An-Najah National University

Faculty of Engineering and Information Technology

Chemical Engineering Department

Graduation project 2

Microwave Steam Distillation & essential oils application

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بسم الله الرحمن الرحيم

الحمدلله الذي بنعمته تتم الصالحات

الى من غرس في نفسي حب العلم منذ نعومه اظافري "والدي الحبيب"

الى رمز العطاء امي الحبيبه

الى اهلنا و اصدقائنا الطيبين

الى كل من شجعنا في رحلتنا الى التميز و النجاح

الى كل من ساندنا ووقف بجانبنا

الى كل من قال لنا: لافكان سببا في تحفيزنا

الى كل من كان النجاح طريقه والتفوق هدفه و التميز سبيله

الى كل من ساهم هذا العمل

الدكتور المشرف رئيس القسم الفاضل رئيس قسم الهندسه الكيميائيه حسني عوده

اعضاء الهيئه التدريسيه و المشرفين الافاضل

اليكم جميعا الشكر و التقدير والاحترام

Abstract:

The main objectives of this project are to develop simple domestic Microwave unit to be applied to extract essential oils (E.O) from different plants. The Microwave Steam Distillation (MSD) unit has a benefit on saving time and energy; also, it produces high quality of essential oil.

The developed microwave steam distillation (MSD) unit is applied to extract different essential oils such as, lemon grass and Rose mary oils. Experiments were carried out using fresh green plants (without previous drying) in this unit. The green herbs were chipped and trimmed to small pieces, and then they are placed into round flask. The quantities of treated samples were of 20-200gramm. The amounts of extracted essential oils were of 0.1-1.5ml. The extraction time was 6 minutes. The oil amounts were similar to that extracted by traditional steam distillation.

The extracted essential oils have different industrial applications such as preservative material and have shown anti-bacterial effects. The Rosemary essential oils are used recently as green corrosion inhibitor on cast iron & steel. Different types of Rosemary solution extracts were tested with 0.1 M HCL and 1 M HCL solutions. 4X5 cm plates of cast iron and stainless steel are immersed into different acidic solutions. Some inhibition effects were experienced. More time is needed for final consistent conclusions.

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Chapter 1

1.1 Introduction

Essential oil (E.O) is basically the life blood of a plant. It can be found in the glandular hairs, glands, veins or sacs of a plant, grass or tree. The 'oil' is extracted from flowers, trees, fruits, roots and leaves. It is the actual aroma which is extracted and used in aromatherapy to treat a number of ailments, essential oils are volatile; that is, they evaporate at, or above, room temperature.

Essential oils are capable of being antiseptic; they help the body fight infection and disease and build up the body's natural defenses to further attack. The last year graduation project has discussed this issue media otitis in particular.

Certain essential oils have a pronounced sedative and calming effect on the nervous system, for example, Lavender that used as green corrosion inhibitor as well.

Different ways to extract (E.O) such as: conventional steam distillation, Hydrollation steam distillation, supercritical CO_2 fluid extraction (SCF), Solvent extraction Cooled pressing, Microwave steam distillation (MSD) and other innovative techniques. [1]

Project 1 and previous graduation projects [] has used steam distillation to extract the essential oil of rose Merry, lavender, menthol and oregano.

- In this part of our project the work focuses innovative technique for extraction called MSD that save time, energy, power, and have a good quality.
- Building up microwave steam distillation equipment, using the extracted oils as a green corrosion inhibitor.

What is?

- Microwave steam distillation (free solvent microwave extraction (SFME)
- Corrosion
- Green corrosion inhibitor

1.2 Free solvent microwave extraction (SFME)

Microwave is a non-contact heat source which can achieve a more effective and selective heating. With the help of microwave, distillation can now be completed in minutes instead of hours with various advantages that are in line with the green chemistry and extraction principles. In this method, plant materials are extracted in a microwave reactor with or without organic solvents or water under different conditions depending on the experimental protocol. The first Microwave-Assisted Extraction (MAE) of EOs was proposed as compressed air microwave distillation (CAMD). Based on the principle of steam distillation, the compressed air is continuously injected into the extractor where vegetable matrices are immersed in water and heated by microwave. The water and EOs are condensed and separated outside the microwave reactor. The CAMD can be completed in just 5 min and there is no difference in quantitative and qualitative results between extracts of CAMD and 90 min conventional extraction using steam distillation.

Solvent-free microwave extraction (SFME) was developed with considerable success in consistent with the same principles as MAE. Apart from the benefits mentioned before, the SFME simplifies the manipulation and cleaning procedures so as to reduce labor, pollution and handling costs. The SFME apparatus allows the internal heating of the in situ water within plant materials.

A cooling system outside the microwave oven allows the continuous condensation of the evaporated water-oil mixture at atmospheric pressure. The excessive water is refluxed to the reactor in order to maintain the appropriate humidity of plant materials. It is interesting to note that the easy-controlled operating parameters need to be optimized for maximization of the yield and final quality. The potential of using SFME at laboratory and industrial scale has been proved on familiar plant materials with a considerable efficiency compared to conventional techniques. Inspired by SFME, a number of its derivatives have emerged, which offer significant advantages like shorter extraction time, higher efficiency, and cleaner.

There are many applications on using essential oils as corrosion inhibitors; these will be discussed later in literature survey. We have used E.Os for this purpose. [2]

It's worth to give short description on corrosion.

1.3 Corrosion

Natural phenomenon, degradation of materials' properties due to interactions with their environments, and corrosion of most metals is inevitable. While primarily associated with metallic materials, all material types are susceptible to degradation, corrosion is something we hope to avoid; but ultimately it is something we must learn to deal with.[cor.p]

The actual mechanism in the corrosion of iron and steel is extremely complex. [1]

The surfaces of all metals in air are covered with oxide films. When such a metal is immersed in an aqueous solution, the oxide film tends to dissolve. If the solution is acidic, the oxide film may dissolve completely leaving a bare metal surface, which is said to be in the active state.[2]

Iron will corrode only in the presence of both water and oxygen

$4Fe \rightarrow 4Fe^{++} + 8e^{-}$ (anodic reaction)..... (1)

Water and oxygen are also needed for corrosion

$4H_2O + 8e^{-} + 2O_2 \rightarrow 8(OH)^{-}$ (anodic reaction)..... (2)

After overall corrosion of the iron is thus a combination of (1) and (2):

$4Fe + 4H_2O + 2O_2 \rightarrow 4Fe(OH)^{2}$ (anodic reaction)

The iron hydroxide reacts further with air to form hydrated ferric oxide – rust:

$4Fe(OH)^{2} + O^{2} \rightarrow 2Fe_2O_3H_2O + 2H_2O$ [3]

1.4 Green corrosion inhibitor

The use of inhibitors is one of the best options of protecting metals and alloys against corrosion. The environmental toxicity of organic corrosion inhibitors has prompted the search for green corrosion inhibitors. Green corrosion inhibitors are biodegradable and do not contain heavy metals or other toxic compounds. Some research groups have reported the successful use of naturally occurring substances to inhibit the corrosion of metals in acidic and alkaline environment, rosemary leaves were studied as corrosion inhibitor. [4]

1.5 Innovative Techniques for essential oils extraction method

Since economy, competitiveness, eco-friendly, sustainability, high efficiency and good quality become keywords of the modern industrial production; the development of essential oil's (Eos) extraction techniques has never been interrupted. Strictly speaking, conventional techniques are not the only way for the extraction of EOs such that: Steam Distillation, Hydro-diffusion, and Cold Expression.

Novel techniques abided by green extraction concept and principles have constantly emerged in recent years for obtaining natural extracts with a similar or better quality to that of official methods while reducing operation units, energy consumption, CO_2 emission and harmful co-extracts in specific cases.

The principles of green extraction can be generalized as the discovery and the design of extraction processes which could reduce the energy consumption, allow the use of alternative solvents and renewable/ innovatory plant resources so as to eliminate petroleum-based solvents and ensure safe and high quality extracts or products. [2]

- ***Turbo Distillation:***

This technique is developed to reduce energy and water consumption during boiling and cooling in hydro-distillation. The turbo extraction allows a considerable agitation and mixing with a shearing and destructive effect on plant materials so as to shorten distillation time by a factor of

2 or 3. Furthermore, it is an alternative for extraction of EOs from spices or woods, which are relatively difficult to distil. Besides, an eco-evaporator prototype could be added with aspect of the recovery and the reuse of the transferred energy during condensation for heating water into steam [2]

❖ ***Ultrasound-Assisted Extraction:***

With the aim of higher extraction yields and lower energy consumption, ultrasound assisted extraction has developed to improve the efficiency and reduce the extraction time in the meanwhile. The collapse of cavitations bubbles generated during ultrasonication gives rise to micro-jets to destroy EOs' glands so as to facilitate the mass transfer and the release of plant EOs. This cavitations effect is strongly dependent to the operating parameters (e.g. ultrasonic frequency and intensity, temperature, treatment time, etc.) which are crucial in an efficient design and operation of distillation unit. In addition to the yield improvement, the EOs obtained by Ultrasound-Assisted Extraction (UAE) showed less thermal degradation with a high quality and a good flavour. However, the choice of sonotrode should be careful as the result of the metallic contamination which may accelerate oxidation and subsequently reduce EOs' stability. This technique has already proved its potency to scale up, which shows 44 % of increment on extraction yield of EOs from Japanese citrus compared to the traditional methods [2]

❖ ***Simultaneous distillation extraction (SDE):***

In this technique either hydro distillation or steam distillation is combined with solvent extraction, which is frequently used for the isolation of volatile compounds from EOs bearing plants. Solvent used should be insoluble in water and of high purity. SDE has been modified into several variants with the consideration of efficiency, scale and quality of end-products.

Less solvent, elimination of excessive thermal degradation and dilution of extract with water are the advantages of this method, in contrast artefact production, loss of hydrophilic compounds are the disadvantages. [2]

- ***Pulsed electric field assisted extraction (PEF):***

This technique applies short pulses at high voltage in order to create electro compression, which causes plant cells to be ripped open and perforated. The treatment chamber in PEF consists of at least two electrodes with an insulating region in between, where the treatment of plant materials happens, preserved fresh character, low heating impact and energy consumption are the advantages, only for pumpable materials, restricted by viscosity and particle size of products, high cost are the disadvantages [2].

1.6 Problem

Palestine has diversity of herbs and aromatic plants, spite of this fact we import essential oils. Our project realized novel technique for extraction essential oils. The microwave extraction method, which is rapid and clean.

The extracted oils as green corrosion inhibitors are used for protecting metals and alloys against it, The environmental toxicity of organic corrosion inhibitors has prompted the search for green corrosion inhibitors as they are biodegradable, do not contain heavy metals or other toxic compounds. As in addition to being environmentally friendly and ecologically acceptable, plant products are inexpensive, readily available and renewable.

1.7 The objectives of the project

The main objectives of this project are building and installation of the microwave distillation unit. Then to extract essential oils from aromatic plants such as (rosemary, mint, and lemon grass) in very short time in a comparison with the traditional technique, and use these oils to inhabit corrosion.

Chapter2

2.1 Literature Review

This is to discuss the recent research on using essential oils as corrosion inhibitor:

- Experiments on Salvia essential oil were done as a green corrosion inhibitor of mild steel by Oudia and his co-partners.

Hydrodistialtion extract method was used to extract the essential oil. The major components of E.O have been analyzed by gas chromatography- mass spectrometry (GC/MS) followed by principal component analysis.

The corrosion experiments were done in 1M HCl solution. Different concentration of essential oil & extract were taken (0.5, 1, 2, 4, 8, [ml/L] E.O) (8, 10, 12, 14, 16, [ml/L] extract), respectively.

Weight loss measurements, potentiodynamic polarization, electrochemical impedance spectroscopy (EIS) were used on the samples tests, they conclude that inhibition efficiency increases with increase in the concentration of the essential oil and extract of Salvia but decreases with rise in temperature, The corrosion process was inhibited by adsorption of the organic matter on the mild steel surface, obtaining the formation of the film on the metal/acid solution interface, decreasing the degradation of the material, this demonstrated that the essential oil and extract of Salvia act as efficient corrosion inhibitors of the mild steel in 1 M HCl solution. [5]

- Lotfi and co-workers has study the effect of anise oil as an eco- friendly inhibitor for carbon steel corrosion

1M HCL solution within the absence and presence of different concentrations of anise oil by polarization curves, electrochemical impedance spectroscopy (EIS) and gravimetric techniques. Anise oil is considered as a green inhibitor for carbon steel in 1.0 M HCl The inhibition

efficiency augmented with increase in anise oil concentration but reduced with growth in temperature. He has got the same conclusion as Oudia done. [6]

- El Mounsi and his co-partners carried out experiments to examine the effectiveness of the hexane extract of Nigella Sativa L (SH NS) to inhibit of mild steel.

1 M HCl solution using the weight loss measurement by 6 hours of immersion at room temperature, polarization curves and electrochemical impedance spectroscopy (EIS) with the concentration range of inhibitor employed was (0.5 – 5) (g/L) to evaluate corrosion rate and inhibition efficiency.

This demonstrated that Hexane extract (SH NS) successfully retarded mild steel corrosion in HCl solutions, and the efficiency of inhibition increases with increased inhibitor concentration & can be used as an effective solution of steel corrosion in acid media. [7]

- Ben Hmamou1 and his co-partners have been tested the Chamomile oil as a corrosion inhibitor of steel.

Chamomile oil obtained by hydro-distillation and Gas Chromatography (GC) to identify the major substances.

1M HCl solution was used using electrochemical impedance spectroscopy (EIS), Tafel polarisation methods and weight loss measurements, by immersion time for 8 h at 298 K the weight loss has been made.

They conclude that chamomile oil provides a good inhibition of corrosion of steel in normal hydrochloric acid medium, the inhibition efficiency increases with increased chamomile oil concentration & efficiency of chamomile oil is independent of temperature. [8]

- American scientist [1996] has done experiments to isolate the essential oil (E.O) from rosemary by hydrodistilation (HD) and Microwave Hydrodiffusion and Gravity (MHG).

Five hundred grams of each aromatic herb were submitted to hydrodistillation and extracted oil for 90 min (until no more essential oil was obtained). The essential oil was collected and stored at (-4) until used.

(MHG) has been performed using the ‘‘DryDist” 500 g of fresh plant material were heated using a fixed power density of 1W/g for 15 min without addition of solvent or water. A mixture of hot steam are used .The oily condensate is collected continuously in a receiving flask where essential oil forms a film on the surface of the water and the film is skimmed off the top. At the end the essential oil is collected and stored at (- 4) C until used.

(HD) and (MHG) methods have been compared and evaluated for their effectiveness in the isolation of essential oil from fresh Rosemary leaves. The microwave method offers important advantages over traditional alternatives (HD), namely: shorter isolation times (15 min against 3 h for hydrodistillation), environmental impact (energy cost is fairly higher to perform HD than that required for rapid MHG isolation), cleaner features (as no residue generation and no water or solvent used), increases antimicrobial activities, increases antioxidant activity and provides a more valuable essential oil (with high amount of oxygenated compounds). It offers also the possibility for a better reproduction of natural aroma of the essential oil

The yields of essential oil extracted from rosemary with the different isolation methods are respectively 0.35% and 0.33% for the HD and MHG. An isolation time of 15 min with MHG provides yields similar to those obtained after 180 min by means of HD, which is one of the reference methods in essential oil isolation. [9]

Microwave method has been developed in our project to extract E.O from Rose Merry.

Chapter3

3.1 Experimental part

Part 1:

3.1.1 Design process

Our group has built a microwave system that can extract the essential oils from aromatic plants such as (rosemary, mint, and lemon grass) in very short time compare to traditional techniques. Then we have use these oils for different purposes such as testing against steel corrosion

Some modifications had done on microwave device: drilling a proper hole on the top surface of microwave, with whole diameter is about 22 mm and, removal of moving parts that can hinder working and distillation inside M.W

The perforation is passed through the surface of the above metallic sheets with sophisticated work. The volume of sample that can be treated in microwave is 100-1000 ml, and the sample is placed in volumetric round flask

The heat input and time is controlled by adjustable switch, so the minimal heat input of the M.W system is about 10 W, this value is increased to higher values of 300 W. For safe and stable working conditions the heat input is selected to be 30 W

The water/oil condenser system is designed with a dimension to avoid any foaming what may occur. The foaming or jumping up of raw material through condenser tubes will put an end to the experiment.

Figure 1: microwave steam distillation device

Many experiments are achieved to test the equipment, to extract essential oils & to ensure the good working of apparatus by using different grinded plants such as rose marry, lemon grass and mint

This apparatus presents very important alternative to treat different green fresh smashed plants without prior drying .This is because of water content inside the plant cells.

Part 2:

- ***3.1.2 Extract essential oils by using M.W apparatus***
- ***The extraction steps are :***

- The fresh plant leaves are collected sliced and ground. then placed into volumetric flask
- Installation of condenser system on microwave device
- Adding water to flask to cover plants
- Turn on the microwave and adjust the heat input and time
- At heat input 30 W ,the condensing of liquid start

- The devices turn off automatically then wait for the unit to cool. At this point, the essential oil will have risen to the top of the water in reseiver
- The process needs about 15 minutes to finish.

The experiment carried out by using about:

50g of rose Mary, 200g of rose Mary

50g of mint

50g of lemon grass

Part 3:

❖ 3.1.3 Using essential oils as corrosion inhabit

- Weighing of iron and steel pieces.
- Preparation of 0.1 M HCL
- green solution: solution that in the plant and gathering in the tank of steam distillation
- white solution: liquid that gathering in the receiver where E.O immerge with
- . preparation of solution tests:
    1. Put 50 ml water + 50 ml HCL
    2. 50 ml green solution + 50 ml HCL
    3. 50 ml white solution + 50 ml HCL
    4. 50 ml water +0.8 ml rosemary essential oil +50ml HCl
- Immerse iron and steel in each of solution.
- Day after day take the pieces from solution dry and weight each metallic piece. The gravimetric results are documented for all solutions.

From experiments got these quantities of essential oils:

Table 1: Weight of essential oil

plant	Quantity of E.O (ml)
Rose Merry	**1.5, 0.1**
Mint	**0.3**
Lemon grass	**0.1**

Chapter 4

Result and Discussion:

We design special technique by using microwave radiation to extract essential oils from rosemary, mint and lemon grace. This technique provides a rapid extraction of essential oils compare to other technique. Many experiments were done to find normative conditions for apparatus task. It preferring to work on power 30W

The aim of this project is to prove that the essential oils have an anti-corrosion activity against steel and iron. The essential oils obtained from rosemary plant is in agreement with literature value which is 0.1-0.3g/100g dried solid. We test the essential oils that extracted from rose marry by using weight loss method to see the ability of this essential oils in inhibiting the corrosion of steel and iron.

The result shows that when using 0.1 M of HCL alone the reduction in weight was 0.032g for steel and 0.32 g for iron ,and green solution (which contains low concentration of essential oils) and white solution(which contains higher concentration of essential oils than green solution) with 0.1M of HCL , the net loss in weight after 21 days was 0.028g and 0.024g for steel piece and 0.27g and 0.19g for iron piece ,respectively .The mixture of 0.1M of HCL and pure essential oils with 0.1 HCL was also tested , the reduction in the weight was 0.023g for steel and 0.11g for iron .

Also , the same four solutions was tested to inhabit corrosion but with 1M HCL ,the results shows that when using 1M HCL solution the reduction in weight was 0.5 g for steel and 0.66 g for iron ,. the net loss in weight for green and white solution was 0.38 g and 0.30g for steel and 0.63g,0.498 g for iron , respectively .Also pure essential oil with 1M HCL was tested and the reduction in the weight was 0.14 for steel and 0.119 for iron.

These results shows that there is decreasing in weight of steel and iron pieces when increasing in essential oils concentration that the pure essential oils gives the smallest reduction in the weight of steel and iron compare to other solutions which means the higher activity against corrosion , also increasing in weight loss when increasing the concentration of HCl

For 0.1M HCl:

Table 2: Sample 1 (acid + water)

Date	day	Steel weight(g)	Iron weight(g)
4/10/2015	0	18.052	28.54
8/10/2015	4	18.040	28.43
11/10/2015	7	18.03	28.32
18/10/2015	14	18.02	28.24
22/10/2015	18	18.02	28.22
25/10/2015	21	18.02	28.22

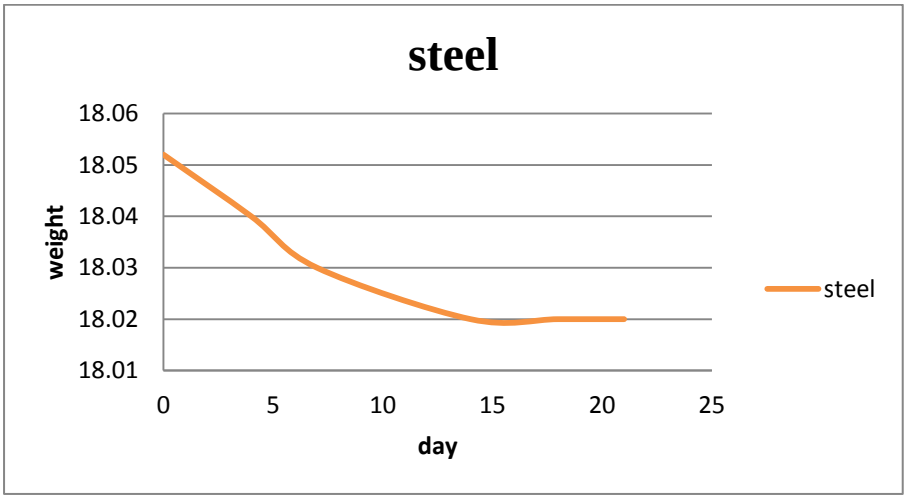


Figure 2: Reduction of weight of steel in acid &water solution

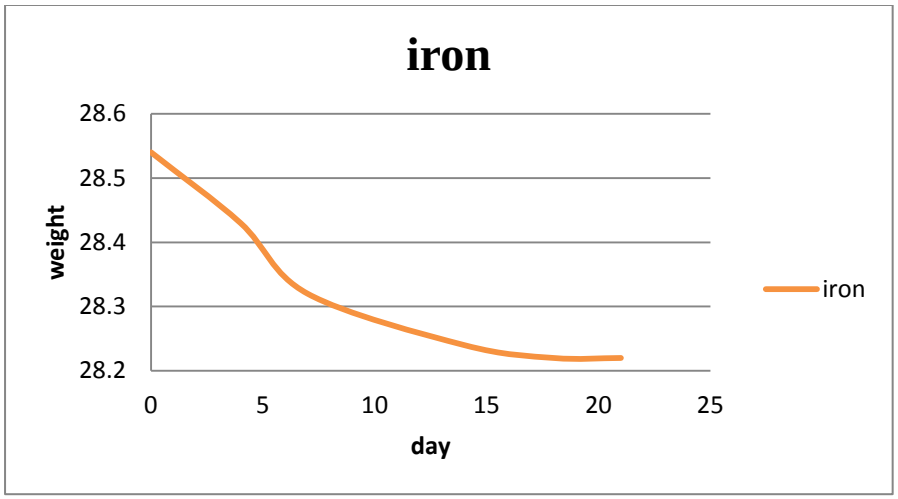


Figure 3: Reduction of weight of iron in acid &water solution

Table 3: Sample 2(acid + green t solution)

Date	Day	Steel weight(g)	Iron weight(g)
4/10/2015	0	18.08	28.92
8/10/2015	4	18.06	28.77
11/10/2015	7	18.058	28.74
18/10/2015	14	18.056	28.68
22/10/2015	18	18.052	28.67
25/10/2015	21	18.052	28.65

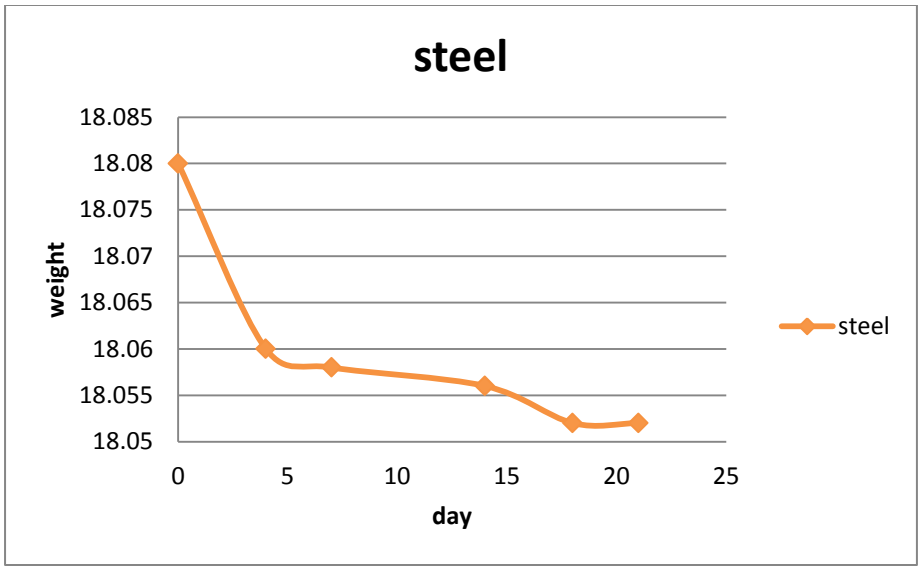


Figure 4: Reduction of weight of steel in acid & green solution

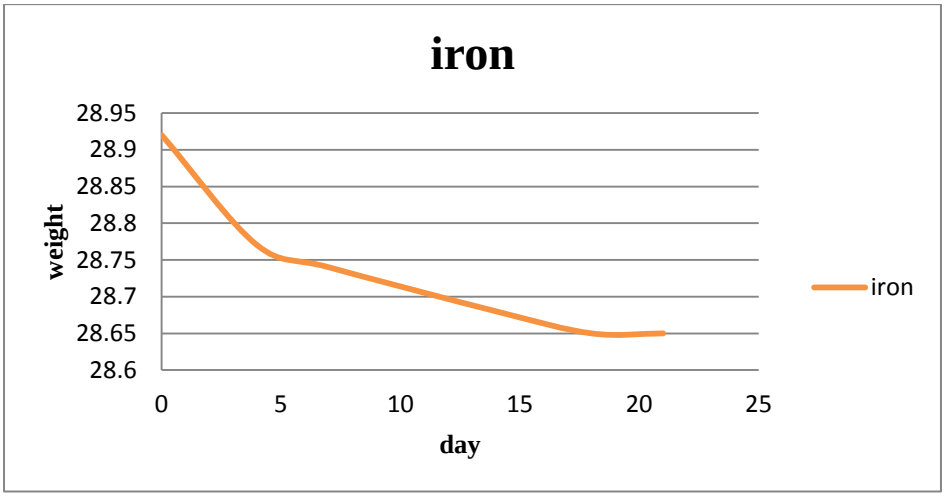


Figure 5: Reduction of weight of iron in acid & green solution

Table 4: Sample 3 (acid + white solution)

Date	day	Steel weight(g)	Iron weight(g)
4/10/2015	0	18.054	27.10
8/10/2015	4	18.047	26.95
11/10/2015	7	18.040	26.93
18/10/2015	14	18.03	26.92
22/10/2015	18	18.03	26.91
25/10/2015	21	18.03	26.91

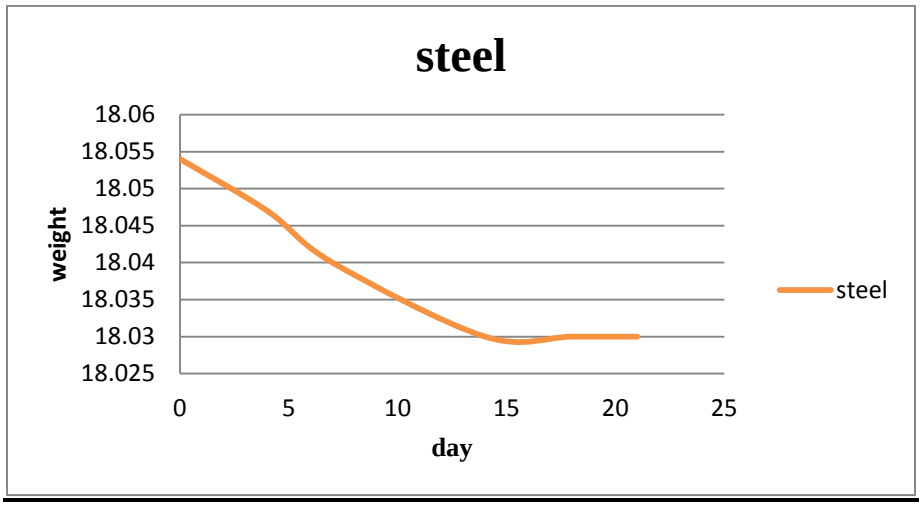


Figure 6: Reduction of weight of steel in acid & white solution

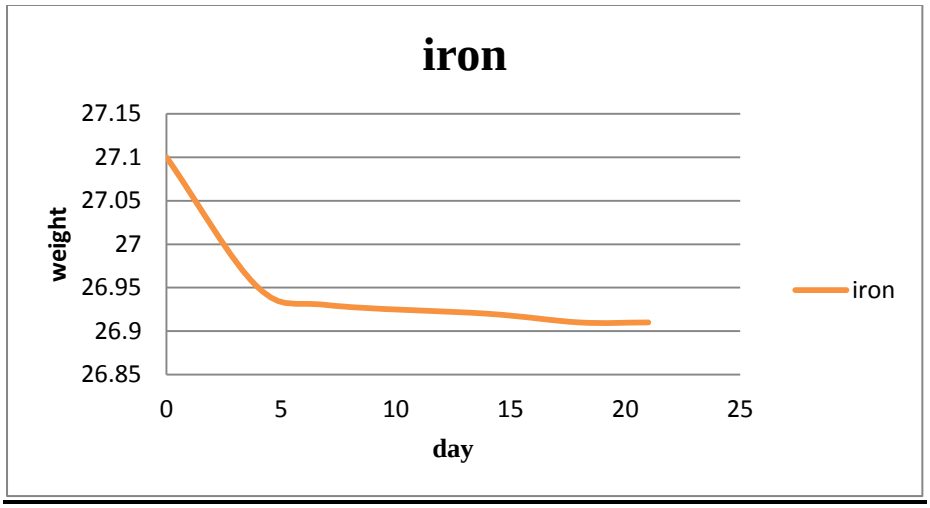


Figure 7: Reduction of weight of iron in acid & white solution

Table 5: Sample 4 (water +0.8 ml rosemary essential oil+HCL)

Date	day	Steel weight(g)	Iron weight(g)
4/10/2015	0	18.055	31.32
8/10/2015	4	18.046	31.28
11/10/2015	7	18.042	31.25
18/10/2015	14	18.032	32.22
22/10/2015	18	18.032	31.21
25/10/2015	21	18.032	31.21

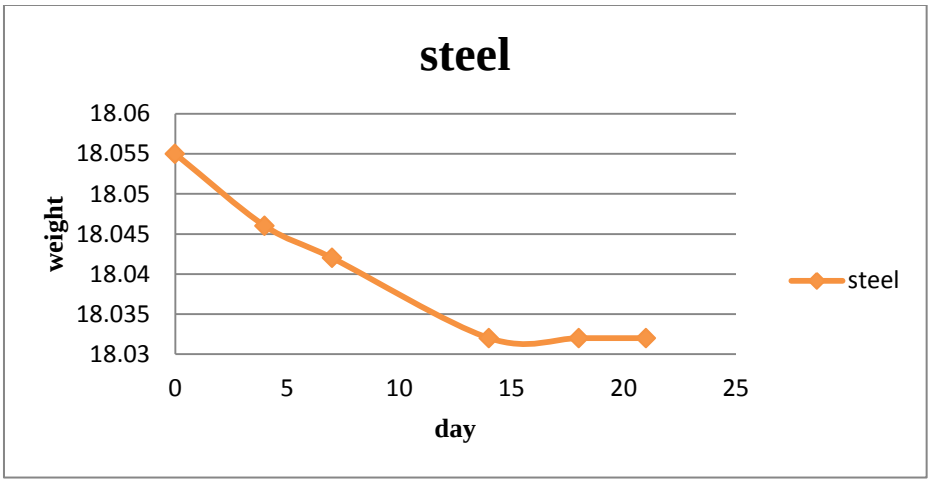


Figure 8: Reduction of weight of steel in 0.8 ml essential oil &acid

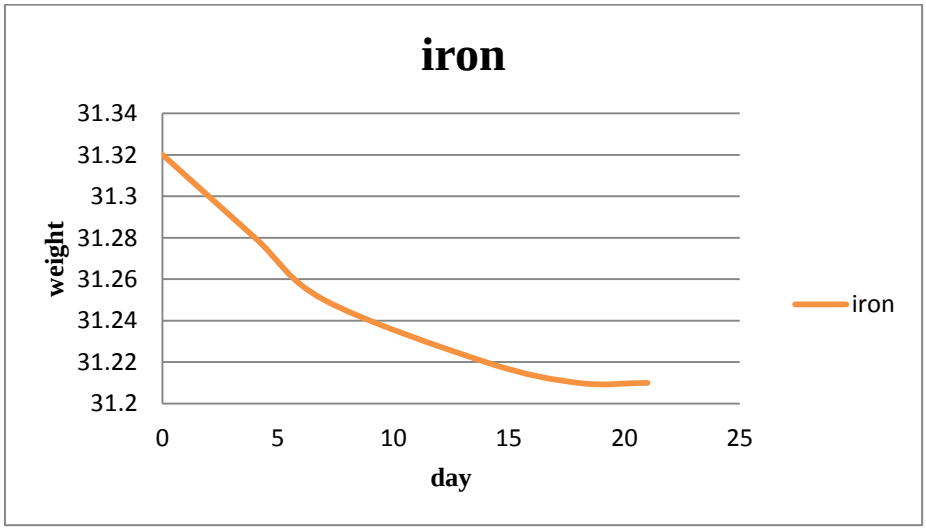


Figure 9: Reduction of weight of iron in 0.8 ml essential ois &acid

For 1M HCl

Table 6: Sample 1 (acid + water)

Date	day	Steel weight(g)	Iron weight(g)
16/11/2015	0	17.73	27.66
17/11/2015	1	17.72	27.655
19/11/2015	3	17.71	27.64
29/11/2015	13	17.23	27.0

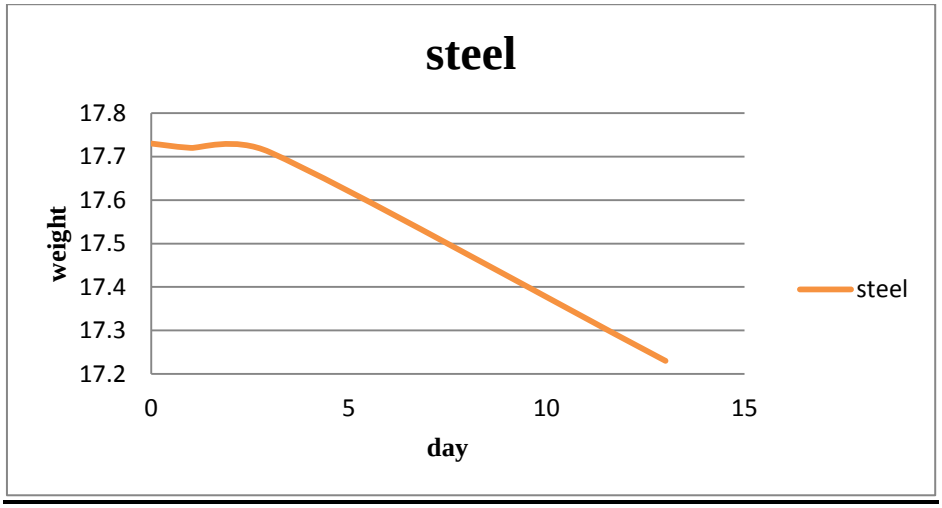


Figure 10: Reduction of weight of steel in acid&water

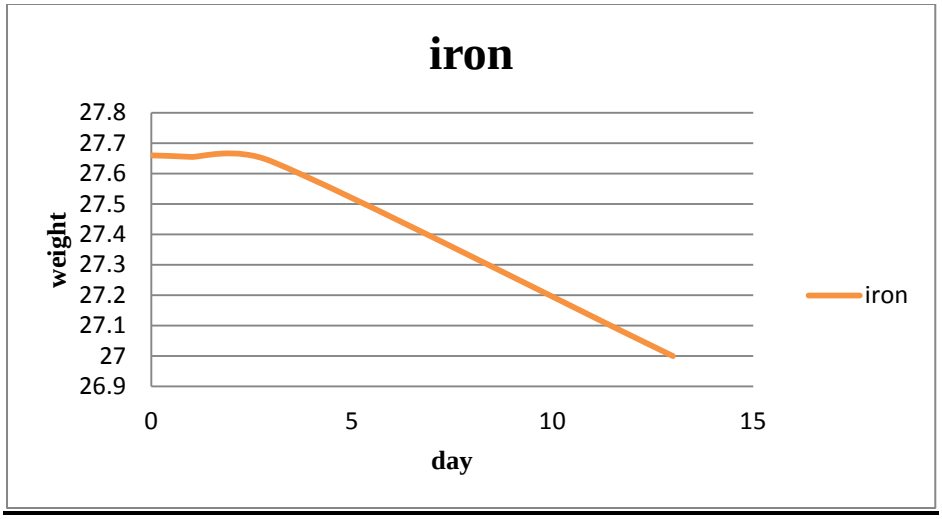


Figure 11: Reduction of weight of iron in acide & water

Table 7: Sample 2 (acid + green solution)

Date	day	Steel weight(g)	Iron weight(g)
16/11/2015	0	18.05	26.9
17/11/2015	1	18.041	26.88
19/11/2015	3	18.035	26.86
29/11/2015	13	17.67	26.27

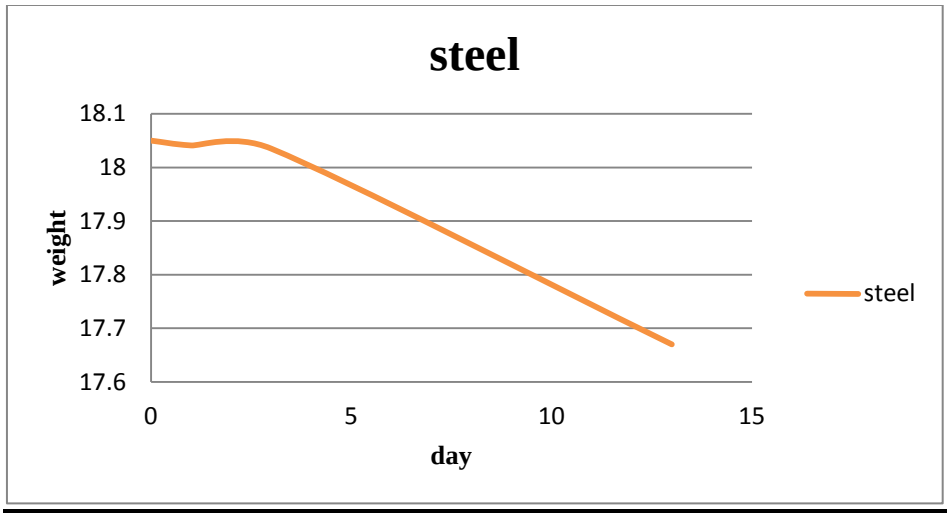


Figure 12: Reduction of weight of steel in acid &green solution

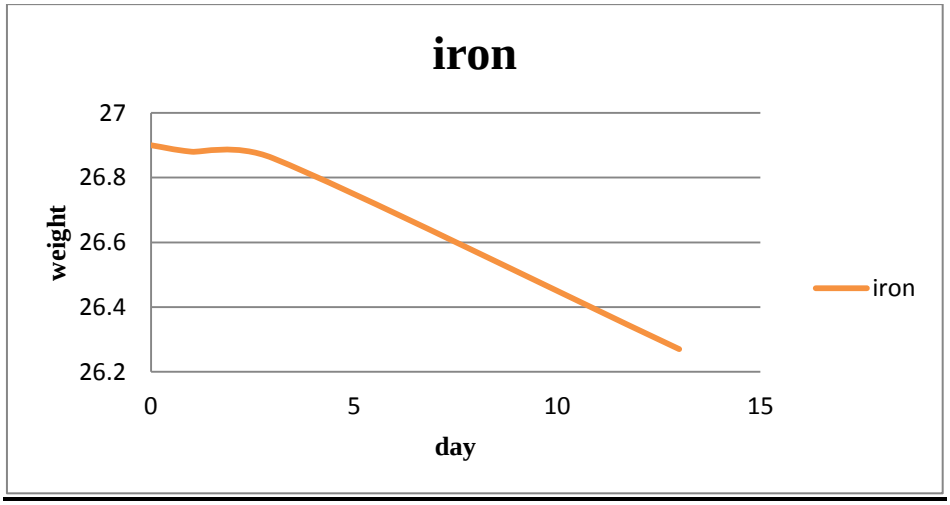


Figure 13: Reduction of weight of iron in acid &green solution

Table 8: Sample 3 (acid + White solution)

Date	day	Steel weight(g)	Iron weight(g)
16/11/2015	0	18.03	28.5
17/11/2015	1	18.02	28.46
19/11/2015	3	18.01	28.43
29/11/2015	13	17.73	28.002

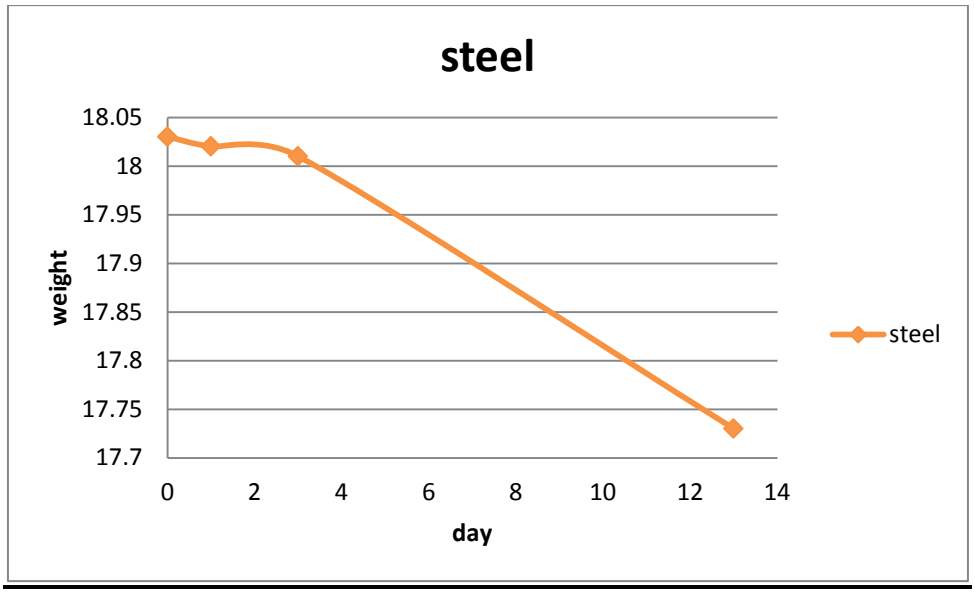


Figure 14: Reduction of weight of steel in acid&white solution

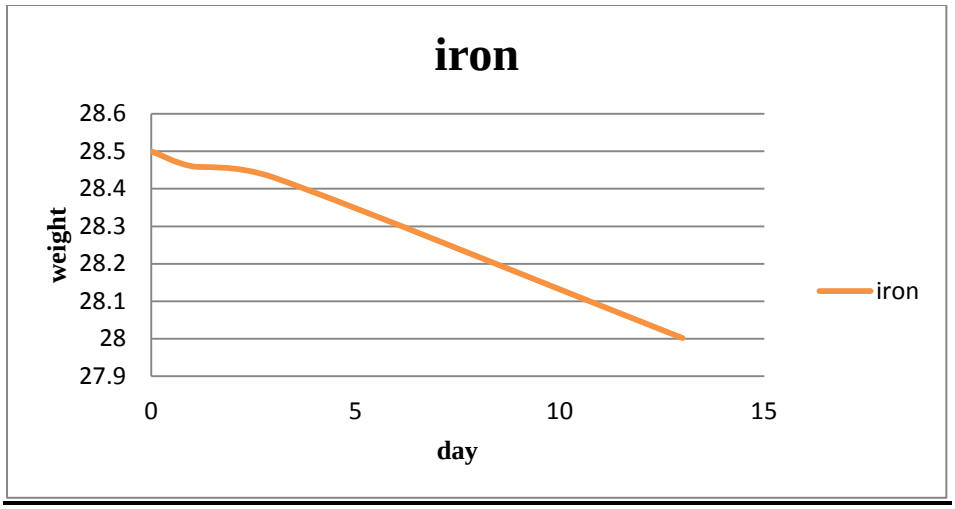


Figure 15: Reduction of weight of iron in acid &white solution

Table 9 : Sample 4 (water +0.8 ml rosemary essential oil)

Date	day	Steel weight(g)	Iron weight(g)
16/11/2015	0	17.72	30.94
17/11/2015	1	17.71	30.89
19/11/2015	3	17.7	30.87
29/11/2015	13	17.58	30.821

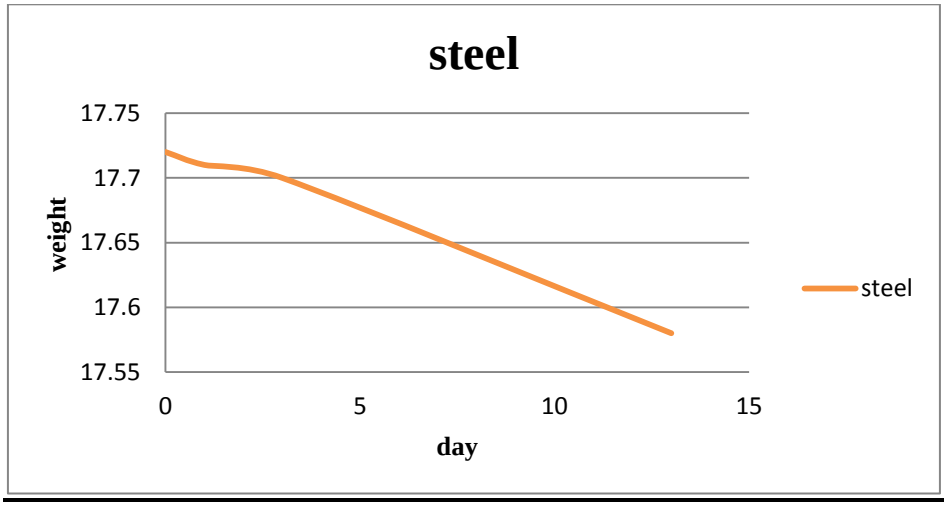


Figure 16: Reduction of weight of steel in 0.8ml essential oil & acid

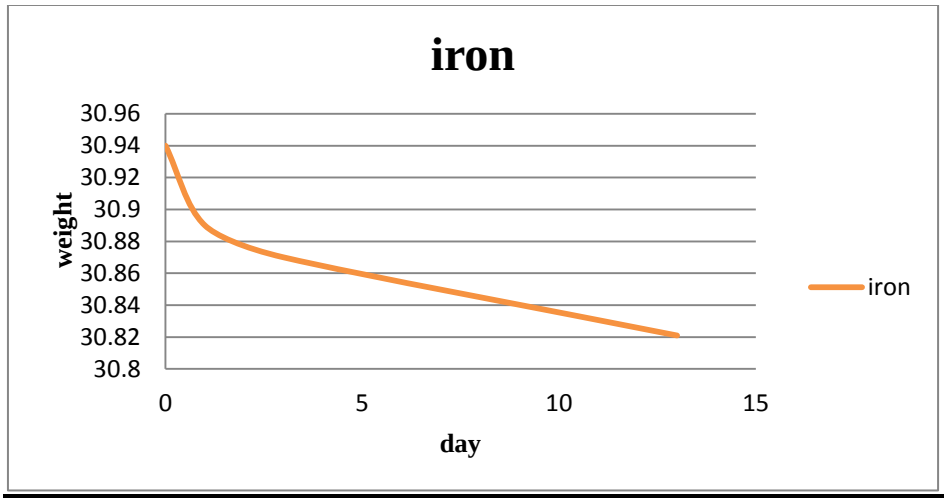


Figure 17: Reduction of weight of iron in 0.8 ml essential oil & acid

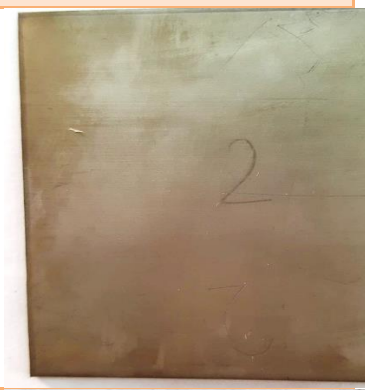
Table 10: Average weight for corrosion solutions during 20 day in 0.1 HCL

0.1M HCl	Steel (g)	Cast Iron (g)
water	**0.032**	**0.32**
green solution	**0.024**	**0.19**
White solution	**0.048**	**0.27**
0.8 ml rosemary essential oil	**0.023**	**0.11**

Table 11: Average weight for corrosion solutions during 20 day in 1 M HCL

1M HCl	Steel (g)	Cast Iron (g)
water	**0.5**	**0.66**
green solution	**0.38**	**0.63**
White solution	**0.51**	**0.498**
0.8 ml rosemary essential oil	**0.119**	**0.14**

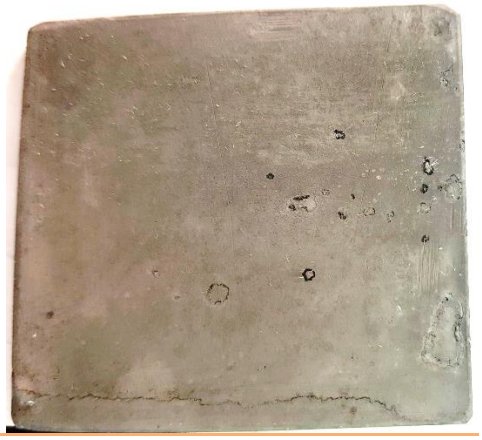
Table 12: Steel pieces before and after testing

Sample	Before	After
1 (water &acid)		
2 (acid &green solution)		
3 (acid & white solution)		

4 (acid & 0.8 ml essential oils)		

Table 13: iron pieces before and after testing in 0.1 Hcl

sample	Before	After
1- (acid & water)		
2- (acid &green solution)		

3 - (acid &white solution)		
4- (acid &0.8 ml essential oil)		

Chapter 5

5.1Conclusion:

In this present project a modern extraction method was applied by using microwave distillation system in the unit laboratory at An Najah university .the system contain of three main parts which were the microwave device where the plants put in it, the condenser system to catch volatile essential oils and adjustable switch to control heat input and time

Some modifications had done on the microwave device ,insulation the condenser system with proper hight ,many experiments are achieved to test the equipment & to ensure the good working of apparatus by using different grinded plants such as Rose marry, lemon grass and mint then use essential oils to inhabit corrosion

The result shows that there is decreasing in weight of steel and iron pieces when increasing in essential oils concentration. And increasing in weight loss when increasing the concentration of HCl

5.2 Recommendation:

- In spite of dumped many plant as solid waste we can use it in many applications that include E.Os that have many applications in our life we talk about previously,
- We use E.O as corrosion inhibitor on iron steel & mild steel because it find in wide applications in industry due to its excellent mechanical properties and low cost. It is extensively used in various industries as construction material for chemical reactors, heat exchanger and boiler systems, storage tanks, and oil and gas transport pipeline
- The apparatus gives very important alternative to treat different green and fresh smashed plants without prior drying.
- We should select proper height of condenser to prevent foam.
- We need more time to find consistent result

Chapter6

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