SYNTHESIS AND CHARACTERIZATION OF NANO ALUMINIUM OXIDE FROM WASTE ALUMINIUM CANS

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Abstract

The majority of the energy drinks are labelled as "canning" (in which aluminum sheet is commonly used). Can is a waste material that pollutes our environment. This research aims to take advantage of aluminium waste cans (Coca Cola) by using them as raw materials for preparing alumina (Al_2O_3) by the co-precipitation method. The synthesis of α-Al_2O_3 from waste aluminium cans is presented in this study. The proposed technique was the precipitation of aluminum chloride with NaOH to produce aluminium hydroxide. The obtained Al $(OH)_3$ was washed, crushed, and dried at 105 °C, and then it was converted to alumina by calcination using different calcination temperatures (500, 600, 700 and 800°C) for 2 h. The prepared aluminium oxide nanoparticles were characterized by EDXRF, FT IR, SEM and XRD techniques. The γ-Al_2O_3 phase was found in the sample calcined at 600 °C, according to XRD data. The methodology has the capability to produce nano-alumina powder; the average crystal size was 30.05– 51.49 nm. Furthermore, the SEM image of these samples revealed that the γ-Al_2O_3 phase had an irregular spherical shape. Thus, the use of waste aluminium can precursors simplifies the process, and the synthesized alumina is a valued added material.

Keywords*:* Waste aluminium can, co-precipitation method, nano-alumina

Introduction

Aluminium is one of the most valuable component materials of municipal refuse in terms of cigarette and candy casings, cans, wrapping foil, doors, siding, car machine and body portions, icy food dishes, pie plates and other various domestic waste. Aluminium waste is known by various names, including dross, salt cake, baghouse fines, and others. Aluminium waste recycling is important to the environment (Nada *et al.*, 2017). Aluminium waste can be recycled to yield numerous beneficial products (such as alumina). Therefore, many studies have focused on the use of waste for several applications. Aluminium oxide (Al_2O_3) is the only oxide formed by the metal aluminium. Aside from α-Al_2O_3, other types of metastable alumina include ρ, γ, η, θ, δ, χ and κ-Al_2O_3 (Noor *et al.*, 2019).

Alumina has many appealing properties, which make the material interesting for applications in many different areas. It is a very hard substance, and its hardness is exceeded only by diamond and a little artificial material (Hosseini and Khosravi, 2016). Al_2O_3 is an electrical insulator with high thermal conductivity; it is also used in the glass industry as a catalyst and as filler. Alumina adsorbents are widely used as desiccants in both heated (temperature swing adsorption) and heatless (pressure swing adsorption) dryers (Bayus *et al.*, 2016).

In addition, alumina is widely used as an adsorbent to remove dissolved pollutants from contaminated water (Kumar *et al.*, 2006). Accordingly, in the present work, the synthesis of nano alumina powder is achieved by the simple and cost effective, co-precipitation method using NaOH as precipitant and aluminium waste as raw material in order to get rid of those wastes by turning it into a useful product (Das *et al.*, 2007)

In the present research, alumina nanomaterials were synthesized by the sol-gel method using waste aluminium cans as a precursor.

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Materials and Methods

Synthesis of Aluminium Oxide

Waste aluminium cans (Coca Cola) were boiled in a water bath at 100 °C for 30 min, and then treated with acetone to remove dyes and the internal covering polymer before being cut up into aluminium pieces. The obtained aluminium pieces were treated with a digestive substance, hydrochloric acid, in concentrations of 2, 4 and 6 M, each on its own, as follows: Five grams of prepared aluminium pieces were weighed and then they were digested in 100 mL of hydrochloric acid. The sample was stirred by a magnetic stirrer for 60 min to obtain an $AlCl_3$ solution. The aluminium chloride solution was filtered to remove the impurities. And then, NaOH solution (5M) was added dropwise, producing aluminium hydroxide. The precipitate was washed several times with distilled water. The precipitate was then filtered, dried at 90 °C for 24 h and calcined at four different temperatures ranging from 500 to 800 °C for 2 h. Finally, aluminium oxide nanoparticles were obtained.

Characterization of Prepared Aluminium and Aluminium Oxide

The purity of aluminium and alumina was characterized by an Energy Dispersive X-Ray Fluorescence spectrometer (EDXRF -700 spectrometer, Shimadzu, Japan), and the measurement was performed in accordance with the recommended standard as reported in the EDXRF spectral catalogue. The functional groups of prepared alumina were evaluated by FT IR spectrometer. The surface morphology of the prepared sample was studied with a Scanning Electron Microscope (JSM-5610, JEOL Ltd., Japan). The prepared alumina was identified and characterized by X-Ray Diffraction Spectrometer (Regaku X-ray diffractometer, RINI 2000/PC software, Cat. No. 9240 J 101, Japan) in accordance with the recommended standard as reported in the catalogue.

Results and Discussion

Characterization of Waste Aluminium Cans and Prepared Aluminium Oxide Materials

EDXRF analysis

The elemental compositions of waste aluminium cans and prepared alumina were confirmed by EDXRF analysis. The relative abundance of elements in the waste aluminium can (Coca Cola) is shown in Table 1 and Figure 1. The purity percent of aluminium (Al) is 95.30 % and it is the main constituent in waste aluminium can. The purity of aluminium oxide present in prepared alumina samples at different HCl concentrations and different calcination temperatures was evaluated by EDXRF and the results are shown in Figures 2- 4 and Tables 2-4. The prepared alumina materials contained 37.09 to 56.14 % alumina (Al_2O_3).

Table 1. Relative Abundance of Elements in Waste Aluminium Can (Coca Cola)

Elements	Relative abundance (%)
Mg	0.935
Al	**95.300**
Si	0.661
P	0.425
S	0.056
Ti	0.034
V	0.013
Cr	0.038
Mn	1.240
Fe	0.719
Co	0.007
Ni	0.011
Cu	0.263
Zn	0.102
Ga	0.015

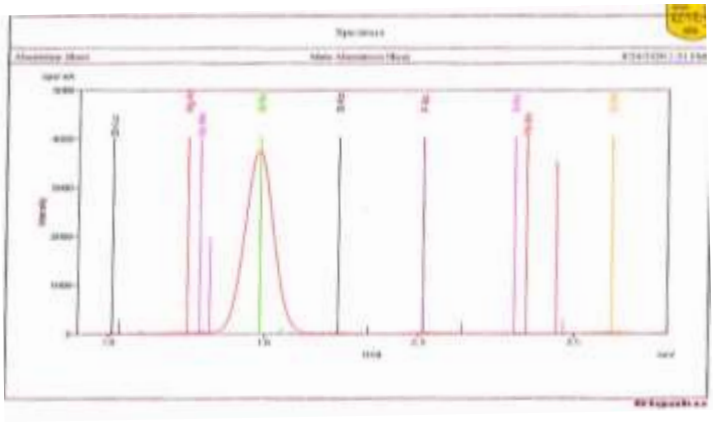
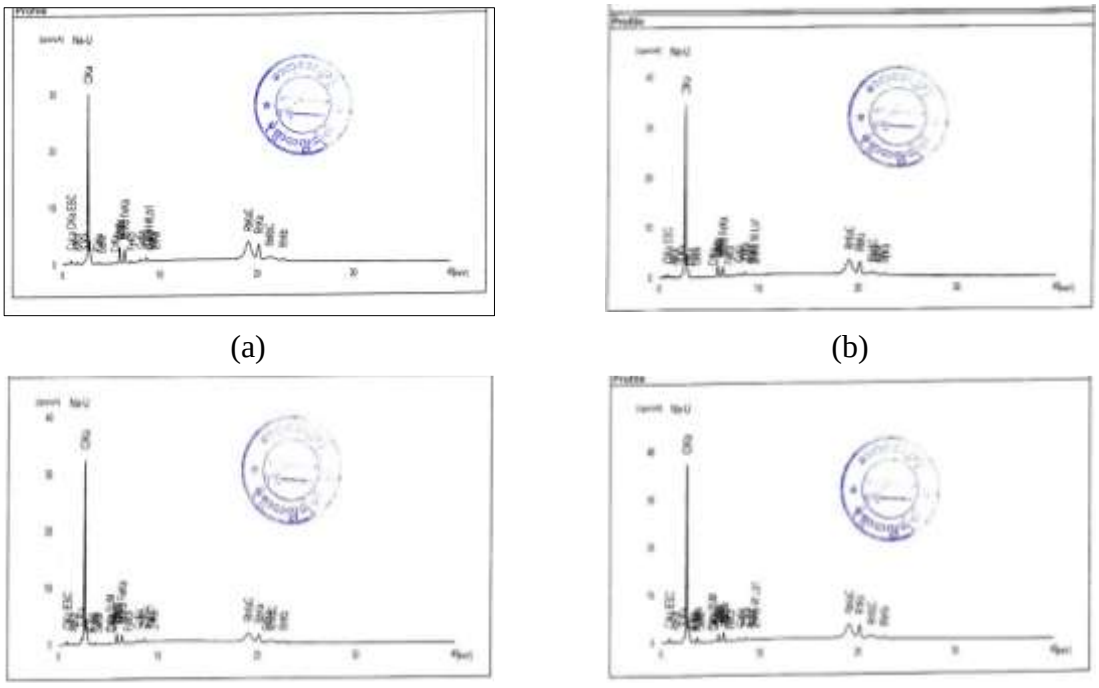


Figure 1. EDXRF spectrum of aluminium waste can (Coca Cola)

Table 2. EDXRF Analysis of Elements Present in Al_2O_3 Powder at Different Calcination Temperatures for 2 M HCl

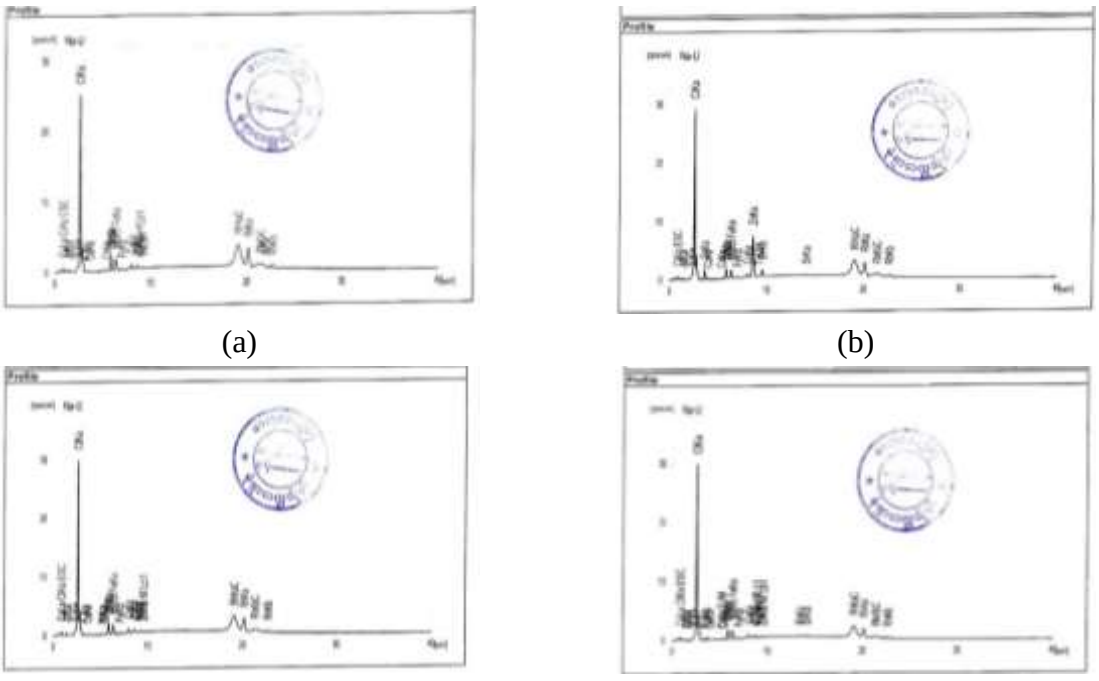
Calcined temperature (°C)	Relative abundance (%)
500	52.27
600	42.04
700	37.09
800	56.14



(a) (b)

(c) (d)

Figure 2. EDXRF spectra of prepared Al_2O_3 nanoparticles calcined at (a) 500 °C, (b) 600 °C, (c) 700 °C and (d) 800 °C for 2 M HCl



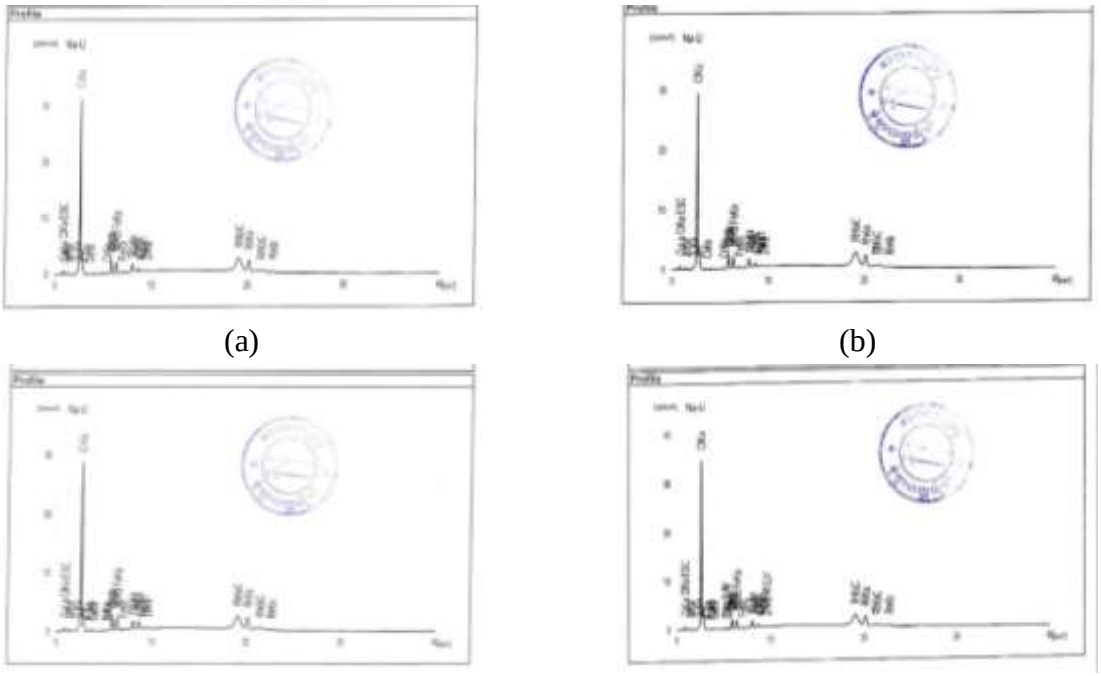
(a) (b)

(c) (d)

Figure 3. EDXRF spectra of prepared Al_2O_3 nanoparticles calcined at (a) 500 °C, (b) 600 °C, (c) 700 °C and (d) 800 °C for 4 M HCl

Table 3. EDXRF Analysis of Elements Present in Al_2O_3 Powder at Different Calcination Temperatures for 4 M HCl

Calcined Temperature (°C)	Relative abundance (%)
500	56.14
600	48.54
700	53.79
800	41.15



(a) (b) (c) (d)

Figure 4. EDXRF spectra of prepared Al_2O_3 powder calcined at (a) 500 °C, (b) 600 °C, (c) 700°C and (d) 800 °C for 6 M HCl

Table 4. EDXRF Analysis of Elements Present in Al_2O_3 Powder at Different Calcination Temperatures for 6 M HCl

Calcined temperature (°C)	Relative abundance (%)
500	47.40
600	47.14
700	53.29
800	38.01

FT IR analysis of selected Al_2O_3 nanoparticles

FT IR spectrum of selected aluminium oxide nanoparticles is shown in Figure 5. The characteristic peaks of aluminium oxide were depicted in Table 5. The Peaks at 611 $cm^{-1}$and 631 cm^{-1} are assigned to the aluminium oxide stretching. The peak at 1128.36 cm^{-1}indicates the triply

degenerative vibrational mode of chloride ion. The peaks at 1639.49 $cm^{-1}$and 3473.80 cm^{-1} are assigned to the bending and stretching vibration mode of O-H.

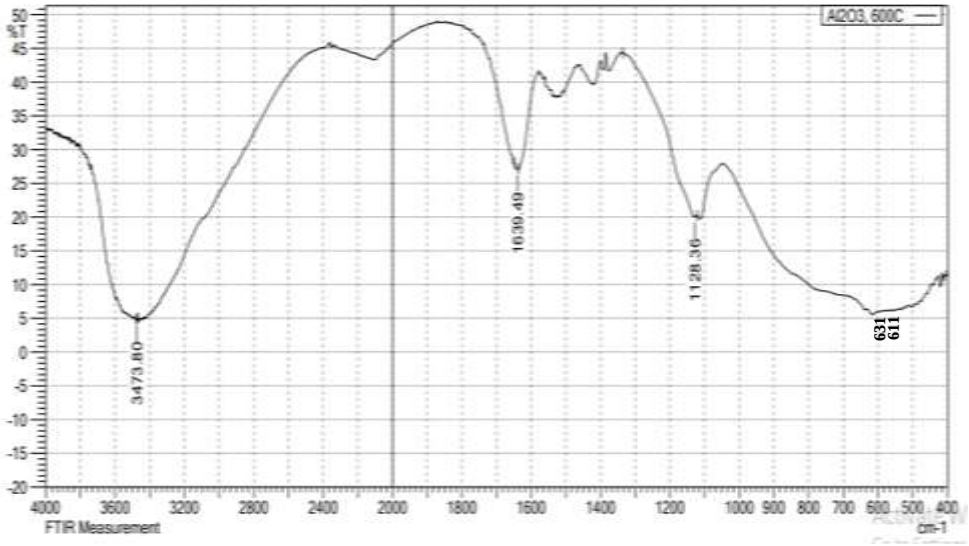


Figure 5. FT IR analysis of selected Al_2O_3 nanoparticles

Table 5. FT IR Band Assignment of Prepared Alumina

Wavenumber (cm^{-1})		Band assignments
Prepared alumina	***Literature**	
3473.80	3526	O-H stretching
1639.49	1646	O-H bending
1128.36	1127	Triply degenerative vibrational mood of Chloride ion
611	615	Al-O stretching
631	636	Al-O stretching

* Manyasree *et al.*, 2018

SEM analysis of prepared Al_2O_3

The morphology of prepared alumina was examined by the SEM analysis, and the SEM image is shown in Figure 6. The surface morphology of aluminium oxide consists of smaller crystal agglomerates. It is apparent that this feature influences the final crystal size of calcined samples, as can be seen in Figure 6. Heat-treated powders at 600 °C for 2 h form agglomerates of submicrometer crystals. From the XRD results, the measured crystal size was 30.05 to 51.49 nm for obtained alumina samples from aluminum hydroxide.

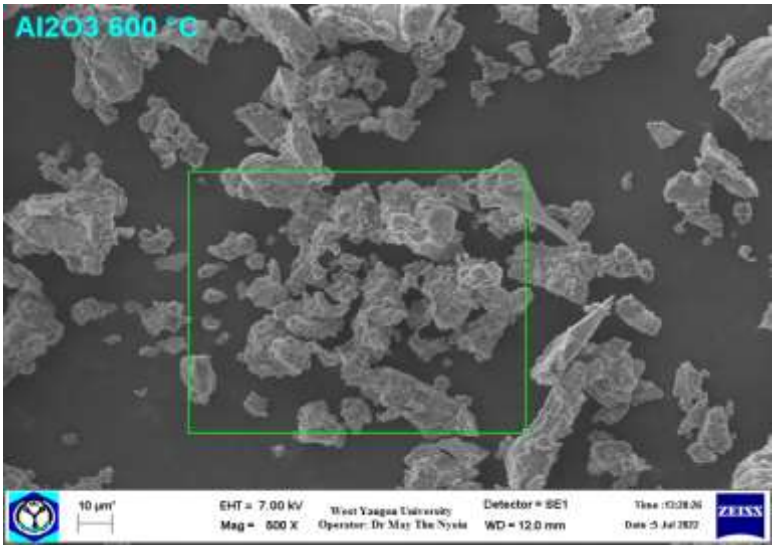


Figure 6. SEM microphotograph of selected Al_2O_3 nanoparticles

XRD analysis

The XRD diffraction patterns of different calcination temperatures and different concentrations of hydrochloric acid are shown in Tables 6, 7, and 8 and Figures 7, 8, and 9. As shown in figures, the XRD peaks can be assigned to alumina structure characterized by 2θ values at 31°, 45°, and 66°, respectively. It was obvious from Figure 7 that those increasing calcinations temperature to 600ºC showed a comparable pattern with the characteristic peaks located at 2θ of 31.27°, 45.01°, 64.22° and 65.78°, respectively.

Table 6. XRD Data of Prepared Alumina Using 2 M HCl

No.	Calcined Temperature (°C)	2θ values (degree)	Average crystallite size (nm)	Crystal system
1	500	27.15,31.49,45.25,56.01, 65.78	48.89	Cubic
2	600	31.27, 45.01, 56.01, 64.22, 65.78	33.73	Cubic
3	700	31.34,45.04,53.48, 56.09, 65.82	30.05	Cubic
4	800	31.59,45.33,56.33, 66.09	47.99	Cubic

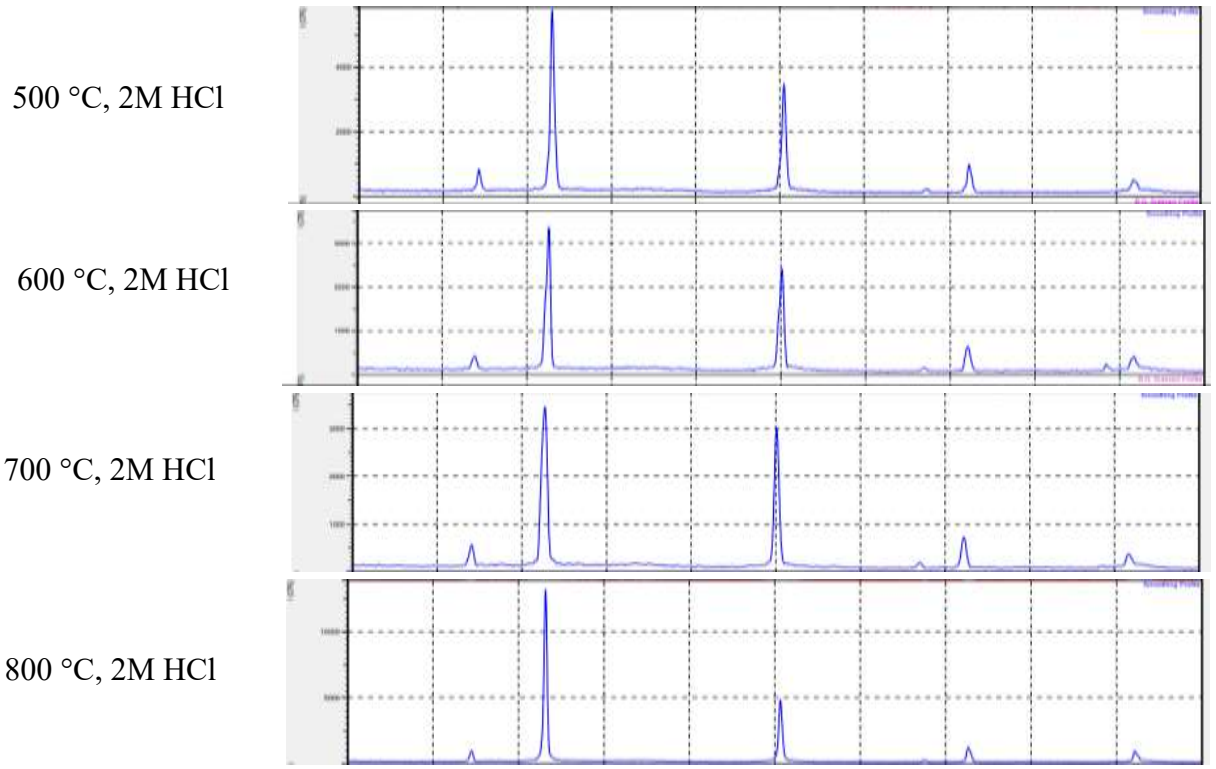


Figure 7. X-ray diffractograms of prepared Al_2O_3 nanoparticles calcined at 500°C, 600°C, 700°C and 800°C using 2 M HCl

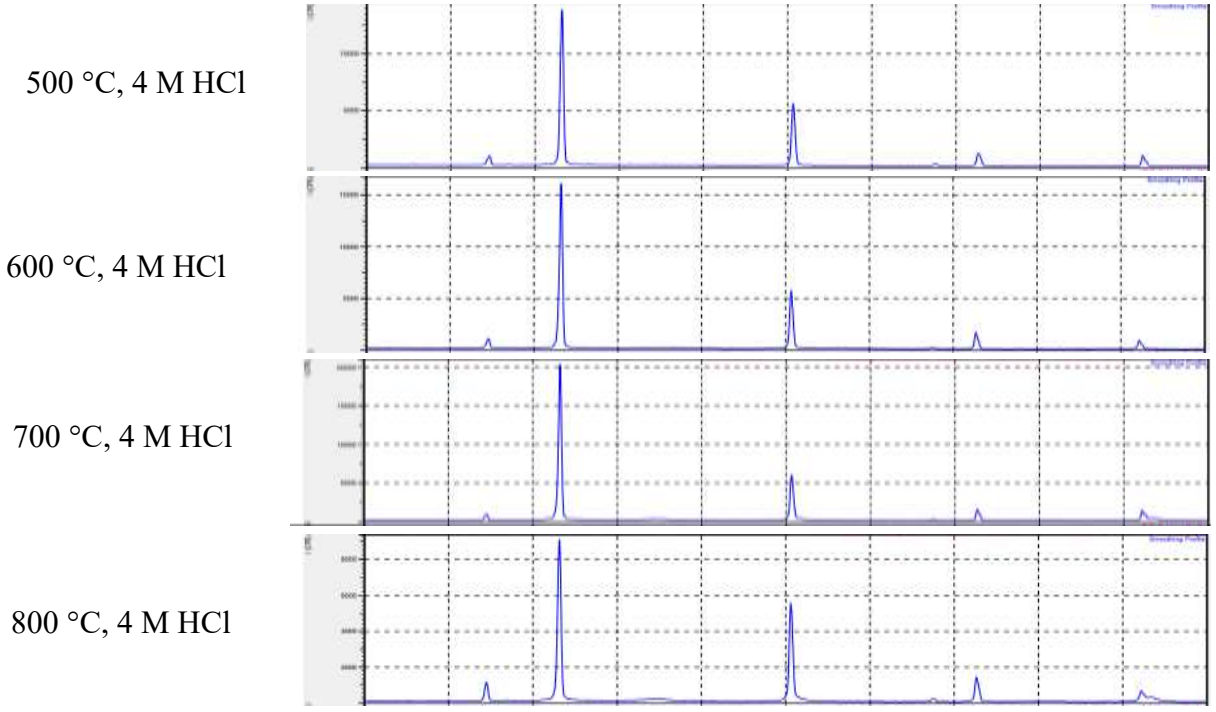


Figure 8. X-ray diffractograms of prepared Al_2O_3 nanoparticles calcined at 500 °C, 600 °C, 700°C and 800 °C using 4 M HCl

Table 7. XRD Data of Al_2O_3 Nanoparticles Using 4 M HCl

No.	Calcined Temperature (°C)	2θ values (degree)	Average crystallite size (nm)	Crystal system
1	500	31.60,45.33,56.33, 66.11	48.03	Cubic
2	600	31.63,45.34,56.36, 66.11	50.56	Cubic
3	700	31.63,45.33,56.34, 66.10	51.97	Cubic
4	800	31.58,45.31,56.33, 66.11	34.17	Cubic

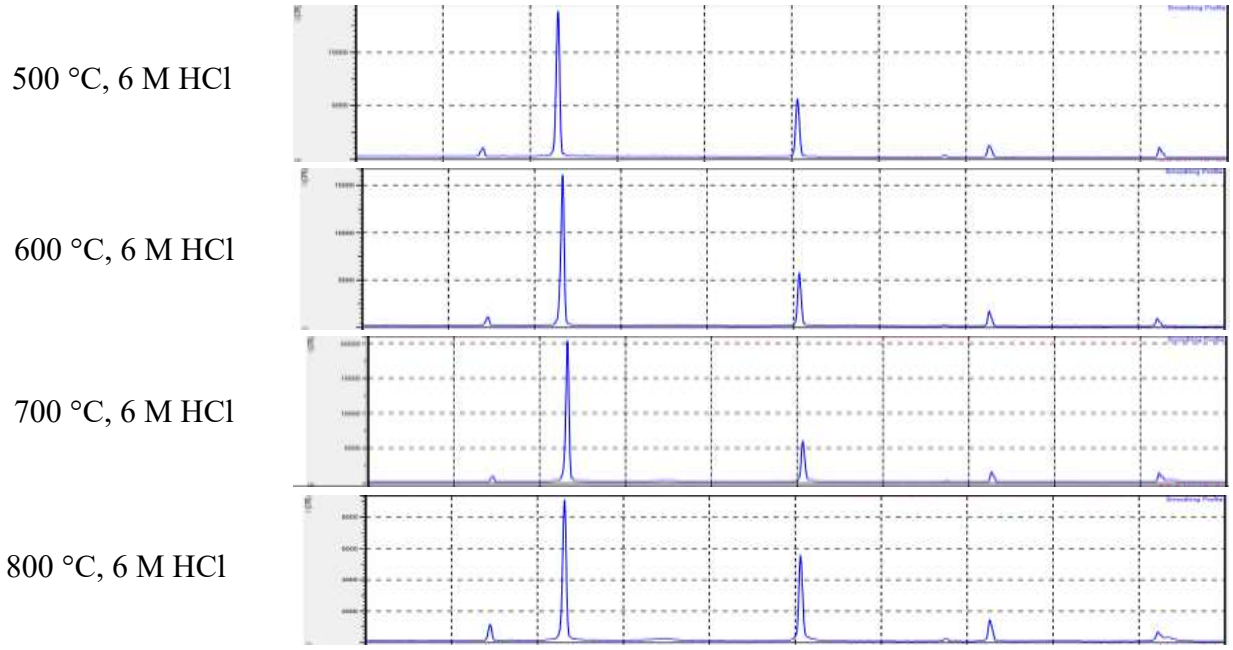


Figure 9. X-ray diffractograms of prepared Al_2O_3 nanoparticles calcined at 500 °C, 600°C, 700 °C and 800 °C using 6 M HCl

Table 8. XRD Data of Al_2O_3 Nanoparticles Using 6 M HCl

No.	Calcined Temperature (°C)	2θ values (degree)	Average crystallite size (nm)	Crystal system
1	500	31.62,45.39, 56.38, 66.14	44.98	Cubic
2	600	31.61,45.35, 56.38, 66.13	51.49	Cubic
3	700	31.19,45.13,55.97,64.25,65.73	53.77	Cubic
4	800	31.33,45.08, 56.08, 65.88	46.40	Cubic

The relationships between calcination temperature and crystallite sizes of samples are illustrated in Tables 6, 7, and 8. The crystallite sizes showed an increasing trend from 30.05 to 51.97 nm with increasing the calcination temperature from 500 to 700 ºC; however, the crystallite size was significantly decreased at 800 °C for three different concentrations of HCl. It can be proved that the prepared alumina contains alumina nanoparticles. Moreover, it contains noticeable that alumina calcined at 550, 600, and 700 ºC had identical XRD peaks positions and cubic crystal structure.

Conclusion

Starting with waste aluminium cans, alumina was synthesized. The current study demonstrated the feasibility of recycling waste aluminium cans into valuable nanoparticles of alumina via co-precipitation. FT IR spectra of selected aluminium oxide nanoparticles have shown that the peaks at 611 cm^{-1} and 631 cm^{-1} were assigned to Al-O (Al_2O_3) stretching. According to the XRD results, the smallest size of alumina nanoparticles was found at 2 M HCl and calcination temperature at 600°C, and its crystallite size is 33.73 nm in comparison with 30.05 nm of higher temperature (800°C), considering the energy saving aspect. The obtained alumina crystalline powders had crystallite sizes ranging from 30 to 52 nm indicating that the prepared alumina composed of alumina nanoparticles. It can be considered that this type of compound is a good candidate for the green light because its preparation is simple, has a low economic cost, and reduces the environmental pollution of waste cans.

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