

# Inhibitive tendency of zinc gluconate for aluminium alloy in sulphuric acid solution

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The corrosion inhibition of aluminium alloy in 0.5M H<sub>2</sub>SO<sub>4</sub> solution in the presence of zinc gluconate at 301 K was investigated using weight loss and an electrochemical method. Surface analysis of the aluminium alloy sample was reviewed by a high resolution scanning electron microscope equipped with energy dispersive spectroscopy (HR-SEM/EDS). The readings were taken after 48 h for 28 days while the concentration of the inhibitor was varied from 0.5 to 2.0% g/v with an interval of 0.5. The result of the investigation shows that zinc gluconate has a good corrosion inhibition effect for aluminium alloy in 0.5 molar sulphuric acid solution and its efficiency attains more than 67% at 1.5% g/v concentration of zinc gluconate at 301 K. The potentiodynamic polarization data showed that zinc gluconate acts as a mixed type corrosion inhibitor. The adsorption of zinc gluconate on aluminium alloy has been found to obey Freundlich adsorption isotherm at all the concentration of zinc gluconate studied. The results obtained from different methods are in good agreement.

**Keywords:** aluminium, zinc gluconate, inhibition, weight loss, potentiodynamic polarization, SEM/EDS.

## INTRODUCTION

Aluminium and its alloy are broadly used for different applications such as building construction, containers and packaging, transportation, machinery and equipment. It is due to their favorable mechanical properties, low density, good electrical and thermal conductivities, high ductility, relatively good corrosion resistance, availability<sup>1, 2, 3</sup>. However, it is well-known that aluminium is susceptible to corrosion, especially pitting corrosion in aggressive solution and as a result, a number of studies have been carried out on the corrosion behavior of aluminium and its alloy in various environments<sup>4</sup>. Addition of corrosion inhibitor to corrosive medium to impede corrosion has been known as one of the practical and effective means of preventing corrosion of metals in acidic media<sup>5</sup>. Diverse attempts have been made to study the corrosion inhibition by organic inhibitors in acid solution<sup>6-9</sup>. The reports also show that various organic compounds containing hetero atoms like N, O, S and multiple bonds in their molecules have been proved to be effective inhibitors for the corrosion of aluminum alloys in acid and alkaline media<sup>4, 10</sup>.

Methods such as weight loss<sup>1, 2</sup>, hydrogen evolution<sup>11</sup> and polarization<sup>1</sup> have been used in corrosion inhibition studies of aluminium alloy. A number of studies have appeared in literatures regarding the topic of the corrosion of aluminium alloy in acidic solution. Titanium (iv) oxide<sup>12</sup>, organic compounds<sup>13-17</sup>, dyes<sup>18</sup>, natural products<sup>3</sup> have been studied and proved to be good corrosion inhibitors for aluminium alloy in acidic media. A perusal of literature revealed that zinc gluconate has not been studied as a corrosion inhibitor for aluminium alloy in the acidic medium. In the present work, the inhibitive effectiveness of zinc gluconate has been studied in retarding corrosion of aluminium alloy in 0.5 M H<sub>2</sub>SO<sub>4</sub> solution. Weight loss, potentiodynamic polarization and high resolution scanning electron microscopy equipped

with energy dispersive spectroscopy (HR-SEM/EDS) techniques were used to study the inhibiting effect of zinc gluconate.

## EXPERIMENTAL TECHNIQUES

### Materials

The material used was aluminium alloy specimen and the chemical composition is given in Table 1. Rectangular specimens of aluminium alloy of size 12 × 12 x 2 mm and thickness 3 mm with a small hole of about 3 mm diameter at the centre of the specimen were used for the determination of weight loss. The specimens were polished using standard metallographic practice-belt grinding followed by abrading on emery papers of 80, 120, 600, 800, 1000 and 1200 grades, finally on a polishing wheel to obtain mirror-like finish, degreased with acetone, washed with double distilled water and dried before immersing in the acid medium. The samples used for potentiodynamic polarization measurement were connected to an insulated copper wire to one side of the sample using an aluminum conducting tape and cold mounted using cold setting methyl methacrylate resin, so that the exposed surface area of the metal to the medium is 1.0 cm<sup>2</sup>.

### Medium

The corrosive solution (0.5M H<sub>2</sub>SO<sub>4</sub>) used for the investigation was prepared by dilution of the analytical grade of concentrated sulphuric acid with double distilled water. The experiment was carried out at 301 K. The inhibitive action of zinc gluconate on the corrosion of aluminium alloy in 0.5M H<sub>2</sub>SO<sub>4</sub> solution was studied by introducing different concentrations of zinc gluconate ranging from 0.5 to 2.0% g/v with an interval of 0.5 into the solution.

**Table 1.** The chemical composition of the aluminum alloy used (%wt.)

Si	Fe	Cu	Mn	Mg	Cr	Ti	Ca	Zr	V	Al
0.157	0.282	0.0025	0.024	0.51	0.023	0.006	0.0011	0.002	0.0035	Balance

## Weight loss method

In the weight loss method, the specimens were exposed to 0.5 M  $\text{H}_2\text{SO}_4$  solution in the absence and presence of different concentrations of zinc gluconate in the range 0.5 to 2.0% g/v. The specimens were suspended by a glass hook in each beaker containing 200 ml of the test solution which was open to the air at 301 K. The samples were degreased in ethanol, dried, weighed and stored in a desiccator in order to avoid a prolonged exposure to the atmosphere. The experiment was carried out for 28 days and the readings were taken at an interval of 48h<sup>19</sup>.

## Electrochemical measurements

Electrochemical experiments were carried out using a standard electrochemical three-electrode cell. Aluminium alloy was used as working electrode, graphite rod as counter electrode and saturated calomel electrode (SCE) as reference electrode. The finely polished aluminium alloy specimens were exposed to corrosion medium of sulphuric acid in the absence and presence of different concentrations of zinc gluconate at 301 K using an AUTOLAB Potentiostat (Model Reference-668). The Tafel plots were recorded by polarizing the specimen to  $-1.5$  V cathodically and  $+1.5$  V anodically with respect to the corrosion potential ( $E_{\text{corr}}$ ) at a scan rate of 0.0016 V/Sec. From the Tafel corrosion analysis, corrosion rate (CR), corrosion potential ( $E_{\text{corr}}$ ), linear polarization resistance ( $R_p$ ) and corrosion current density ( $i_{\text{corr}}$ ) were obtained in a static solution<sup>19</sup>.

## SEM/EDS ANALYSIS

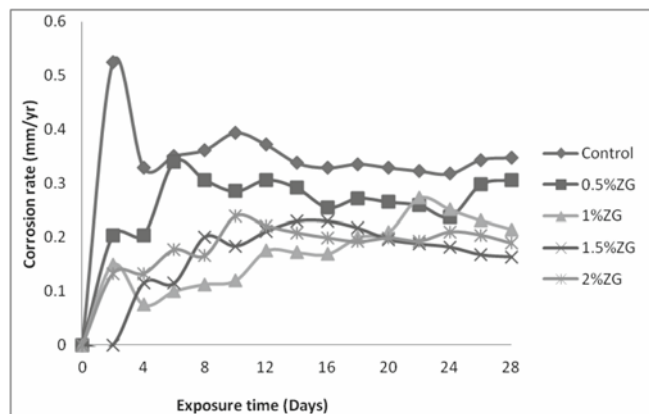
The surface morphology of the aluminium alloy samples in the absence and presence of zinc gluconate was investigated after the weight loss test using Jeol JSM – 7600 F. The SEM/EDS images with magnification 200 $\mu\text{m}$  of the metal surfaces after weight loss tests were taken.

## RESULTS AND DISCUSSION

### Weight loss method

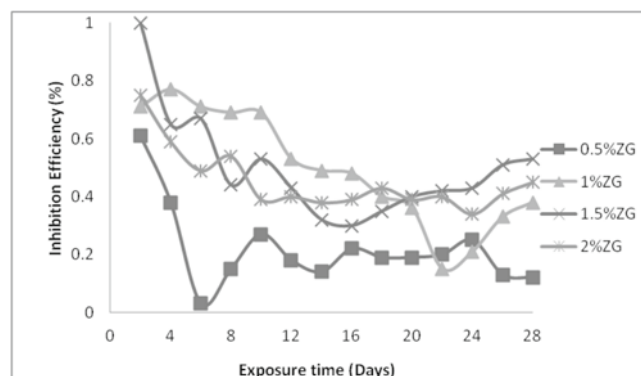
#### Corrosion rate and inhibition efficiency

The corrosion rate of aluminium alloy in the absence and presence of zinc gluconate at 301 K was studied using the weight loss method. Figure 1 shows the va-



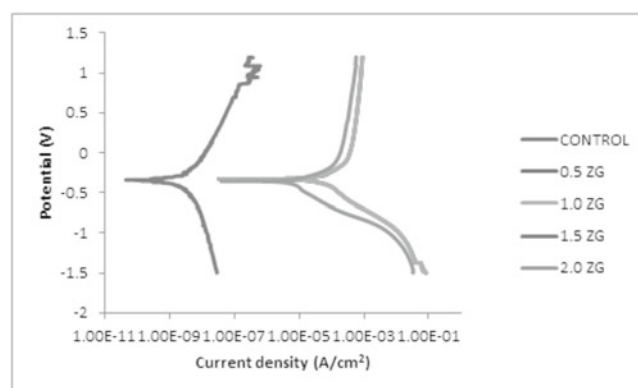
**Figure 1.** Variation of corrosion rate with exposure time for aluminium alloy specimen immersed in 0.5M  $\text{H}_2\text{SO}_4$  solution with varied percent concentrations of added zinc gluconate

riation of corrosion rate of aluminium alloy specimen with exposure time in the absence and presence of different concentrations of ZG. This indicates that in the absence of ZG, the corrosion rate of aluminium alloy specimen increased to 0.393 mm/yr after 10 days of exposure time to the corrosive medium. After 10 days, there was a slight decrease in the corrosion rate value of the aluminium alloy specimen, and the corrosion rate after 28 days of exposure time was 0.346 mm/yr. There was a reduction in the corrosion rate in the presence of all the studied concentrations of ZG from 0.5 to 2.0% g/v with an interval of 0.5. The results show that the inhibitor inhibited the corrosion of aluminium alloy in 0.5 M  $\text{H}_2\text{SO}_4$  solution. The variation of inhibition efficiency (IE) of aluminium alloy in 0.5M  $\text{H}_2\text{SO}_4$  solution in the presence of different concentrations of ZG is shown in Fig. 2. The inhibition efficiency was found to depend on the concentration of the inhibitor. As the concentration of the inhibitor increases, the inhibition efficiency (%IE) also increases. The inhibitory action of the inhibitor against aluminium alloy corrosion can be ascribed to the adsorption of ZG molecules on the aluminium alloy surface, which confines the dissolution of the latter by blocking the corrosion sites and thus decreasing the corrosion rate, with increasing inhibition efficiency as the concentration increases. Similar reports have been reported elsewhere<sup>20, 21</sup>.



**Figure 2.** Variation of inhibition efficiency with exposure time for the aluminium alloy specimen immersed in 0.5M  $\text{H}_2\text{SO}_4$  solution with varied percent concentrations of added zinc gluconate

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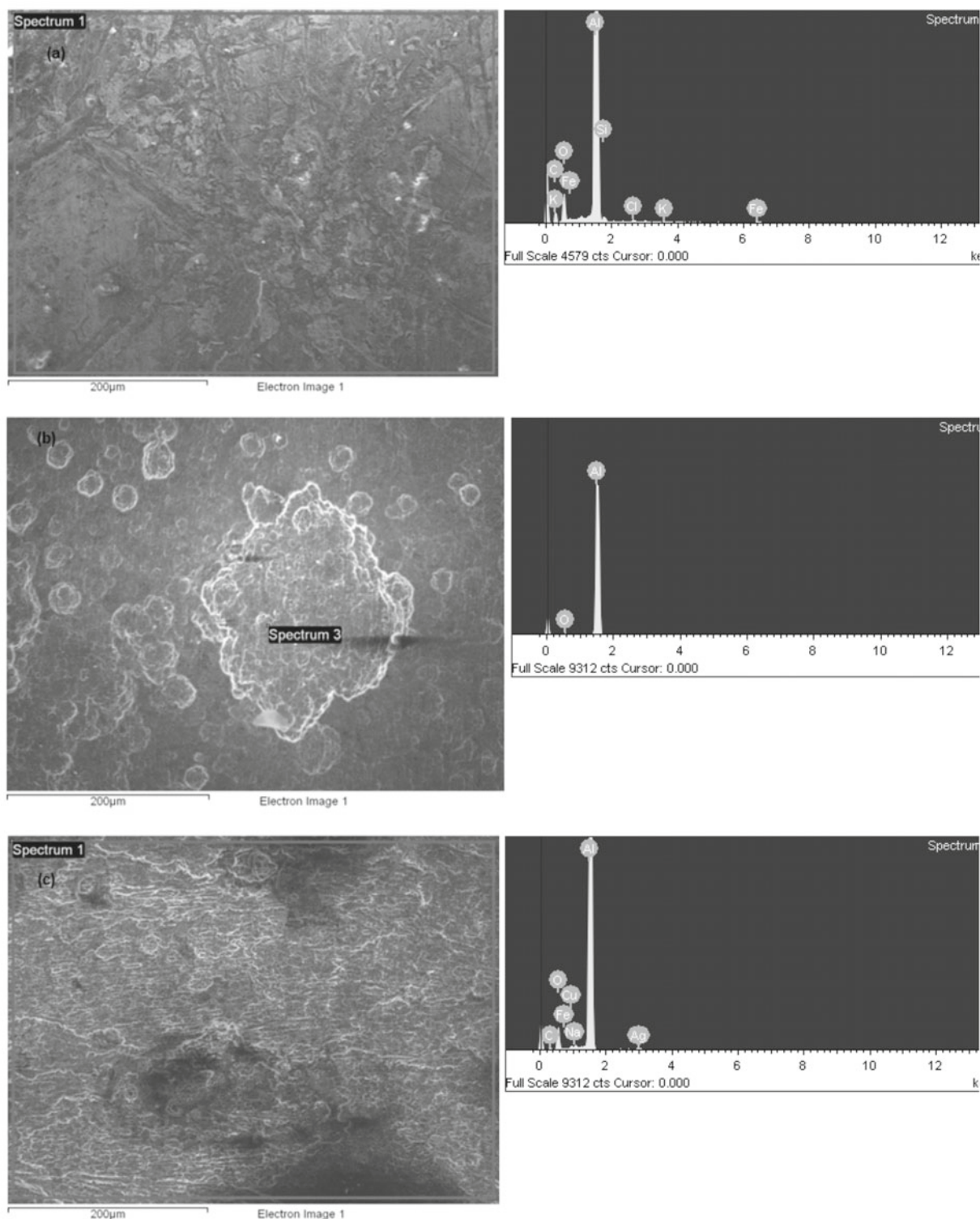


**Figure 3.** Linear polarization curves for aluminium alloy in 0.5M  $\text{H}_2\text{SO}_4$  solution in the absence and presence of different concentrations of ZG at 301K

## ELECTROCHEMICAL TECHNIQUES

Table 2 shows the electrochemical corrosion kinetics parameters; corrosion potential ( $E_{\text{corr}}$ ), corrosion rate (CR), linear polarization resistance ( $R_p$ ), anodic and cathodic Tafel slopes ( $\beta_a$  and  $\beta_c$ ) and corrosion current density ( $i_{\text{corr}}$ ) obtained by extrapolation of the Tafel lines. Figure 3 shows the polarization curves for the inhibition of aluminium alloy in the absence and presence of different concentrations of ZG. It can be seen that by increasing the inhibitor concentration, the corrosion rate decreased while the linear polarization values increased. The addition of ZG decreases the corrosion current

density ( $i_{\text{corr}}$ ) values significantly at all the studied concentrations due to the increase in the blocked part of the metal surface by adsorption. It is also obvious from this study that the inhibition of aluminium alloy is based on both cathodic and anodic control, thus ZG can be classified as a mixed type inhibitor. No definite trend was observed in the shift of corrosion potential ( $E_{\text{corr}}$ ) values in the presence of all the studied concentrations of ZG, suggesting that zinc gluconate act as a mixed type inhibitor. Also, the inhibitor causes no change in the anodic and cathodic Tafel slopes, indicating that the inhibitor is adsorbed onto the aluminium alloy surface



**Figure 4.** SEM micrographs of the surface of aluminium alloy samples after weight loss test in 0.5M  $H_2SO_4$  solution (a) as-received aluminium alloy (b) Without ZG (c) With 0.5% g/v ZG



**Table 2.** Electrochemical kinetic parameters obtained for aluminium alloy in 0.5M H<sub>2</sub>SO<sub>4</sub> solution in the absence and presence of different concentrations of ZG at 301K

S/N	C(% g/v)	I <sub>corr</sub> (A/cm)	ba(v/dec)	bc(v/dec)	LPR Rp(Ωcm <sup>2</sup> )	-E <sub>corr</sub> (V)	CR(mm/yr)
1	0	1.73E-05	0.025551	0.12493	532.51	0.33054	0.5596
2	0.5	6.46E-06	0.054932	0.032904	1382.6	0.33054	0.20909
3	1.0	5.43E-06	0.042048	0.035871	1547.6	0.33054	0.17571
4	1.5	6.30E-09	0.89218	1.7276	4.06E+07	0.34318	0.000206
5	2.0	3.78E-06	0.17278	0.07264	5872.6	0.35751	0.12369

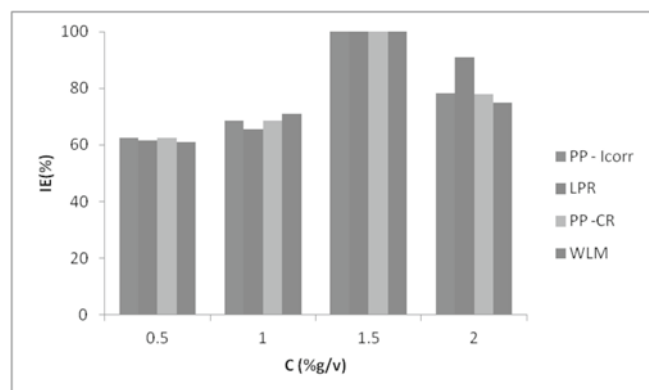
### SEM/EDS ANALYSIS

The surface morphology of aluminium alloy specimens exposed to 0.5 M H<sub>2</sub>SO<sub>4</sub> solution in absence and presence of ZG after weight loss tests were examined by high resolution scanning electron microscopy equipped with energy dispersive spectroscopy (HR-SEM/EDS). Figure 4 shows the SEM/EDS images of aluminium alloy surface before and after immersed in 0.5M H<sub>2</sub>SO<sub>4</sub> solution in the absence and presence of 0.5% g/v concentration of ZG. It was clear that the specimen surface was damaged in the absence of inhibitor due to the metal suspension in the acidic solution. A large number of pits with a large size of cracks distributed over the surface are seen (Fig. 4b). However, minimal pits and cracks were observed in the micrograph in the presence of 0.5% g/v concentration of ZG to the acidic solution (Fig. 4c). Inhibitor molecules adsorbed on active sites of aluminium alloy and a smoother surface was observed when compared to the surface of the as-received aluminium alloy specimen (Fig. 4a).

### Inhibition efficiency and Adsorption behavior

The computed data for the percentage inhibition efficiency (%IE) using potentiodynamic polarization-corrosion rate (PP-CR), potentiodynamic polarization-corrosion current density (PP-icorr), linear polarization resistance (LPR) and weight loss method (WLM) are presented in Fig. 5 for 0.5 molar sulphuric acid solution at different concentrations of ZG. From the given graph, it is evident that the given data obtained by different methods are in good correlation at all the concentrations of the inhibitor studied.

Essential information on the interaction between the organic compounds and metal surface can be provided from the adsorption isotherms. The values of surface coverage ( $\theta$ ) for the different concentration of zinc



**Figure 5.** The comparative chart of inhibition efficiency (IE) for aluminium alloy in 0.5M H<sub>2</sub>SO<sub>4</sub> solution in the presence of different concentrations of ZG obtained from Weight loss and electrochemical methods

gluconate at 301K have been used to explain the best adsorption isotherm to determine the adsorption process of zinc gluconate on aluminium alloy. Some adsorption isotherms (Langmuir isotherm, Freundlich isotherm and Temkin isotherm) were tested for the description of adsorption behavior of zinc gluconate and it was found that adsorption of zinc gluconate on aluminium alloy surface in 0.5M H<sub>2</sub>SO<sub>4</sub> solution obey the Freundlich adsorption isotherm. The Freundlich plots of log  $\theta$  vs log C for adsorption of ZG is given in Fig 5. Which gave straight lines with a regression coefficient (R<sup>2</sup>) close to 1, showing adsorption of ZG in acidic solution is best fitted to the Freundlich adsorption isotherms.

### CONCLUSIONS

The present study leads to the following conclusions in controlling the corrosion of aluminium alloy by zinc gluconate in 0.5 M H<sub>2</sub>SO<sub>4</sub> solution.

Zinc gluconate acts as a good inhibitor for the corrosion of aluminium alloy in 0.5 M H<sub>2</sub>SO<sub>4</sub> solution.

The corrosion rate of zinc gluconate decreases while inhibition efficiency increases with increasing inhibitor concentration.

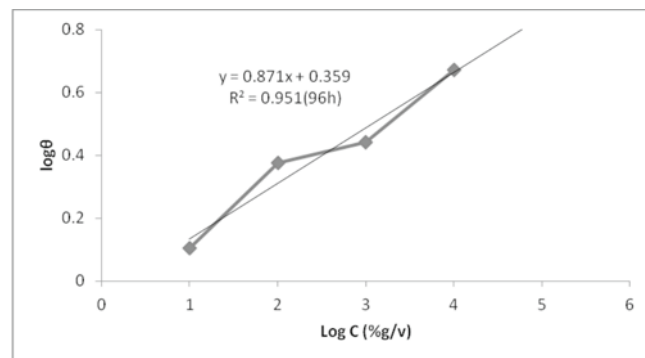
The adsorption of the zinc gluconate obeys the Freundlich adsorption isotherm.

Zinc gluconate inhibits both anodic and cathodic reactions by adsorption and hence behaves like the mixed type inhibitor.

The obtained results about inhibition efficiencies from weight loss and electrochemical study are in good agreement.

### ACKNOWLEDGEMENT

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**Figure 6.** Freundlich adsorption isotherm for the adsorption of different concentration of ZG on aluminium alloy surface in 0.5M H<sub>2</sub>SO<sub>4</sub> solution obtained from weight loss method at 280°C

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