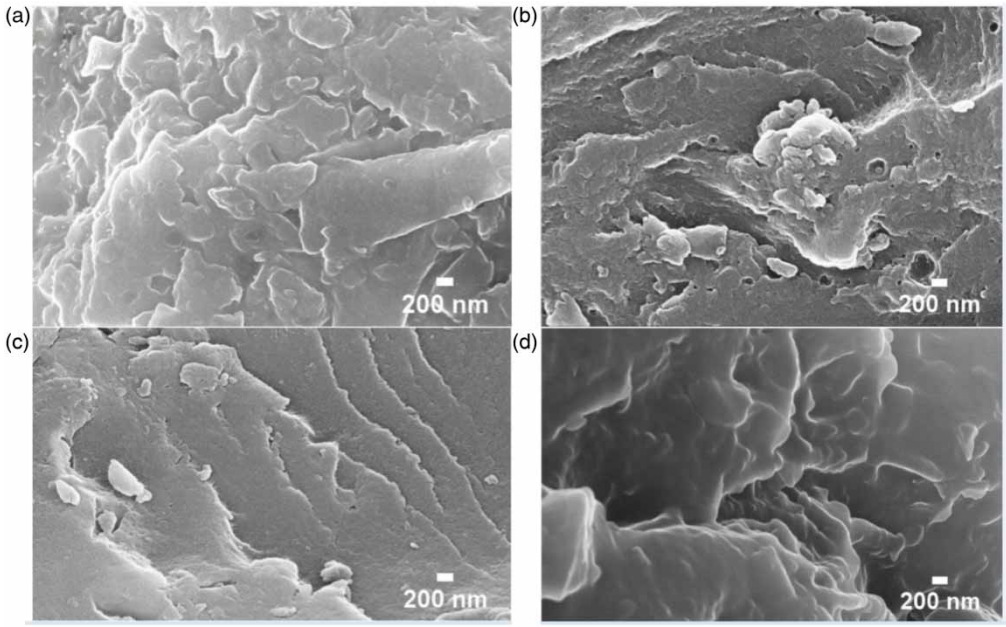


Figure 3 | FESEM images of food waste samples before $ZnCl_2$ activation of WCVR (a), MFPW (b), WCR (c) and MFW (d).

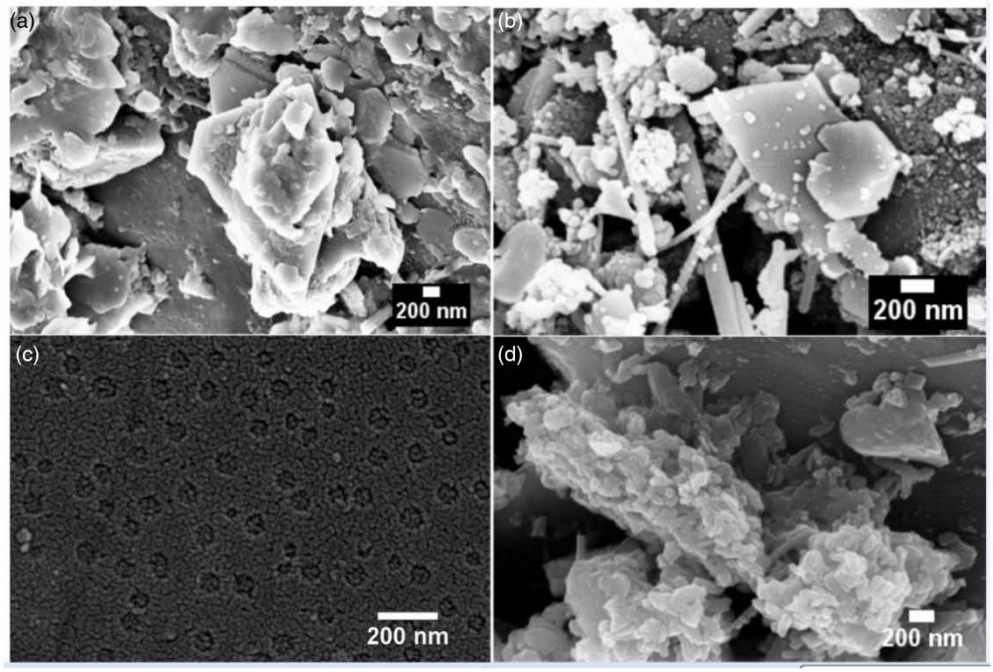


Figure 4 | FESEM images of food waste samples after $ZnCl_2$ activation of WCVR (a), MFPW (b), WCR (c) and MFW (d).

oxygen atoms on the aromatic and aliphatic backbone skeletons. The significant shifts of peaks between the samples may be predicted to be due to the interactions that originate from different activated functional groups (Ahmaruzzaman & Gupta 2011).

3.3. Biodiesel and wash water characterization

The moisture content, density, FFA, kinematic viscosity, resistance to corrosion, cloud and pour point, flash and fire point and calorific value of WCO were determined. Free fatty acid of WCO was found to be 0.11%, which helped in the choice of

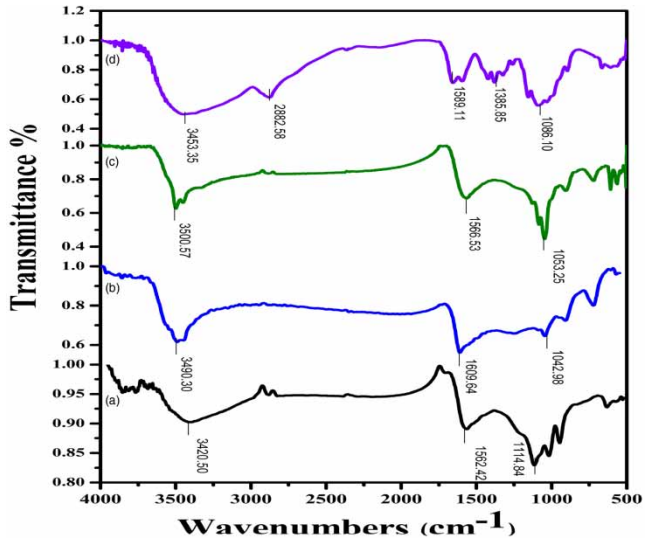


Figure 5 | FTIR spectra of raw WCVR (a), MFPW (b), WCR (c) and MFW (d).

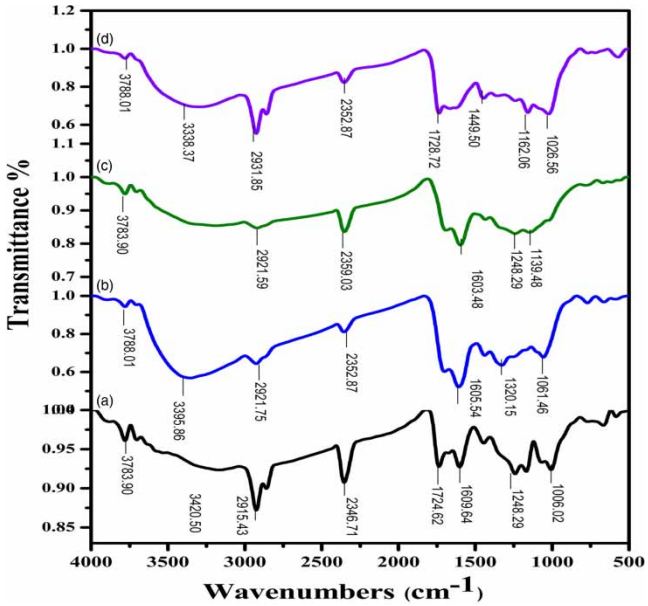


Figure 6 | FTIR spectra of $ZnCl_2$ activated WCVR (a), MFPW (b), WCR (c) and MFW (d).

biodiesel production by the single stage transesterification process. Here, 1 mol of WCO was transesterified with 3 moles of methanol in the presence of alkali catalyst (5 g/L) at 60 °C for 90 min. Biodiesel yield was 97.3%, wash water formation after wet washing was 133 L and crude glycerol (byproduct) yield was 6.9 L. Density, kinematic viscosity and flash point of WCO before and after transesterification are given in Table 2. The properties were determined following ASTM International standards and it is evident that transesterification has yielded a fuel compatible to that used in diesel engines either in pure form or in blends. The collected wash water was characterized: a pH of 10, turbidity of 63 NTU, COD of 150 mg/L and oil and grease of 98 mg/L were determined.

3.4. Adsorption using food waste activate carbon samples

The pH, turbidity, COD, oil and grease of biodiesel wash water before and after treatment are listed in Table 3. It is evident that water quality parameters tested were reduced considerably by treatment with $ZnCl_2$ food waste activated carbon (Bashir *et al.* 2018), paving the way to carry out detailed investigations and optimization of adsorption conditions.

Table 2 | Physiochemical properties of waste cooking oil and biodiesel

Parameters	ASTM standards	WCO properties	WCOBD properties
Density (g/cc)	ASTM D792	0.925	0.875
Kinematic viscosity @ 40 °C (cSt)	ASTM D445	9.38	2.18
Flash point by PMCC method (°C)	ASTM D93	245	189
Fire point by PMCC method (°C)	ASTM D93	261	202
Copper strip corrosion @60 °C	ASTM D130	1a (slight tarnish)	1a (slight tarnish)
Cloud point (°C)	ASTM D2500	12	8
Pour point (°C)	ASTM D2500	4	2
Moisture content (%)	ASTM D2709	2.6	0.021
Acid value	ASTM D664	0.11%	0.218 mg NaOH/g of biodiesel
Calorific value (cal/g)	ASTM D480913	9,598.5	8,522.978

Table 3 | Pollutant removal efficiency of food waste-based activated carbon from biodiesel washwater

Source of activated carbon	pH		Turbidity (NTU)			COD (mg/L)			Oil and Grease (mg/L)		
	Initial	Final	Initial	Final	% Removal	Initial	Final	% Removal	Initial	Final	% Removal
WCVR	10 ± 0.1	7.2 ± 0.2	63 ± 0.008	1 ± 0.1	98.41	150 ± 0.18	91 ± 0.9	39.33	98 ± 0.2	0.938 ± 0.01	99.04
MFPW	10 ± 0.2	6.9 ± 0.3	63 ± 0.1	1 ± 0.23	98.41	150 ± 3	84 ± 0.3	44	98 ± 0.15	0.92 ± 0.08	99.06
WCR	10 ± 0.1	6.8 ± 0.15	63 ± 0.12	1 ± 0.2	98.41	150 ± 0.5	89 ± 0.23	40.66	98 ± 0.21	0.926 ± 0.02	99.05
MFW	10 ± 0.2	6.5 ± 0.21	63 ± 0.8	1 ± 0.3	98.41	150 ± 0.82	88 ± 0.36	41.33	98 ± 0.08	0.925 ± 0.01	99.05

WCVR, Kitchen waste (rice, vegetables, oil and spice); MFPW, Mixed fruit peels; WCR, Mess hall waste (plain rice); MFW, Mixed food waste (rice, dhal, vegetables, fruits, meat and bones).

pH is the measure of alkalinity or acidic nature of a solution. WHO in 1958 instructed that pH for domestic usage of water (drinking, washing, etc.) has to be 6.5–9.2. Later, the pH of commercial usage of water was changed to 6.5–8.5. In this study the effect of activated carbon on pH reduction of biodiesel wash water was explored with 100 mL of wash water, 0.5 g of activated carbon at time of 60 min and agitation at 150 rpm. From the results (Table 3), the pH of the wash water was reduced to 6.5 from 10 for the activated carbon produced from MFW. The pH of wash water was reduced to 7.2, 6.9 and 6.8 respectively when treated with activated carbon produced from other wastes (WCVR, MFPW, WCR) used in the study. Recently, $ZnCl_2$ incorporated activated carbon (3.2 g) produced from wastepaper and cotton reduced the pH to 8.21 from 9.43 with reduction efficiency of 12.9% (Mustafa & Asmatulu 2020).

Turbidity of the solution depends upon the presence of a large number of suspended solids, which results in cloudiness of the solution. Turbidity is also one of the parameters that define the quality of water. Quality of water is inversely proportional to the value of turbidity. The turbidity of drinking water should not exceed 5 NTU (Girotto *et al.* 2015). In this study the effect of food waste activated carbon on turbidity reduction of biodiesel wash water was also explored. From the results (Table 3), it is evident that the turbidity of the wash water reduced to 1 NTU from 63 NTU for the activated carbon produced from mixed food waste (MFW). The turbidity reduction efficiency was 98.41%. The turbidity of the wash water obtained after treatment with activated carbon produced from other wastes (WCVR, MFPW, WCR) was also reduced to 1 NTU respectively. Recently, ZnCl2 incorporated activated carbon (3.2 g) produced treated water of 1.8 NTU from an effluent of 147 NTU with reduction efficiency of 98.77% after removal of 147 NTU turbidity showing 98.77% efficiency (Girotto *et al.* 2015).

It is evident from Table 3, that the COD of the wash water was reduced to 88 mg/L with activated carbon produced from MFW. The COD reduction efficiency was 41.33% .The COD of the wash water treated with activated carbon produced from other wastes (WCVR, MFPW, WCR) were 91, 84 and 89 mg/L, respectively. The oil and grease was reduced to 0.952 mg/L from 98 mg/L under the optimum adsorption conditions when MFW activated carbon was used. The removal efficiency of activated carbon with respect to oil and grease was found comparable at 99.5% (Santos *et al.* 2020). The activated carbon

produced from other waste (WCVR, MFPW, WCR) also proved effective in oil and grease reduction to 0.938, 0.925 and 0.926, respectively.

4. CONCLUSION

As outcomes of this study, the fixed carbon percentages of MFW samples were found to be between 22 and 23% which shows the applicability of MFW samples for the synthesis of $ZnCl_2$ activated carbon nanomaterial as evident from the FESEM data indicating nanoparticles of 44.87 nm. The uniform pore mesoporous distribution surface of $ZnCl_2$ activated adsorbent was been observed under FESEM analysis, and is an important factor required for the use of activated carbon in water treatment. The $ZnCl_2$ activated food waste carbon proved effective in treating biodiesel wash water as it reduced the pH to neutral, turbidity to 1 NTU, COD to 88 mg/L and oil and grease to 0.925, making the treated water suitable for reuse.

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CONFLICT OF INTEREST

None.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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