DESIGN AND MANUFACTURE A SMALL UNIT FOR ACTIVATED CARBON PRODUCTION FROM SOME AGRICULTURAL RESIDUES

By

MARIAM AHMED AMER
B.Sc. Agric. Sci. (Agricultural Engineering), Fac. Agric., Cairo Univ., 2006
M.Sc. Agric. Sci. (Agricultural Engineering), Fac. Agric., Cairo Univ., 2012

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of

DOCTOR OF PHILOSOPHY

In

Agricultural Sciences
(Agricultural Engineering)

Department of Agricultural Engineering
Faculty of Agriculture
Cairo University
EGYPT

2017

APPROVAL SHEET

DESIGN AND MANUFACTURE A SMALL UNIT FOR ACTIVATED CARBON PRODUCTION FROM SOME AGRICULTURAL RESIDUES

Ph.D. Thesis
In
Agric. Sci. (Agricultural Engineering)

By

MARIAM AHMED AMER
B.Sc., Agric. Sci., (Agricultural Engineering), Fac. Agric., Cairo Univ., 2006
M.Sc., Agric. Sci., (Agricultural Engineering), Fac. Agric., Cairo Univ., 2012

APPROVAL COMMITTEE

Dr. Tarek Zaki Hussien Fouda……………………………………
Professor of Agricultural Engineering, Fac. Agric., Tanta University
Dr. Mohamed Samer ……..………………………………………
Associate Professor of Agricultural Engineering, Fac. Agric., Cairo University

Dr. Nahed Khairy Ismail……………………..…………………
Senior Researcher (Associate Professor) of Bio-System Eng. Dept., Agric. Eng. Res. Inst. (AEnRI), Agric. Res. Cen. (ARC)

Dr. Ahmed El Raie Emam Suliman ……………………………
Professor of Agricultural Engineering, Fac. Agric., Cairo University

Date: / / .

SUPERVISION SHEET

DESIGN AND MANUFACTURE A SMALL UNIT FOR ACTIVATED CARBON PRODUCTION FROM SOME AGRICULTURAL RESIDUES

Ph.D. Thesis
In
Agric. Sci. (Agricultural Engineering)

By

MARIAM AHMED AMER
B.Sc., Agric. Sci., (Agricultural Engineering), Fac. Agric., Cairo Univ., 2006
M.Sc., Agric. Sci., (Agricultural Engineering), Fac. Agric., Cairo Univ., 2012

SUPERVISION COMMITTEE

Dr. AHMED EL RAIE EMAM SULIMAN
Professor of Agricultural Engineering, Fac. Agric., Cairo University

Dr. KHALED MOHAMED ABDELBARY
Assistant Professor of Agricultural Engineering, Fac. Agric., Cairo University

Dr. NAHED KHAIRY ISMAIL
Senior of Bio-System Eng., Agric. Eng. Res. Inst. (AEnRI), Agricultural Research Center

Name of Candidate: Mariam Ahmed Amer **Degree:** Ph.D.
Title of Thesis: Design and Manufacture A Small Unit for Activated Carbon Production from Some Agricultural Residues.
Supervisors: Dr. Ahmed El Raie Emam Suliman,
Dr. Khaled Mohamed Abdelbary and
Dr. Nahed Khairy Ismail.
Department: Agricultural Engineering **Approval:** / /

ABSTRACT

This study was carried out at the laboratory of Agricultural Engineering Department, Faculty of Agriculture, Cairo University and laboratory of Agricultural Engineering Research Institute, Agricultural Research Center during 2013 to 2016.

The objective of this study was performance evaluation of design activated carbon prototype productivity.

This aim was achieved through the following steps: 1. Collecting data and selecting agricultural residues. 2. Estimating the percentages of some properties for each agricultural residue. 3. Produce and evaluate the activated carbon from each of agricultural residues using laboratory unit at variable pyrolysis temperatures (FT) of 400, 500, 600 and 700 ºC and pyrolysis time (TF) of 1.0, 1.5 , 2.0 and 2.5 hours. 4. Design, test, evaluating and compare an activated carbon prototype and quality of its production. 5. Evaluating the performance of the designed unit.

Corn stalks, trimming peach trees residues and date kernels were selected to be pyrolized as activated carbon. Through laboratory experiments; the solid materials (yield) and carbon concentration for all samples are determined at (FT) and (TF) were recorded under 400, 700, 400 ºC at 1.0, 2.0, 2.0 h for corn stalks, trimming peach trees residues and date kernels respectively. In this optimum pyrolysis process the quality of activated carbon product were tested. Experiments were carried out using designed unit at the recommended optimum variables, quantities and qualities of produced activated carbon are determined.

The efficiency of produced activated carbon is applied to drink water treatment at activated carbon height of 1.0, 2.5 and 5.0 cm. The designed unit performance showed the highest value of C%, surface area, pore volume and SEM for trimming peach trees residues and date kernels activated carbon compared to the laboratory but the studies variables unsuitable for pyrolized corn stalks.

The performance of activated carbon produced was estimated as productivity that were 0.28, 1.13 and 3.16 kg.h^{-1} and the kilogram cost of activated carbon were 201.18, 50.20 and 17.92 LE.kg^{-1} for corn stalks, trimming peach trees residues and date kernels, respectively.

The study recommended that: 1. Using prototype to produce activated carbon from untapped agricultural residues with high quality specially from date kernels and trimming peach trees residues while its prefer to do experiment at lowest temperature and time on corn stalks. 2. The efficiency of produced activated carbon is high for purification drinking water. 3. Possibility to increase capacity unit of prototype or grinding raw- material to suffice local market requirements

Keywords: Activated carbon, Agricultural residues, Isolated furnace, Carbon percentage, Ash percentage, Surface area, Pore volume, SEM, Water treatment.

DEDICATION

*I dedicate this work to whom my heartfelt thanks; to my parents (**Dr.Ahmed Amer & Eng. Madiha Youssef),** my sisters (**Dr. Alia Amer & Eng. Hadia Amer)** for their patience, help and for all the support they lovely offered during my post-graduation studies.*

ACKNOWLEDGEMENT

I wish to express my sincere thanks, deepest gratitude and appreciation to **Dr. Ahmed. El Raie Emam Suliman** and **Dr. Khaled Mohmed Abdelbary** professors of agricultural engineering, Faculty of Agriculture, Cairo University for suggesting the problem, supervision, continued assistance and their guidance through the course of study and revision the manuscript of this thesis.

Sincere thanks to Dr. **Nahed Khairy Ismail** senior researcher, Agricultural Engineering Researches Institute, Agricultural Researches Center for supervision, sincere helping, moral support, valuable advice, continuous encouragement, beneficial discussions, careful revision of the thesis are deeply appreciated and for providing all the facilities during the work.

Grateful appreciation is also extended to all staff members of **Agricultural Engineering Dept., Faculty of Agriculture, Cairo University** and all employees **in Metallurgical Research Center** for helping, advice and allowing working in the laboratory.

Special deep appreciation is given to my best friends **Dr. Heba Belal Kandil for helping me in microbiology work.**

CONTENTS

Page

INTRODUCTION……………………..………………………..……...…… 1

REVIEW OF LITERATURE………………………………………….… 3

1. Description of activated carbon……………………………… 3
2. Production methods of activated carbon …………………. 7
3. Factors effecting of activated carbon production ……….. 10
4. Mechanisms of pyrolysis operation………………..……...…… 20
5. Designed machine for pyrolysis operation……………..……... 21
6. Activated carbon production…………………………..…………. 23
7. Quality of activated carbon……………………………...…… 26
8. Water purification……………………….…………………….... 34
9. Evaluation of activated carbon…………………….………….. 37
10. Overheads…………………….………...……………………..…… 39

MATERIALS AND METHODS……………………...…………….. 41

RESULTS AND DISCUSSION……………....…………………….... 81

SUMMARY AND CONCLUSION …………...……..………… 133

REFERENCES………..……………………...……………………………… 141

APPENDICES…………………………………...……………………………… 153

ARABIC SUMMARY……………………………...…………………….

LIST OF TABLES

No.	Title	Page
1.	Physical activation of agricultural residues…………………	12
2.	Chemical activation of agricultural residues………………..	12
3.	The physical properties and allowable temperatures heating wire…………………………………………………...	49
4.	Summarize of Carbon component of some agriculture residues…………	59
5.	Cultivated areas and agricultural solid waste production for major crops ………………………………………………	59
6.	Volume of H_3PO_4 versus agricultural residues mass..…...……....…...……....…..………....…..………………....…...….…	61
7.	Properties of residues before pyrolysis……………………..…	83
8.	Mass behavior of corn stalks before and after pyrolysis...	85
9.	Mass behavior of trimming peach trees residues before and after pyrolysis…………………………………………………	87
10.	Mass behavior of date kernels before and after pyrolysis	88
11.	Some properties of activated carbon….......................................	101

12. Recommendation optimum parameters for each type of agricultural residue.. 109

13. Cost estimation for the activated carbon prototype.......... 120

14. Effect of activated carbon type on water quality................ 132

LIST OF FIGURES

No.	Title	Page
1.	Schematic diagram of experimental apparatus…………..…	22
2.	Schematic diagram of the experimental setup…………..….	23
3.	Gasification/Activation Reactor System…………………..…	23
4.	Schematic diagram of activated carbon prototype ……..…	43
5.	Photography of activated carbon prototype component….	44
6.	The components of activated carbon furnace…………….…	45
7.	Schematic diagram of activated carbon furnace……………	45
8.	The ceramic fiber roll………………………………………………	46
9.	Refractory used in lining……………………………………...…	47
10.	Lining grooves for electric wire…………………………...….	47
11.	Furnace door……………………………………………………...…	48
12.	The heating spiral wire…………………………………………..…	49
13.	The heating wire supported in the furnace lining grooves……………………………………………………………...…	49
14.	The regulator gas components…………………………...….	51

15. Circuit of activated carbon furnace………………………..… 53

16. Furnace on/off and temperature controller box…………..… 53

17. Laboratory furnace test in Metallurgical Research Center……………………………………………………………… 54

18. The hearth……………………………………………………..… 55

19. The control unit……………………………………………….… 56

20. Corn stalks collected from Gimmeza Research Station… 57

21. Residues of trimming peach trees collected from Horticultural Research Institute………………………………… 57

22. Date kernels collected from Horticultural Research Institute……………………………………………………..… 58

23. Layout of the pyrolysis operations…………………………..… 62

24. Samples washed by warm distilled water……………..…… 63

25. Treated of drinking waste water……………………………… 65

26. Drying oven……………………………………………………… 67

27. Preparation the pyrolyzed samples to determine the adsorption by methylene blue test……………………………… 69

28. The spectrophotometry device………………………...………… 69

29. The standard fit curve for absorbance methylene blue and blank concentration………..……………………………… 70

30. The scanning electron microscope…………………………... 71

31. pH meter……………………………………………………….. 72

32. The turibidmeter………………………………...……………… 72

33. The conductivity meters………………………………………... 73

34. Determination of furnace power……………...………………… 79

35. Chemical components of raw materials for agricultural residues ……………………………………………………………… 82

36. Bulk density of agricultural residues…………………………... 83

37. Moisture content of agricultural residues…………………… 84

38. Effect of pyrolysis time on mass reduction of corn stalks at different furnace temperatures …………..…………………… 86

39. Effect of pyrolysis time on mass reduction of trimming peach trees residues at different furnace temperature......… 86

40. Effect of pyrolysis time on mass reduction of date kernels at different furnace temperature……………………… 88

41. Effect of furnace temperatures on carbon concentration at different pyrolysis time for corn stalks…………………….. 90

42. Effect of furnace temperatures on carbon concentration at different pyrolysis time in trimming peach trees residues …………………………………………………………… 92

43. Effect of furnace temperatures on carbon concentration at different pyrolysis time in date kernels…………………… 93

44. Effect of furnace temperatures on yield percentage at different pyrolysis time for corn stalks.……………..………… 96

45. Effect of furnace temperatures on yield percentage at different pyrolysis trimming peach trees residues ………... 97

46. Effect of furnace temperatures on yield percentage at different pyrolysis date kernels………………………………… 98

47. Some chemical properties of activated carbon…………….. 100

48. Bulk density of activated carbon…………………………..…. 101

49. Moisture content of activated carbon………………………… 102

50. Surface area for different activated carbon………………... 103

51. Pore volume for different activated carbon……………….. 103

52. Scanning electron micrographs for activated carbon produced from corn stalks at 400°C in 1 h……………..…… 105

53. Scanning electron micrographs for activated carbon produced from corn stalks at 700°C in 2.5 h………..…….. 105

54. Scanning electron micrographs for activated carbon from trimming peach trees residues at 700°C in 2 h………..…… 106

55. Scanning electron micrographs for activated carbon produced from trimming peach trees residues at 500°C in 2.5……..…………………..…………………...…… 107

56. Scanning electron micrographs for activated carbon produced from date kernels at 400°C in 2 h………………… 108

57. Scanning electron micrographs for activated carbon produced from date kernels at 700°C for 2.5 h………….. 109

58. Effect of pyrolysis operation on activated carbon yield…. 110

59. Effect of pyrolysis operation on some chemical components of activated carbon………………………………… 111

60. Effect of pyrolysis operation on bulk density of activated carbon……………………………………………………… 112

61. Effect of pyrolysis operation on surface area of activated carbon.. 113

62. Effect of pyrolysis operation on pore volume of activated carbon.. 114

63. The scanning electron micrographs (SEM) for activated carbon produced from corn stalks................................ 115

64. The scanning electron micrographs (SEM) for activated carbon produced from trimming peach trees................. 116

65. The scanning electron micrographs (SEM) for activated carbon produced from date kernels................................ 116

66. Effect of pyrolysis operation on moisture content of activated carbon.. 117

67. Productivity of activated carbon..................................... 118

68. Cost estimation for the activated carbon prototype......... 119

69. Comparative between laboratory unit and prototype production in activated carbon yield 121

70. Comparative between laboratory unit and prototype production in carbon content 122

71. Comparative between laboratory unit and prototype production in bulk density………………………………………… 123

72. Comparative between laboratory unit and prototype production in surface area ……………………………………… 123

73. Comparative between laboratory unit and prototype production in pore volume ………..……………………………… 124

74. Effect activated carbon height on purification time………. 126

75. Effect activated carbon height on turbidity………………….. 127

76. Effect activated carbon height on total dissolved solids..... 129

77. Effect activated carbon height on No. of microorganism 131

78. Drinking water before and after purification ……………….. 131

79. Drinking water after purification…………………………… ….. 132

INTRODUCTION

Agricultural residues are national wasted wealth and are one of the riches untapped, because of burning and disposing in different ways. Total agricultural residues in Egypt are about 43 million Mg, where the total winter season residues 2013/2014 are 8.13 million Mg, while total summer season are 8.44 million Mg, whilst the Nile season residues 8.4 million Mg, in addition to the 3.4 million Mg of palm wastes and 7.6 million Mg fruit trees, and 6.4 million Mg oil trees (Ministry of agricultural, 2013-2014).

It is possible to use residues in manufacturing fertilizer, animal feed, bricks, as well as for use in bioenergy and organic coal, and for many of new products such as biocarbon, biochar, activated carbon, polymers, and etc.

Also, benefit from the recycling residues lead to employment opportunities for young people to overcome unemployment in country, noting that can use it as a small project.

Activated carbon can be prepared from large number of precursor materials with a high carbon contents, cellulose, lignocellulose, lignin and low level of ash including coal, woods and bones. In addition, some agricultural by-products residues from agriculture and agro-industries can be also used as raw materials for preparing activated carbon. Therefore, activated carbon is worldwide used in gas purification, gold purification, metal extraction, medicine, sewage treatment, air filters in gas masks and filter masks along with water and wastewater treatment also as catalyst support and many other applications. Adsorption capacity of activated carbon depends essentially on their production methods and initial structural properties.

Activated carbon plays an important role as adsorbent, due to its unique distinguished properties. Activated carbon is a form of carbon that has been processed to make its extremely large pores and thus to have a very large surface area available for adsorption or chemical reactions. Also, it can be prepared either by physical (dry) or chemical activation.

Egypt faces a paucity of activated carbon producing; otherwise it is often used in Egypt. Moreover, the export of activation carbon represents about of 90% (Ministry of Industry and Trade, 2016) of the total usage. Consequently, it is important to highlight the specifications form of carbon production and methods of activated carbon, as well as the economics of production.

For this reason, the aim of the present work is performance evaluation of design activated carbon prototype productivity.

REVIEW OF LITERATURE

1. Description of activated carbon

Activated carbon can called activated charcoal or activated coal. Activated carbon is a form of carbon that has been processed to make it extremely large pores and thus to have a very large surface area available for adsorption or chemical reactions (Hiremath *et al.*, 2012)**.**

a. Definition of activated carbon

Bostancioglu and Oruç (2012) defined that activated carbon as based that material had a highly pores carbon and due to its well-developed porosity and surface functional groups.

Farah (2001) explained that activated carbon as a pores carbonaceous material, that prepared by carbonizing and activating organic substances of mainly biological origin. The most important property is a very large adsorption power, which is due to highly developed pores structure that produces a surface area in order of 800 - 1200$m^2.g^{-1}$.

Activated carbon is related to properties such as surface area, pore volume and porosity. These unique characteristics are dependent on the type of raw materials employed and the method of activation (Tsai *et al.*, 2001).

b. Pre-sources to produce activated carbon

Bostancioglu and Oruç (2012) showed that many kinds of materials can be used as the pre-sources for producing activated carbon. This material include wood, charcoal; agricultural by-products like nut shells, fruit pits, rice husk, corncob wastes and synthetic polymers were commonly used as the starting material.

In addition, some residues from agriculture and agro industries can be also used as raw materials for preparing activated carbon. Many research work reported more than residues which able to product activated carbon these included almond shells, apricot and peach stones, cashew nuts, linseed straw, olive stones, maize cob, rice hulls and saw dust (Bousher *et al*., 1997; Rengaraj *et al*., 1999; Kadirvelu *et al*., 2000 and Bacaoui *et al*., 2001)

Also, Hiremath *et al*. (2012) indicated that some material can use to produce activated carbon coconut shells, eucalyptus bark, linseed cake, tamarind seeds and tea waste ash suffocated coal, baggase, ground nut husk, activated bauxite, palm seed coat, de-oiled soya, cement kiln dust.

c. Usages of activated carbon

Mohammad and Ansari (2009) conducted that activated charcoal is one of the most important adsorbent that can be employed for these purposes. The use of AC is perhaps the best broad spectrum control technology. It was also quite possible to increase the amount of adorption of inorganics by impregnating the activated carbon with suitable chemicals.

Activated carbon used as adsorbents in many applications such as impurities and contaminations. The adsorption capacities of activated carbon depended it's on porosity and surface area (Duran *et al*., 2005; Sudaryanto *et al*., 2006 and Shalna and Yogamoorthi, 2015).

Bostancioglu and Oruç (2012) cleared that activated carbon is one of the most widely used adsorbents for the various gas separation and purification processes, the recovery of solvents, the removal of organic pollutants from drinking water and as a catalyst support.

Cobb *et al*. (2012) mentioned that activated carbon has the capacity to remove suspended solids and microbial pathogens from water sources. By activated carbon production process using agricultural waste like coconut shell charcoal with chemical activation techniques (sodium chloride).

The removal of organic matter in aqueous or gas phases with granular activated carbon (GAC) is commonly performed for the treatment of water or the volatile organic compounds. GAC adsorbers have been proved to be effective in removing a large number of organic molecules (Gamage and Sathasivan, 2017).

d. Applications of activated carbon

The carbon produced from brewer’s spent grain lignin showed high capacity for adsorption of metallic ions, mainly nickel, irons, chromium, and silicon. The concentration of phenolic compounds and color were also reduced by these sorbents (Mussatto *et al*., 2010).

El-Sayed *et al*. (2011) showed that activated carbon was prepared from maize stalks had an ability to adsorb disperse 2BLN dye from aqueous solutions.

Aidan (2012) showed that the furfural reduction from water solutions as more important substances for chemical synthesis and as solvent extraction in petroleum refineries. Organic compound entering in soil and water system are considered such a serious problem is that all have some a cut and long term toxic effects.

Baseri *et al*. (2012) said that the activated carbon was prepared from *Thevetiaperuviana* when was selected as a best quality adsorbent for the removal of dyes from textile industry effluent.

Hiremath *et al*. (2012) mentioned that activated carbon produced from agricultural wastes, as sorbents and as promising materials for wastewater treatment from furfural.

Okibe *et al*. (2013) cleared that the obtained activated carbon from brachystegia eurycoma and prosopis africana seed hullsare of commercial grade had the potential for application in liquid and gaseous phase adsorption.

Shalna and Yogamoorthi (2015) examined activated carbon produced from tea dust in chromium removal from tannery effluent.

Abbaszadeh *et al*. (2016) reported that activated carbon produced from papaya peel as a locally available bio-derived adsorbent in the removal of Pb^{+2} from metal-contaminated water. Utilization of natural bio-wastes, such as papaya peel, in this way could assist with waste minimization at the same time as providing a new source of activated carbon for wastewater treatment.

Demiral and Güngor (2016) mentioned that batch adsorption for the removal of Cu^{+2} from aqueous solutions have been carried out using the produced activated carbon from grape bagasse by phosphoric acid activation.

Gonsalvesh *et al*. (2016) found that activated carbon perform better in Ni^{+2} removal probably due to its more proper surface area, pores texture characteristics and the nature of the organic surface groups and perhaps also the mineral matter content. They signed that Ni^{+2} adsorption by steam activated carbon was found to occur through cation exchange mechanism.

2. Production methods of activated carbon

Becnaddi *et al*. (1998) and Hiremath *et al*. (2012) explained that two main steps for the preparation and manufacture of activated carbon: first step is the carbonization of the carbonaceous raw material below 800°C, in the absence of oxygen, and second step is the activation of the carbonized product (char), which is either physical or chemical.

Amaya *et al*. (2005) showed that it is necessary to include a leaching step to obtain physically activated carbon from grape stalk, under standard activation conditions. That is because the leaching operation removes approximately 70% of grape stalk total ash content. By chemical activation this step was not necessary and it was attributed to a complementary leaching effect of phosphoric acid.

Bostancioglu and Oruç (2012) reported that there are basically two methods for preparing activated carbon: physical and chemical activation. Physical activation consists of two steps: the carbonization of starting material at 400-500°C to eliminate the bulk of the volatile matter and the activation of char by using the both of carbon dioxide and water steam at 800-1000°C or with air at low temperature. In chemical activation the both of carbonization and activation steps proceed simultaneously.

a. Physical activation

Zhang *et al*. (2004) explained that the activation gas is usually CO_2, since it is clean, easy to handle and it facilitates control of the activation process due to the slow reaction rate at temperatures around 800^oC.

Hiremath *et al*. (2012) said that physical activation involves two steps; in first step precursor material will undergo carbonization process (600-900°C) in the absence of oxygen and second step involves activation/oxidation by gases like carbon dioxide, oxygen and steam. Also they mention that carbonization temperature range between 400 and 850^oC, and sometimes reach 1000^oC, and activation temperature range between 600 and 900^oC. The activated carbon produced by physical activation did not have satisfactory characteristics in order to be used as adsorbents or as filters.

b. Chemical activation

Tsai *et al*. (1997) and (1998) and Zhang *et al*. (2004) reported that in the chemical activation process, the two steps carbonization and activation are carried out simultaneously, with the pre-sources being mixed with chemical activating agents, as dehydrating agents and oxidants. Chemical activation offers several advantages since it is carried out in a single step, performed at lower temperatures and therefore resulting in the development of a better pores structure, although the environmental concerns of using chemical agents for activation and influence of more effective pores structures. Besides, part of the added chemicals (such as zinc salts and phosphoric acid), can be easily recovered.

Bostancioglu and Oruç (2012) reported that major advantages of chemical activation compared to physical activation were lower treatment temperatures and shorter treatment times. In addition, activated carbon obtained by chemical activation exhibits a larger surface area and better developed mesoporosity than physical activation. In addition, they stated that some disadvantages of the chemical activation process, such as corrosiveness of the process and the washing steps after carbonization.

However, Becnaddi *et al*. (1998) stated that the disadvantage of chemical activation is the incorporation of impurities coming from the activating agent which may affect the chemical properties of the activated carbon. They also demonstrated that the chemical activation is to be performed in only one step and at a relatively low temperature: < 500°C for activation of wood by phosphoric acid, between 600 and 700°C for the activation of lignocellulosic materials impregnated with $ZnCl_2$.

Patil and Kulkarni (2012) mentioned that chemical activation given higher carbon yield than physical activation.

Okibe *et al*. (2013) stated that the yields and the properties of the activated carbon produced in chemical activation such as surface area, heat flow, iodine sorption capacity and methylene blue number reveals that they have pore structures comparable to those of commercial activated carbon adsorbents.

c. Steam pyrolysis/activation

There is also an additional one-step treatment route, denoted as steam-pyrolysis (Minkova *et al*., 2000 and 2001; Savova *et al*., 2001; Fan *et al*., 2004 and Gonsalvesh *et al*., 2016) where the raw agricultural residue was either heated at moderate temperatures (500-700°C) under a flow of pure steam, or heated at 700-800°C under a flow of just steam.

Minkova *et al*. (2001) studied the residues treatment with steam pyrolysis/activation method by using olive, straw, birch, bagasse, miscanthus, apricot stones, cherry stones, grape seeds, nutshells, almond shells, oat hulls, corn stover, and peanut hulls.

3. Factors effecting of activated carbon production

The most important factors to prepare activated carbons were described at type and properties of raw material, activation agent, mass ratio of pre-source to activating agent, heating speed, carbonizing temperature, carbonizing time and gas flow speed.

a. Raw materials

Many research work, (Ahmedna *et al*., 2000; Marcilla *et al*., 2000; Girgis *et al*., 2002 ; Oh and Park, 2002; Malik, 2003; Yang and Lua, 2003; Lua *et al*., 2004 and Haykiri *et al*., 2006) cleared many raw materials that can be activated by physical activation method these included rice husk, corn cob, oak, corn hulls, corn stover, rice straw, rice hulls, pecan shells, peanut hulls and almond shells as showed in (Table 1).

Savova *et al*. (2001) found that materials with a greater content of lignin (grape seeds, cherry stones) developed activated carbon with macropores structure, while raw materials with a higher content of cellulose (apricot stones, almond shells) yield activated carbon with a predominantly micropores structure.

However, (Ahmadroup and Do, 1997; Yalcm and Sevinc, 2000; El-Hendawy *et al*., 2001; Aygun *et al*., 2003; Stavropoulos and Zabaniotou, 2005 and Sudaryanto *et al*., 2006) showed that chemical activation was used in most of the studies for corn cob, olive seeds, rice husks, rice straw, cassava peel, pecan shells, macadamia nutshells, hazelnut shells, peanut hulls, apricot stones and almond shells as shown in (table 2), and Hiremath *et al*. (2012) indicated that the most common chemical agents are $ZnCl_2$, KOH, H_3PO_4 and less K_2CO_3.

Tsai *et al*. (2001) said that the influence of activation temperature on the final products was studied by examining their physical characterizations such as BET surface area, total pores volume and true density. They reported that an elevated temperature was favorable for producing carbon products with high surface area and total pore volume. Also, the values of the true density and the porosity increased with increase in the activation temperature.

Table 1. Physical activation of agricultural residues (Haykiri *et al*., 2006).

Activating agent	**Steam**	**CO_2**
Material	Rice husk, corn cob, olive residues, sunflower shells, pinecone, rapeseed, cotton residues, olive-waste cakes	Oak, corn hulls, corn stover, rice straw, rice hulls, pecan shells, Pistachio nutshells, sugarcane bagasse, Peanut hulls, almond shells

Table 2. Chemical activation of agricultural residues (Sudaryanto *et al*., 2006).

Activating agent	**Material**
$ZnCl_2$	Corn cob, Macadamia nutshells, peanut hulls, almond shells, hazelnut shells, apricot stones, rice husks
KOH	Corn cob, Macadamia nutshells, peanut hulls, olive seed, rice straw, Cassava peel
H_3PO_4	peanut hulls, almond shells, pecan shells, corn cob
K_2CO_3	Corn cob

1. N,C and H content

El-Said (2004) indicated that elemental analyses of N, C and H content for apricot were 6.23, 45.22 and 9.34%, respectively. However, Amaya *et al*. (2005) performed that proximate analysis of grape stalk; they reported that fixed carbon was 23.07% and elemental analyses were 0.366, 46.143 and 5.737% for N, C and H contents, respectively.

Skoulou and Zabaniotou (2005) and Ioannidou and Zabaniotou (2007) showed the elemental analysis elemental analyses of N, C and H content were 0.78, 45.53 and 6.15%, respectively in corn stalks also 0.57, 46.3 and 5.6% in corn cab, respectively. Whereas, the analyzed for peach tree pruning's recorded 0.32, 53 and 5.9%, respectively. Also they manifested apricot tree pruning's were 0.8, 51.4 and 6.29%, respectively. In addition, their proximate and ultimate analysis of N, C and H content for olive tree pruning's were 0.7, 49 and 6%, respectively, cotton stalks were 0.78, 41.23 and 5.03%, respectively, when vineyard pruning's were 1.8, 47.6 and 5.6%, respectively, sugar beet leaves were 1.84, 44.5 and 5.9%, respectively, barley straw were 0.41, 46.8 and 5.53%, respectively, rice straw were 0.7, 41.8 and 4.63%, respectively, oats straw were 1.13, 46 and 5.91%, respectively and sunflower straw were 1.38, 52.9 and 6.58%, respectively.

Jun *et al.* (2010) showed that the ultimate analysis for durian shell had 1.00, 39.30 and 5.90%, respectively of N, C and H content. Therefore Chang *et al.* (1998) and Tsai *et al.* (1998) found that the compositions of cob based on proximate were fixed carbon ratio of 16.1%.

Aidan (2012) reported that C and H content of breaking raw peach stones were 48 and 6.0%, respectively and apricot was 50 and 5.0%, respectively. However, Hiremath *et al.* (2012) performed on the elemental analysis of corn cob granules using elemental analyzer (CHNSO) and thermo flash EA 1112 model, they showed that the content were 0.4, 44.0 and 7.0%, respectively of N, C and H content.

2. Ash content

Some raw material proximate analysis of ash in many researches as Chang *et al.* (1998) and Tsai *et al.* (1998) which recorded that cob was 0.9%; El-Said (2004) mentioned that apricot was 1.2%; Amaya *et al.* (2005) showed that grape stalk was 10.16%, while Jun *et al.* (2010) showed for durian shell was 4.84%. However, Aidan (2012) reported that the analyzed for ash peach tree pruning's recorded 1%.

Skoulou and Zabaniotou (2005) and Ioannidou and Zabaniotou (2007) showed that the percentage of ash was 6.4% in corn stalks and 5.34% in corn cobs, they manifested apricot tree pruning's the ash was 0.2%. Also they showed that the olive tree pruning's percentage of ash was 4.75%, cotton stalks was 13.3%, when vineyard pruning's was 3.8%, sugar beet leaves was 4.8% , barley straw was 4.9%, rice straw was 13.4%, oats straw was 4.9% and sunflower straw was 3%.

b. Activation agents

Ahmadroup and Do (1997) and Tsai *et al.* (2001) used $ZnCl_2$ as an activating agent for macadamia nutshells. Also, Yalcm and Sevinc (2000) used rice husks with $ZnCl_2$ at 500°C for 1 h and at 600°C for 3 h in combination with CO_2, respectively. They concluded that the best characteristics of the activated carbon than with any other agent.

Carbon from macadamia nutshells (Yalcm and Sevinc, 2000) and peanut hulls (Girgis *et al.*, 2002) were activated with KOH at 800°C for 1.0 h and 500 - 700°C for 3 h, respectively compared with the produced using $ZnCl_2$. They reported that activated carbon that was produced did not have good quality as the ones produced with $ZnCl_2$.

Chang *et al*. (2000) reported that corn cob was a suitable precursor for production of good activated carbon by chemical activation. They focused to produce high-quality micropores activated carbon from corn cob agro-waste using N_2 carbonization followed by physical activation with CO_2 or steam.

Tsai *et al*. (2001) analyzed corn cob char that was activated with KOH at 500 - 800°C for 1.0 h; they reported that did not generally give activated carbon with good surface area. They also mentioned that carbon from corn cob were activated with K_2CO_3 at 500 - 800°C for 1.0 h, where the activated carbon produced, comparatively with the results with KOH, had a lower surface area and gave the maximum char yield.

Stavropoulos and Zabaniotou (2005) showed that activation of olive seed carbon took place at 800 - 900°C for 1.0 - 2.0 h and gave activated carbon with high surface area and char yield. However, almond shell chars activated with H_3PO_4 gave carbon with a little lower surface area than those mixed with $ZnCl_2$ (Ahmedna *et al*., 2004).

Olivares *et al*. (2006) explained that $ZnCl_2$ method based on chemical activation is very effective to prepare activated carbon ranging widely in its textural and surface properties at using the 4:1 impregnation ratio. The effect of the increase in the impregnation ratio on the pores structure of activated carbon is stronger than that of the rise in the carbonization temperature.

Cuhadaroglu and Uygun (2008) found when impregnation ratio is fixed at 1 : 1 to determine the effects of carbonization temperature, activation level increases with increasing temperature up to 900ºC but it decreases over 900ºC for active carbon obtained by KOH. For active carbon obtained by NaOH, increasing the carbonization temperature raises the activation level.

Jun *et al*. (2010) produced activated carbon from durian shell by impregnating 10g of sample in 10% (v/v) concentration of phosphoric acid for 24 h, followed by carbonization at 400 and 500°C with different heating durations under nitrogen atmosphere.

Mussatto *et al*. (2010) produced activated carbon from hazelnut shell by chemical activation of brewer's spent grain lignin using H_3PO_4 by impregnation with 3g H_3PO_4/g lignin at 600°C. Furthermore, Al-Qodah and Shawabkah (2009) used activated sludge as a pre-source to prepare activated carbon using chemical activation agent of sulfuric acid and heated to 200°C with continuous agitation for 1.0 h. However, Wang *et al*. (2010) used impregnation ratio of 2 : 1 of H_3PO_4.

Foo and Lee (2010) selected the *Parkia speciosa* pod which known as stink bean or 'petai', for activated carbon preparation by activation with phosphoric acid. They studied the effect of carbonization temperatures ranging from 450 to 650°C and mass ratio of acid to precursor (1 : 1 and 1 : 2) on the porosity formation of the resulting carbon that were studied for a carbonization period of 1.0 hour.

Bostancioglu and Oruç (2012) investigated that chemical activation, pyrolysis char would be impregnated with some chemical agents such as H_3PO_4, $ZnCl_2$, KOH, $CaCl_2$ and H_2SO_4. Chemical agents act as dehydration agents which may restrict the formation of tar and volume contraction during carbonization. The agent concentration have effected especially in lower concentrations. Also, they stated that there was no important change among the activated carbon samples with different acid impregnation ratios while increasing the concentration (40-50%) caused to some extra peaks in region of alkane groups but chemical agent in the pore structure can be the reason of this peaks. However, Cobb *et al*. (2012) mentioned that the adsorption capacity being the most efficient and cost effective activating agent.

Hiremath *et al*. (2012) showed that results for ash of various tests conducted to study the feasibility of activated carbon preparation from corn cob by KOH activation at 600°C was 6.8%, at 700°C was 6.2%, at 800°C was 3.9% and at 900°C was 6.4 %.

Also, Kwaghger and Adejoh (2012) produced the activated carbon from mango nuts by chemical activation method using $ZnCl_2$ by mix ratio of 1 : 2.8g/ml, and activation time of 4.59 h.

Yusufu *et al*. (2012) showed that heat activation at 950°C for 3 h to produce activated bone carbon and at 850°C for 2.5 h for heat activated coconut-shell and wood carbon with concentrated phosphoric acid (1 : 4) carbon: acid (w/w) at 600°C for 2 h to produce acid activated wood, acid activated coconut-shell and acid activated bone samples.

c. Pyrolysis time and temperature

Tsai *et al*. (1997), (1998) and (2001) and Girgis *et al*. (2002) used zinc chloride for the activation of carbon from corn cob in the range of 400 - 800°C, for 0.5 - 4.0 h of agent time soaked, and a 50% solution was mixed with sample of peanut hulls at 300-750°C for 6 h.

The activating conditions for peanut hull chars were 500°C for 3 h (Girgis *et al.*, 2002). While El-Hendawy *et al*. (2001) stated that corn cob chars activated for 500°C for 2 h. Corn cob gave better characteristics of the activated carbon than peanut hull.

Tsai *et al*. (2001) reported that the pores carbon products from agricultural waste corn cob were manufactured by using the combined activation methods. Under their experimental conditions in the activation temperature ranges from 500 - 800°C with less pollution characteristics of potassium hydroxide : potassium carbonate (KOH : K_2CO_3) as chemical agents and subsequent gasification (i.e. physical activation) at the soaking time of 1.0 h.

Oh and Park (2002) clarified that rice straw char activation proceeded firstly in one-stage at 500 - 900°C for 1.0 h and secondly in two - stages at 700 - 1000°C for 1.0 h (carbonization conditions) and then at 900°C for the activation.

Also, Aygun *et al*. (2003) explained that activated almond shells, hazelnut shells and apricot stones with a solution of $ZnCl_2$ (30 wt %) at 750, 800 and 850°C, respectively for 2 h.

Zhang *et al*. (2004) stated that the activation durations of 1.0 and 2 h did not appreciably affect the properties of activated carbon from oak at 700°C. Also they mentioned that the longer the activation duration, the greater the adsorption capacity of the resultant activated carbon from oak and vice versa for the corn hulls and corn stover. Also they mentioned the char was carbonized at 500°C, then soaked for 2 h, and steam-activated at 850°C in a flow of steam/N_2, for 1.0 h.

Fan *et al.* (2004) mentioned that for preparation and characterization of activated carbon derived from oat hulls or corn stover, char it heated at 800°C for 30, 60, 90 and 120 min.

Olivares *et al.* (2006) in contrast, the effect of the increase in carbonization temperature on the surface functional groups and structures are the more important one.

Sudaryanto *et al.* (2006) stated that cassava peel char activated at 650 and 750°C, the higher surface Brunauer-Emmett-Teller (BET) appeared in the second case.

Sugumaran *et al.* (2012) produced activated carbon was produced from banana empty fruit bunch (BEFB) and *delonix regia* fruit pod (DRFP) through single step chemical activation process. They reported that both the lignocellulosic wastes showed maximum weight loss at temperatures lower than 500°C, they were carbonized at 450°C (BEFP) and 400°C (DRFP) respectively after impregnating with H_3PO_4 and KOH.

Abechi *et al.* (2013) stated increase in temperature and time of activation was detrimental because it led to highly reduced yield with little increase in the surface area of the carbon. Significantly reduced yield of product was observed for activation temperature beyond 800°C.

d. Nitrogen rate

Tsai *et al*. (2001) stated that nitrogen flow rate of 200cm^3.min^{-1} at standard temperature and pressure. However, Foo and Lee (2010) mentioned that use nitrogen purge rate of 10cm^3.min^{-1}.

Bouchelta *et al*. (2008) showed the wastes of Algerian date stones produced activated carbon by pyrolysis temperature of 700°C under a 100cm^3.min^{-1} nitrogen flow and then activated under water vapor at 700°C for 6 h.

4. Mechanisms of pyrolysis operation

Becnaddi *et al*. (1998) and Prahas *et al*. (2008) indicated that phosphoric acid induced important changes in the pyrolytic decomposition of the lignocellulosic materials since it promoted depolymerization, dehydration and redistribution of constituent biopolymers, favoring the conversion of aliphatic to aromatic compounds at temperatures lower than for heat treatment in the absence of additive, thus increasing the yield. Moreover treatment with phosphoric acid allowed developing both micropores and mesopores in the resulting carbon materials. In addition they used activation of lignocellulosic materials by phosphoric acid to produce acidic carbon which precluded the use of such materials in the pharmaceutical applications. They reported also phosphoric acid is preferred not only because of the simplicity of its recovery after carbonization, but also because of the decline of the zinc chloride process related to problems of environmental contamination with zinc compounds.

Mussatto and Teixeira (2010) stated that average values of the main components in some lignocellulose wastes such as corn cobs, corn stalks, rice straw and wheat straw were 33.7, 35.0, 36.2 and 32.9%, respectively of cellulose. However, for hemicellulose were 31.9, 16.8, 19.0 and 24.0%, respectively. Furthermore, for lignin were 6.1, 7.0, 9.9 and 8.9%, respectively.

Nasser *et al*. (2016) reported chemical composition of the date palm stone were 32.77% of cellulose, 30.20% of hemicellulose and 37.03% of lignin.

5. Designed machine for pyrolysis operation

Tsai *et al*. (2001) designed a schematic diagram of an experimental apparatus for the sample activation that was identical to chemical activation with $ZnCl_2$ as shown in Fig. (1). The reactor was placed vertically inside an electric tube furnace controlled by the proportional integral derivative controller. The temperatures of the reaction zone were measured by the chromel-alumel (K-Type) thermocouples. The nitrogen gas from a cylinder was dried and purified by molecular sieve tube. The pyrolyzed samples were subjected to physical activation in CO_2 at activation temperature for exposure time of 1.0 h before cooling under nitrogen flow.

Bouchelta *et al*. (2008) prepared activated carbon from date stones by pyrolysis under nitrogen flow and activation under water vapor. Pyrolysis of the raw material was carried out with a horizontal tubular furnace (length of 450 mm and internal diameter of 65 mm). The reactor was a quartz tube (length of 750 mm and internal diameter of 35 mm), which was placed in the furnace as shown in Fig. 2. Two thermocouples were used to measure the temperature in the reactor and for monitoring the furnace.

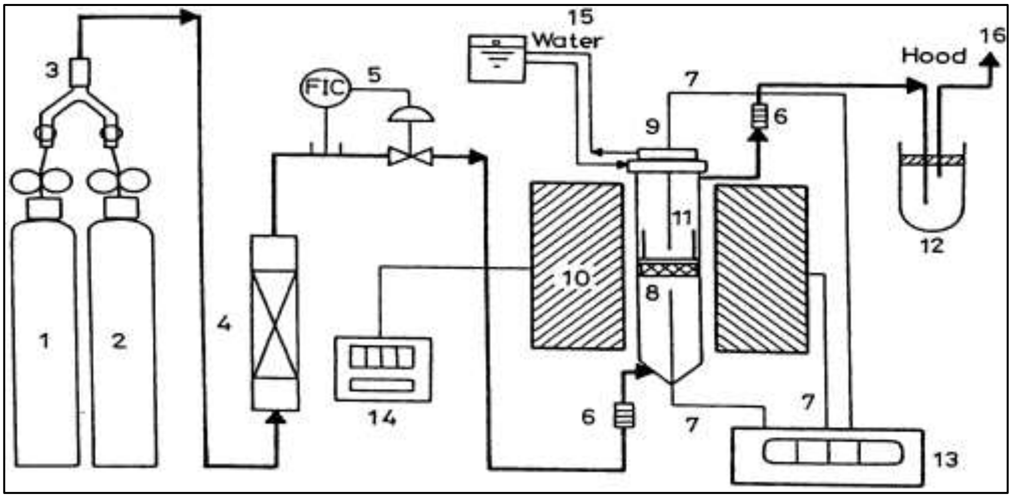


Fig. 1. Schematic diagram of experimental apparatus (Tsai *et al.*, 1998). (1) CO_2 cylinder; (2) N_2 cylinder; (3) Three-way valve; (4) Molecular sieve; (5) Mass flow controller; (6) Fast connector; (7) Thermocouple; (8) Reaction net; (9) Tubular fixed-bed reactor; (10) Heating furnace; (11) Crucible; (12) Oil collector; (13) Temperature recorder; (14) Temperature controller; (15) Cycle water system; (16) Vent to hood.

Buah and Kuma (2016) designed the reactor of a stainless steel chamber of a rectangular cross-section, having a square groove positioned symmetrically at the bottom part of the reactor, which allowed efficient heat transfer into the bed of material being treated. Also, the design allowed easy feeding of pre-sources as well as easy discharging of carbonized products and can be scaled up for commercial production of activated carbon as shown in Fig (3).

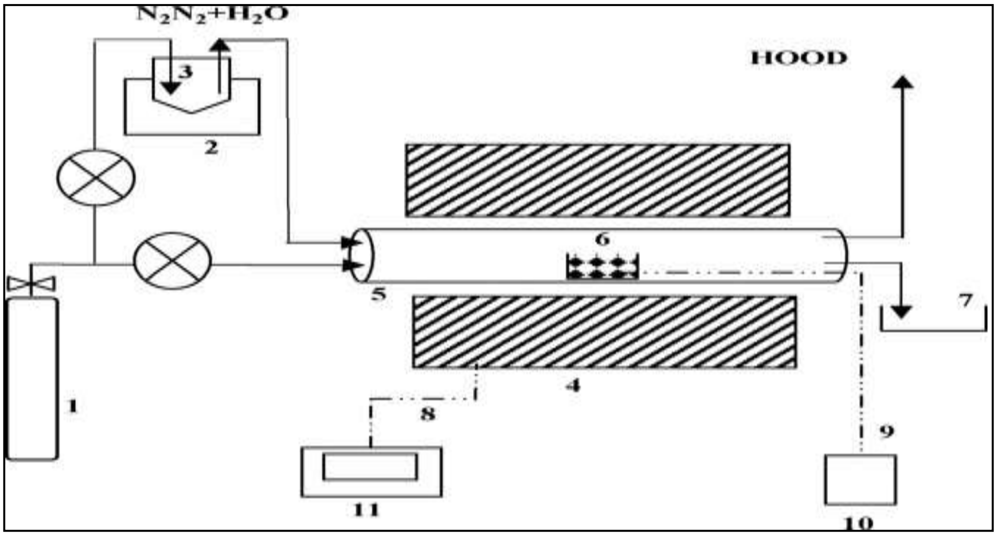


Fig. 2. Schematic diagram of the experimental setup (Bouchelta *et al.*, 2008).

(1) nitrogen gas cylinder; (2) flask heater; (3) water saturator; (4) tubular furnace; (5) tubular reactor; (6) sample; (7) beaker (liquid product collectors); (8) furnace thermocouple; (9) sample thermocouple; (10) temperature recorder; (11) temperature controller.

Fig. 3. Gasification/Activation Reactor System. (Buah and Kuma, 2016).

6. Activated carbon production

Alhamed (2002) tested the optimum operating conditions for production of activated carbon from date stones. He found that carbonization time was 0.5 hour, temperature of carbonization was 600°C and zinc chloride to date stones ratio was 2 : 1. In addition, the best conditions with good phenol adsorption capacity were carbonization temperature 700°C, carbonization time 1.5 hours.

Zhang *et al*. (2004) performed activated carbon by physical activation of oak, corn hulls and corn stover chars at temperatures of 700 and 800^{o}C and durations of 1 and 2 h.

Amaya *et al*. (2005) obtained the activated carbon by physical activation grape stalk was activated at temperature, time and water vapor flow rate higher than 700°C, 105 minutes, and 0.50ml.min^{-1}, respectively. Therefore, by chemical activation was performed using phosphoric acid as activating agent, with an impregnation ratio of 3.37 and 4.22g H_3PO_4/g precursor. The impregnated material was thermally treated at temperatures higher than 500°C for at least 60 minutes.

Wang *et al*. (2010) used pruning mulberry shoot for the production of activated carbon with optimum operation pyrolysis temperature of 500°C, and pyrolysis time of 2 h.

Baseri *et al*. (2012) explained that the activated carbon prepared by impregnation of the vetia peruviana with H_3PO_4 (30%) solution followed by activation at 800ºC.

Whereas, Bostancioglu and Oruç (2012) reported that the optimum operation condition for hazelnut shell was chemically activated with H_2SO_4 and pyrolyzed at 450^{o}C for 2 h produced activated carbon.

Hiremath *et al*. (2012) prepared the activated carbon from corn cob that was mixed with KOH solution in the muffle furnace for carbonization process at 600°C for 2 hour.

Abechi *et al*. (2013) recommended that the best conditions for the preparation of activated carbon from palm kernel shell for adsorption using KOH as activating agent at 800^{o}C for 45 minutes.

Kwaghger and Ibrahim (2013) cleared that the optimum preparation conditions for mango nuts activated carbon were obtained at carbonization temperature of 212.1°C, HCl concentration of 100%, 30min resident time and 1.0ml.g^{-1} mix ratio.

Okibe *et al*. (2013) prepared activated carbon from the pyrolysis of *brachystegia eurycoma* and *prosopis africana* seed hulls at 400°C by chemical activation with H_3PO_4 and pre-sources impregnation ratio of 1.5.

Acikyildiz *et al*. (2014) concluded that the best adsorptive properties of the samples prepared from pine sawdust, rose seed and cornel seed by a one-step chemical activation with zinc chloride were obtained at the carbonization temperature of 400 - 500°C, the impregnation ratio of 1.5 and the impregnation time of 1.0 - 2.0 h.

Buah and Kuma (2016) produced activated carbon using the reactor from corn cobs, coconut shells and palm kernel shells by carbonization at 900°C pyrolysis temperature, followed by steam activation of the derived chars also at 900°C for various durations at steam addition rate of 0.2mol.h^{-1}.g^{-1} char.

Laginhas *et al*. (2016) prepared activated carbon from chitosan used a combination of hydrothermal carbonization with activated with CO_2, $CaCO_3$ and K_2CO_3 to produce activated carbon. The optimal carbonization conditions are 200°C for 24 h using water, precursor ratio of 1:6. The hydrocarbon was all slightly acidic with the point of zero charge 5.9 ± 0.2 and with very low porosity.

7. Quality of activated carbon

a. Dye adsorption

Alhamed (2006) showed that the optimum conditions for activated carbon production was evaluated based on the determination of using methylene blue (MB) as an adsorbate. He found that the maximum unit capacity for MB was $148 mg.g^{-1}$ at carbonization time of 1.0 hour and carbonization temperature of 600°C.

Jun *et al*. (2010) showed that the one of the important properties of activated carbon is the adsorption capacity, which directly affected the surface area. Shape of the adsorption isotherm may tell the qualitative information on the adsorption capacity as well as the extent of surface area available to the adsorbate.

Bostancioglu and Oruç (2012) stated that micro and mezopores which observed on the activated carbon samples with lower concentration were suitable for adsorption characteristics of activated carbon especially for gas-phase applications.

Sugumaran *et al*. (2012) mentioned that the highest iodine removal was observed in KOH treated banana empty fruit bunch

(BEFB) and *delonix regia* fruit pod (DRFP) samples, methylene blue reduction was high in H_3PO_4, KOH and untreated BEFP carbon samples.

Acikyildiz *et al*. (2015) found that the maximum methylene blue indexes were found as 300, 297, and 299mg.g^{-1} for pine saw dust, rose seed and cornel seed, respectively.

b. N, C, H and ash ratios

El-Said (2004) showed the elemental analyses for activated carbon from apricot stones 83.01% for carbon, 2.15% for hydrogen, 2.56% for nitrogen and 4.2% for ash.

Wang *et al*. (2010) reported that elemental analyses for pruning mulberry activated carbon with carbon, hydrogen and nitrogen contents of 44.58, 6.37 and 1.45%, respectively.

Aidan (2012) mentioned that the chemical properties in peach stones activated carbon 74.0% of carbon and 2.5% of hydrogen. 5.5% of ash and apricot stones activated carbon 85.0% of carbon, 2.0% of hydrogen and 5.0% of ash.

Pérez *et al*. (2012) produced two new activated carbon by direct activation with steam from beet pulp (BP-H_2O) and peanut hulls (PH-H_2O) in environmental friendly conditions. BP-H_2O and PH-H_2O presented carbon content about 78 and 91%.

Yusufu *et al*. (2012) stated that the ash for bone carbons ranged from 80.6 to 85.9% while those of coconut shell and wood about 1.1 to 3.5%.

Kwaghger and Ibrahim (2013) revealed that ash content of activated carbon from mango nuts was 5.92%, on the other side, Kwaghger and Adejoh (2012) reported that ash content of 6.51%.

c. Bulk density

Aidan (2012) showed that bulk density was 0.41g/m^3 and attrition was 11.3% from peach stones activated carbon and bulk density 0.46g/m^3 and attrition 8.60% from apricot stones activated carbon.

Sugumaran *et al*. (2012) recorded maximum bulk density by treated *delonix regia* fruit pod (DRFP) with KOH of 0.46g/ml followed treated DRFP by H_3PO_4. The banana empty fruit bunch (BEFB) carbon displayed lower attrition values than DRFP carbon.

Yusufu *et al*. (2012) recorded that bulk densities about 0.40 to 0.79g/cm^3 for of coconut shell and wood.

Shalna and Yogamoorthi (2015) found the characterize of activated carbon prepared using H_3PO_4 as activating agent from tea dust was obtained from the tea stall that bulk density was 0.8g/ml, ash was 12.4%, moisture was 7.2% and percentage of carbon was 73%.

d. Surface area and pore volume

The Brunauer-Emmett-Teller (BET) surface area of activated carbon is important factor because physico-chemical characteristics, it may strongly affect the reactivity and combustion behavior of the activated carbon, (Putun *et al*., 2005).

Tsai *et al*. (1997) and (1998) mentioned that the activated carbon from pyrolysis above 400°C formed a high surface area. The higher surface areas were probably due to the opening of the restricted pores. They reported also that the total pore volume was decrease by increase the both of temperature and soaking time.

Chang *et al*. (2000) stated the BET surface areas of the activated carbon from corn cob at 900°C was 1705m^2/g. while, Diao *et al*. (2001) noted that when activation duration lengthened from 20min to 30min at 500°C, surface area decreased from 1024m^2/g to 768m^2/g, which amounted to 25%. This is because longer heating duration caused some of pores become larger or even collapse, thus contributed to the reduction of surface area. Furthermore, Alhamed (2002) found that carbon with specific surface area in excess of 1100m^2/g.

Ahmedna *et al*. (2004) stated that both the size of micropores, mesopores and macropores determine the adsorptive properties of activated carbon. For instance, small pore size will not trap large adsorbate molecules and large pores may not be able to retain small adsorbates, whether they are charged, polar molecules or uncharged, non-polar compounds.

In contrast, Zhang *et al*. (2004) mention that the surface areas, total pore volume, and pore volume of activated carbon obtained upon 1.0 h of activation were much less than those upon 2 h of activation at 800°C. Obviously, the pore structure of carbon from oak altered substantially for different durations of activation at 800°C. The surface areas and pore volumes of activated carbon from chars generated from corn hulls as well as from corn stover were appreciably greater after 1.0 h of activation than after 2 h of activation. This was in sharp contrast to the results from the activation of char from oak. Plausibly, in activating the chars from both corn hulls and corn stover, the rate of pore structure formation exceeded that the destruction due to the pore enlargement and collapse at the earlier stage and vice versa at the later stage.

Amaya *et al*. (2005) mentioned that the activated carbon pore structure was characterized by nitrogen adsorption at 77°K, and BET specific surface areas was larger than 1000m^2/g.

Menéndez and Martín (2006) mentioned that the pores structure is perhaps the main physical property that characterizes activated carbon. This is formed by pores of different sizes which according to International Union of Pure and Applied Chemistry (IUPAC) recommendations and can be classified into three major groups: micropores with a pore width of less than 2 x10^{-9}m, mesopores with widths from 2.0 to 50 x 10^{-9}m and macropores with a pore width larger than 50 x 10^{-9}m.

Olivares *et al*. (2006) prepared the activated carbon by using chemical activation with $ZnCl_2$ from cherry; the specific surface area of the resultant carbon is high as 1971m^2 g^{-1}.

Demiral *et al*. (2007) mentioned that increasing of activation temperature contributed to formation of new pores because more volatile organic compounds are being released from precursor.

Bouchelta *et al*. (2008) stated that nitrogen adsorption shows that the activated carbon obtained are essentially micropores with an average BET surface area which can be increased by optimization of pyrolysis and activation conditions in order to the develop more micropores and homogeneous surface. Also, they explained that SEM examination of pyrolysed date stones showed that the porosity increases gradually after pyrolysis and activation with the increase in hold time and temperature. The best specific surface area was $635m^2.g^{-1}$ and micropores volume was $0.716cm^3.g^{-1}$ when the date stones are grinded.

Cuhadaroglu and Uygun (2008) used of bituminous coal as a precursor for the preparation of activated carbon using KOH and NaOH. The BET surface areas change between 1295 and $785m^2/g$ for KOH activated active carbon and 1566 and $657m^2/g$ for NaOH activated ones.

Al-Qodah and Shawabkah (2009) showed that activated carbon preparation from activated sludge using a chemical activation agent has a highly pores structure and a specific surface area of $580m^2/g$.

Foo and Lee (2010) showed that the maximum surface area of $190m^2/g$ and pore volume of $0.0950cm^3/g$ are obtained from *parkia speciosa* pod at carbonization temperature of 600°C and impregnation ratio of 1 : 1.

Jun *et al.* (2010) showed that micropore surface area characteristics of activated at 400°C/10min was $87m^2/g$, at 400°C/20 min was $136m^2/g$, at 400°C/30min was $314m^2/g$, at 500°C/10min was $264m^2/g$, at 500°C/20 min was $404m^2/g$ and at 500°C/30min was $347m^2/g$. The activated carbon produced at 500°C for 20min heating duration has the highest BET surface area was 1024m^2/g and largest total pore volume was 0.35cm^3/g.

Dolas *et al*. (2011) found that the activated carbon produced from pistachio shells treated 40% of sodium chloride and activated at 900°C for 90min was 3895m^2/g of surface area.

Aidan (2012) showed that physical properties in peach stones activated carbon surface area of 620m^2/g and apricot stones activated carbon surface area of 710m^2/g.

Baseri *et al*. (2012) mentioned that *Theveti aperuviana* selected as a best quality adsorbent due to highest surface area with large number of pores and low ash content.

Hiremath *et al*. (2012) showed that results of various tests conducted to study the feasibility of preparation of granular activated carbon from corn cob by KOH activation at 600°C was 565m^2/g for surface area, at 700°C was 672m^2/g for surface area, at 800°C was 940m^2/g for surface area and at 900°C was 888m^2/g for surface area., Kwaghger and Adejoh (2012) reported the surface area of activation carbon was 3551.10m^2.g^{-1}. Furthermore, Ketcha *et al*. (2012) mentioned that the carbon obtained from hard part of the cob showed the most significant properties with a specific surface area of 701.68m^2/g and a pores volume of about 0.39cm^3/g. On the other hand, samples obtained from the soft part of the maize cob mixed with small particles of woody belt, gave low specific surface area were 11.62m^2/g and pores volumes were 0.00028cm^3/g.

Patil and Kulkarni (2012) mentioned the highest surface area activated carbon prepared from pistachio shells is 3895m^2/g of surface area.

Pérez *et al*. (2012) produced two new activated carbon by direct activation with steam from beet pulp (BP-H_2O) and peanut hulls (PH-H_2O) the BET surface areas were 821 and 829m$^2 \cdot$g^{-1}, respectively. Also they showed porosities are different: PH-H_2O is mainly micropores 84% with 0.403cm$^3 \cdot$g^{-1} of total pores volume, whereas BP-H_2O develops a mesopores volume of 0.361cm$^3 \cdot$g^{-1} representing 50% of the total pores volume.

Sugumaran *et al*. (2012) reported the H_3PO_4 treated *delonix regia* fruit pod (DRFP) carbon sample showed higher surface area, the untreated DRFP registered higher pore volume. However BET surface area was comparatively low in both the substrates.

Yusufu *et al*. (2012) mentioned that the carbon presented Brunauer, Emmett and Teller (BET) surface areas between 718 and 1018m^2/g, and micropores and mesopores with volumes between 0.004 and 0.776cm^3/g.

Abechi *et al*. (2013) indicated that a low cost and high quality active carbon should be of high surface area, produced at low temperature. They showed relatively high surface area 127m^2/g production from palm kernel shell.

Kwaghger and Ibrahim (2013) found that surface area for activated carbon was prepared from mango nuts by chemical activation method using HCl was 1142.3m^2/g.

Acikyildiz *et al*. (2015) found that the highest surface areas were 1825, 1265, and 1355m^2/g from pine sawdust, rose seed, and cornel seed, respectively. However, El-Shafey *et al*. (2016) mentioned that activated carbon prepared from date palm leaflets has high surface area it was 823m^2/g.

Shalna and Yogamoorthi (2015) found the BET surface area of activated carbon prepared using H_3PO_4 as activating agent from tea dust was obtained locally from the tea stall was 280.39m^2/g.

8. Water purification

a. Main sources of water pollution

Water pollution is a relative concept; where there is no water is completely pure. Water pollution is the contamination of natural water bodies by chemical, physical, radioactive or pathogenic microbial substances (WHO, 2011 and Mohamed *et al*., 2013).

Mohamed *et al*. (2013) and Munir *et al*. (2016) stated that agricultural runoffs, industrial effluents and municipal sewage are being recklessly dumped into the Nile River, gradually making its water unfit for human consumption. Agricultural runoffs frequently contain pollutants from pesticides and herbicides, which have negative effects on the river and the people using it. Industrial effluents are often highly toxic, containing heavy metals that can combine with the suspended solids in domestic wastewater to form muck .

b. Uses activated carbon as a means of purification

Jambulingam *et al.* (2007) prepared activated carbon from L. leucocephala shell using $ZnCl_2$ process; they found that at low concentration of activated carbon of 20mg/L with dye solution, adsorbent could remove up to 98% of the dye molecules present in the solution. Even at the high concentrations of 40mg/L and 60mg/L, adsorbent was able to remove 83.5% of the dye molecules present in the solution. Also these carbons could be conveniently used for textile effluents removal. They explored for the preparation of activated carbon from agricultural wastes like tobacco stem, bulrush *Scripusacutus* stem, *leucaenaleucocephala* shell, *ceibapentandra* shell and *pongamiapinnata* shell the results showed that these agricultural wastes were good adsorbents for organic and inorganic component in water and wastewater.

Dvorak and Skipton (2013) reported that activated carbon purification can effectively reduce some of organic and chemical include solvents, pesticides, industrials wastes, or contaminates from leaking underground storage tank. Contaminate such as benzene, chlorobenzenes, trichloro - ethylene, carbon tetrachloride, methylene chloride and vinyl chloride in drinking water as well as certain harmless taste and odor producing compounds and pesticides, such as atrazine. They also reported the efficiency of the adsorption process is influenced by carbon characteristics (particle and pore size, surface area, density and hardness) and the contaminant characteristics (concentration, tendency of chemical to level the water, solubility of the contaminant and contaminant attraction to the carbon surface area.

Okibe *et al*. (2013) concluded that the activated carbon produced from *brachystegia eurycoma* and *prosopis africana* seed hulls can be used as adsorbents for various environmental applications including the removal color and heavy metals from industrial effluents, and treatment of drinking water.

Yu *et al*. (2016) showed that the addition of activated carbon is an effective measure to cope with seasonal taste and odor problems caused by 2-methylisoborneol (2-MIB) and trans^{-1}, 10-dimethyl-trans^{-9}-decalol (geosmin) in drinking water. Also they approached that the application of the homogenous surface diffusion model (HSDM) to predict the appropriate activated carbon doses for the removal of 2-MIB.

c. Specifications of fresh water

Egyptian standard (2005) and Ministry of Health and Population (2007) mentioned that the general specifications for bottled drinking water, the turbidity not more than 1.0 NTU or equivalent to one unit, while color don’t increased for 5 unit (platinum-cobalt standard). However, the count plat of microorganisms don’t increased for 50cells.mL^{-1} at temperature of 20-22°C and total dissolved solids don’t increased of 1000mg.L^{-1} at 120°C. As well as don’t had any material effect of color, smell, taste and appearance.

GCC standardization organization (GSO) (2008) stated that the drinking water don’t had any material effect of color, smell, taste and appearance, the total dissolved solids ranged between 100 - 600ppm and the pH ranged from 6.5 to 8.

WHO (2011) stated that drinking water are classified according to their content on the TDS (Total dissolved solids) in terms of taste to excellent, which is less than 300ppm, and the good that between 300-600ppm, and accepted that between 600-900ppm, and poor, which is between 900-1200ppm and above, while 1200ppm are unacceptable. In addition, do not contain any material effect of color or smell or taste or appearance.

Mohamed *et al*. (2013) mentioned that the statement of standards and specifications, according to law 48 of 1982 (Article 60 of the Regulations) color does not exceed 100 degrees and total solids is 500mg.L^{-1} (Appendix 1).

9. Evaluation of activated carbon

a. Production of activated carbon

Alhamed (2006) studied that the effect the yield of activated carbon produced from dates stones was made using zinc chloride as an activator the corresponding yield was 32% at carbonization time 1.0 hour and carbonization temperature 600°C and. Also carbonization time 3 hours and carbonization temperature 600°C activated carbon yield of 47.3%.

Bouchelta, *et al*. (2008) stated that the yield of activated carbon is conversely related to activation temperature and hold time. However, Foo and Lee (2010) showed that the carbon yield from *Parkia speciosa* was 41.1%.

Kwaghger and Adejoh (2012) recorded the yield was 85.85% from mango nuts. While, Sugumaran *et al*. (2012) reported that highest yield of 41.09% was recorded in *delonix regia* fruit pod (DRFP) treated with H_3PO_4. Even though, Wang *et al*. (2010) showed carbon yield was 38.12% from pruning mulberry and Kwaghger and Ibrahim (2013) reported that activated carbon yield from mango nuts was 63.2%. Meanwhile, Yusufu *et al*. (2012) stated that yield for coconut shell and wood about 40.40 to 46.21%.

b. Cost estimation

Hunt (1983) and Tani *et al*. (1983) stated that equipment costs represent actual manufacture costs and not investment costs. This capital cost estimate was then used in a procedure to estimate fixed capital investment using ranges of process-plant component costs.

Also, they reported all equipment costs, unless otherwise noted, are based on carbon steel rather than stainless steel. Material transport between equipment, using augers or vibrating beds, was included as a component of the fixed capital investment costs. Likewise, boilers for steam generation are considered utilities and are also a fixed capital investment cost.

Marouli and Maroulis (2005) explained that the most significant magnitudes concerning the cost estimation of an industry are; the fixed capital cost C_{fx} in $, which is paid during the installation period, and the annual operating cost C_{op} in $/yr, which is paid during the operation. However, both fixed capital and annual operating cost estimates are also important in project evaluation, product pricing, process optimization and other techno-economic studies.

Al-Qodah and Shawabkah (2009) showed that activated sludge is a promising low cost precursor for the production of activated carbon. While, Jun *et al.* (2010) showed short heating duration is desirable because it can reduce the manufacturing costs.

Aidan (2012) mentioned that the advantages of activated carbon produced from agricultural wastes in comparison with other sorbents were their low cost, availability of extraction and others.

10. Overheads

From the above review it is evident that:

1. Activated carbon has been produced from several pre-sources, including agricultural residues.

2. Quality of pre-source to produce good activated carbon is content of high amount of carbon, cellulose, hemicellulose and lignin.

3. Chemical activation has an advantages method to produce the activated carbon which used at low treatment temperature and short treatment time to produce displays a large surface area and better developed mesoporosity.

4. The implement used to produce the activated carbon had multi-stages and difficult to use and maintenance.

5. Pyrolysis operation done at best conditions of immigration agent time, temperature, operating time and stable gas to obtain high yield and properties of activated carbon.

6. Activated carbon has much usage as water and gas treatment, pharmacy industry, food industry and chemical industry which ability to absorb gases, microbes, color … etc.

7. The advantages of activated carbon produced from agricultural residues were low cost, availability of extraction.

MATERIALS AND METHODS

The present research study was carried out at laboratory of Agricultural Engineering Department, Faculty of Agriculture, Cairo University and laboratory of Agricultural Engineering Research Institute (AEnRI), Agricultural Research Center (ARC) from September 2013 to September 2016, to performance evaluation of design activated carbon prototype productivity.

On order to achieve the aim of study, these steps were followed:

1. Collecting, testing and selecting appropriate agricultural residue depending on highest content of carbon.
2. In laboratory, each agricultural residue type was tested to determine the activated carbon and tar materials contents after pyrolysis operation under different treatments.
3. The obtained solid materials from each residue after pyrolysis operation treatment were analyzed to determine the high amount of activated carbon, and determine the properties of obtained activated carbon.
4. Designing and manufacturing the Activated Carbon Prototype (ACP).
5. Testing (ACP) at optimum parameters.
6. Determining and comparing (ACP) quality production with the best product from laboratory test.
7. Estimating the cost of Activated Carbon Prototype.

1. Materials

It was included activated carbon production unit, some of agricultural residues and chemicals.

a. Activated carbon production units

The activated carbon in this study was produced using two electrical furnaces.

1. The activated carbon prototype

The activated carbon prototype used in technological processes based on the heating of materials by means of electric energy. Before designed prototype some points take into in design as follow:

1. Easy control of temperature.
2. Concentration of a high energy in small volumes.
3. Possibility to use nitrogen gas as an inert atmosphere to protect the process from the harmful effect of atmospheric air.
4. The prototype is tight closed to prevent the leakage heat.

The activated carbon prototype belt from five main units as shown in (Fig. 4) and photographed in (Fig. 5). The prototype main units are furnace unit, heating unit, gas unit, control units, and source of power, beside frame.

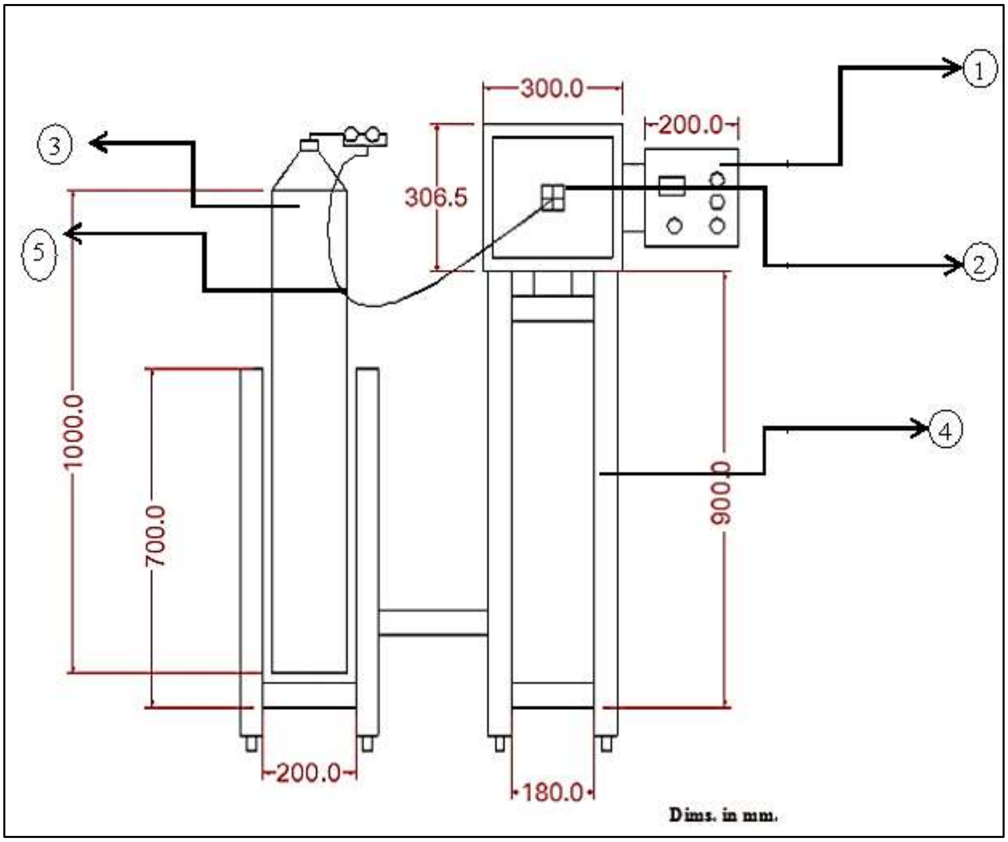


Fig. 4.Schematic diagram of activated carbon prototype.
1- Control units, 2- Furnace unit, 3and 5- Gas unit 4- Frame.

The activated carbon prototype components for each unit are:

a. Furnace unit

The furnace unit is consisted from some parts as shown in Fig. (6). Furnace unit parts are furnace body, furnace door and holes entry and exit gas.

1. Furnace body

The furnace body components are: body shell, ceramic fiber, refractory and grooves for heating elements. From Fig. (7) it can notice that, the furnace body made from carbon steel sheet with 0.8mm thickness which has a dimensions of 306.5 × 300 × 305.5mm length width and height respectively. The steel sheet inside bodyguard contains from outside to inside of ceramic fiber and refractory with35mm thickness. The inside hole space in the activated carbon furnace has 156.5 × 160 × 210mm length width and height, respectively.

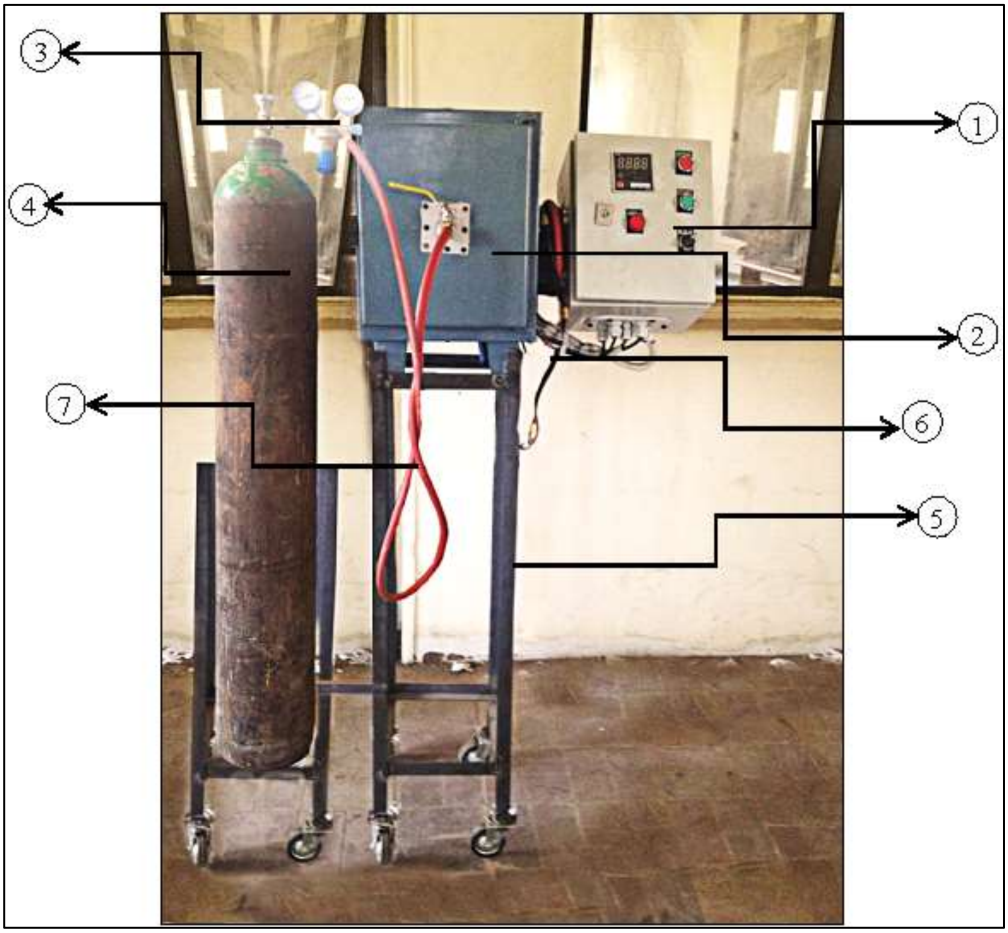


Fig. 5. Photography of activated carbon prototype components.

1- Control units, 2- Furnace unit, 3,4and 7- Gas unit 5- Frame and 6- Source of power.

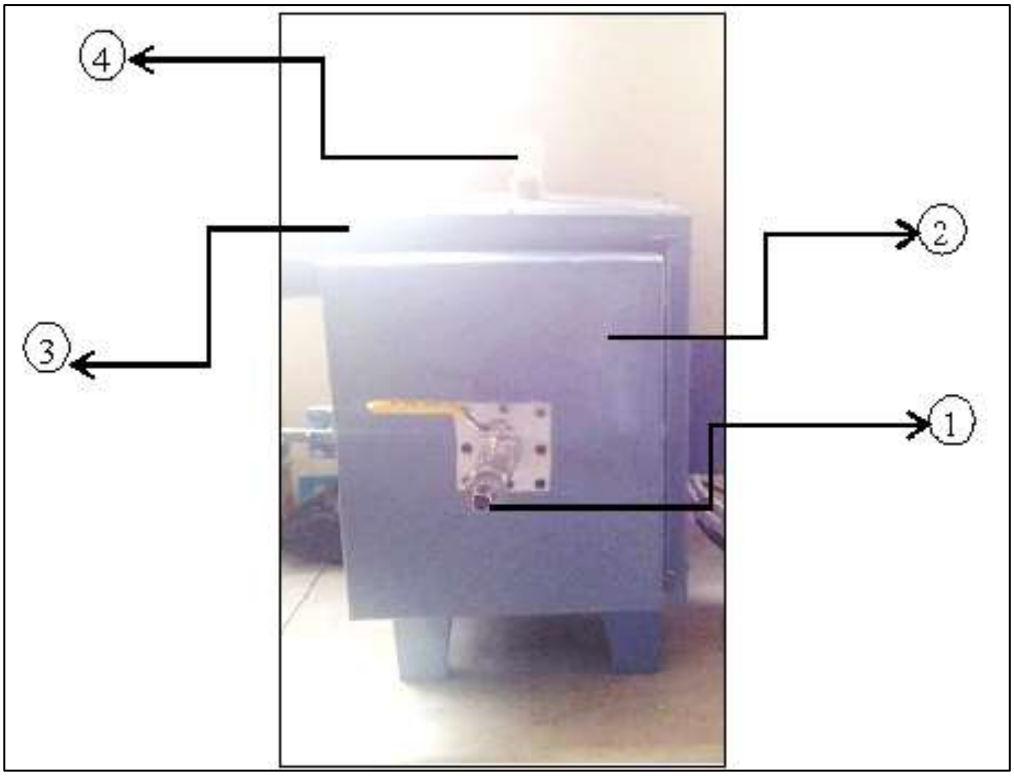


Fig. 6. The components of activated carbon furnace.

2. **Gas inlet, 2- Furnace door, 3- Furnace body and 4- Gas outlet.**

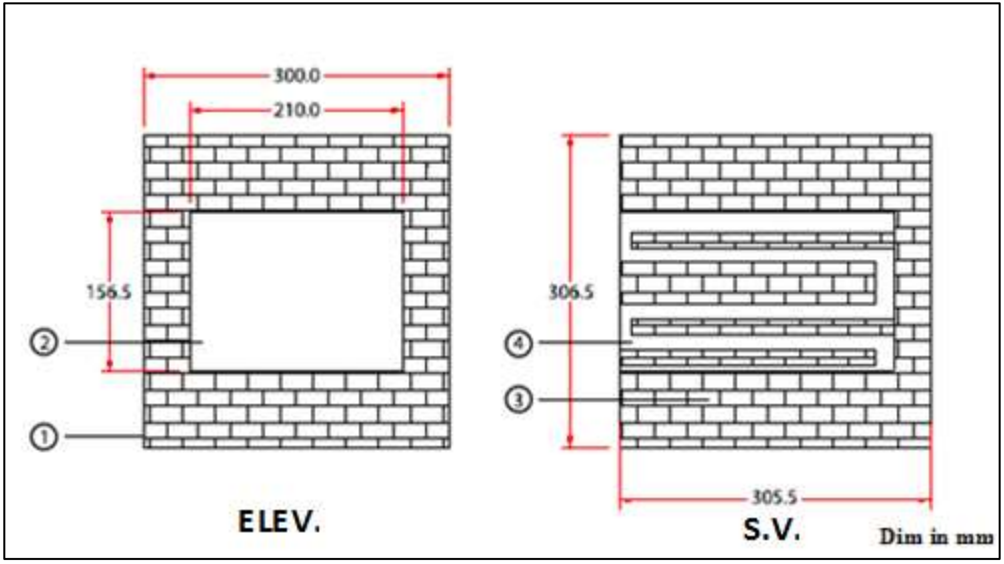


Fig. 7. Schematic diagram of activated carbon furnace.

1- **Steel sheet, 2- Inner space, 3- Refractory lining and 4- Groove for heating element.**

1. Body shell

Hot rolled carbon steel sheets of 0.8mm thickness is used for the building of the furnace body shell. Its main function is to work as carrier and holder of the refractory materials.

2. Ceramic fiber

Ceramic fiber layer of 5mm thickness is used as heat insulation between furnace steel sheet and refractory (Fig. 8). The ceramic fiber advantage is no heat transferred and not absorbed or radiated heat.

Fig. 8. The ceramic fiber roll.

3. Refractory

Refractory a material that retains its strength at high temperatures, is made of SiO_2 (Silica, quartzite) which is used to with stand high temperature, physical and chemical actions of the process (Fig. 9). It is made of quartzite containing at least 93% of SiO_2 for withstand temperatures up to 1300ºC. The refractory bodyguard has six grooves (Fig. 10) at each of the two sides for contain the heating wire. The grove made with 20mm height and 50mm depth.

Fig. 9. Refractory used in lining.

Fig. 10. Lining grooves for electric wire.

2. Furnace door

The furnace door (Fig. 11) is fabricated from furnace constructed with the dimensions of 300 × 260 × 60mm length, height and width, respectively. The inside part has a dimensions at suitable to sealing the breadth of slot furnace. It has dimensions of 200 × 150 × 30mm length width and height, respectively which made from refractory. At the door's center the entry gas hole was done with 15mm diameter.

Fig. 11. Furnace door.

3. Gas inlet and outlet

The two holes to enter and exit gas (Fig. 6) are made as a hole shape with 10mm diameter. The entry hole made at the center of furnace door. Then the exit hole made at the furnace ceiling.

b. Heating unit

The heating unit consists of a spiral wire shape with 3mm diameter (Fig. 12). The heating wire supported in the furnace lining grooves (Fig. 13). The specific properties of selected heating wire are:

1. High electrical resistively (ρ, Ohms.m).
2. Low temperature coefficient of resistively (αρ, K-1).
3. Appropriate refractoriness.
4. Not undergo phase transformations in heating or cooling.
5. Low cost material.

Heating wire is made from NiCr metal. Metallic heaters are made of resistance alloys and high melting metals. Resistance alloys for making the heating element are used in the form of spiral wire. The specification of a heating wire is summarized in Table (3).

Fig. 12. The heating spiral wire.

Fig. 13. The heating wire supported in the furnace lining grooves.

Table 3. The physical properties and allowable temperatures heating wire.

Material	**Density, kg/m^3**	**Melting point, °C**	**Resistively**		**Maximum temperature, T_{max}, °C**
			At T=293°K, $\rho\times10^{-6}$ Ohm.m	At T_{max}, $\rho*10^{-6}$ Ohm.m	
NiCr	8400	1387-1417	1.1	1.2	1200

c. Gas unit

The inert gas unit consists mainly of gas cylinder, rubber elbow and gas flow controller.

1. Inert gas cylinder

The cylinder with dimension of 1100 × 160mm height and diameter respectively and 95kg contains a nitrogen gas as an inert gas is used. The nitrogen cylinder has 7liter. Then the nitrogen contains about 99.9% from the cylinder.

2. Rubber elbow

The rubber elbow with 10mm diameter and 2mm thickness was used to transport the nitrogen gas from cylinder to the entry gas pipe. The rubber elbow made from two layers of rubber as pillared.

d. Controller units

The activated carbon prototype equipped with four controllers; regulator gas, gas entry, exit gas and temperature and on/off. Then the gas controllers are regulator gas as pressure counter, ball hock as gas entry and tightly stopper as exit gas. The circuit of on/off and temperature controllers fabricated by electronic elements in controller-box.

1. Regulator gas

The inert gas must be organizing as a pressure and amount at inside to the furnace. The regulator special for gas with two counters can use to control of the gas pressure and flow rate. The double counters regulator (Fig. 14) consists of:

1. Opening pressure regulator,

2. Nozzle for exit gas from cylinder (inner and external diameter are (8 × 10mm),
3. Amount gauge,
4. Pressure gauge,
5. Opening amount regulator,
6. Nozzle entry gas for rubber elbow (inner and external diameter are 8 × 10mm).

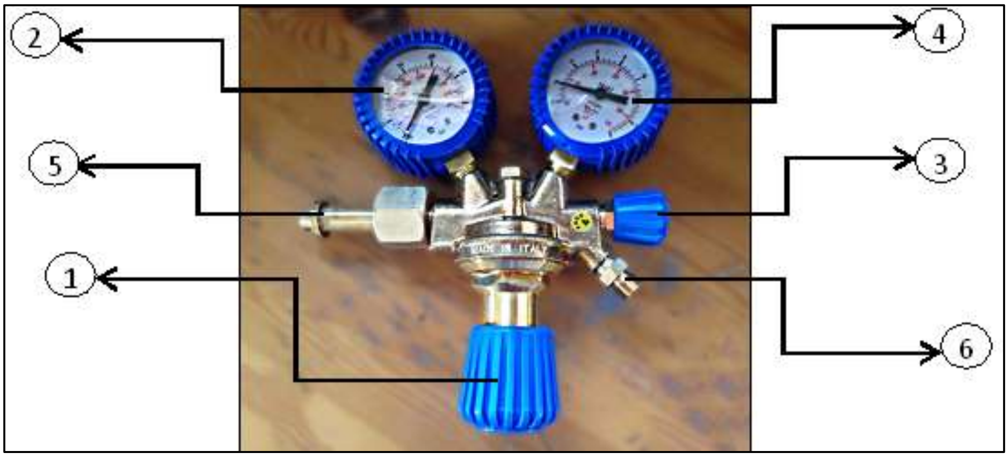


Fig. 14. The regulator gas components.

1- Gas pressure knob, 2- Regulator pressure, 3- Gas amount knob, 4- Regulator amount, 5- Inlet gas nozzle 6- Exodus gas nozzle.

The regulator gas controller is directly connected with gas cylinder by inlet gas nozzle "5". Then rubber elbow connecting with the exodus gas nozzle "6" from the end, but another end connecting to the furnace door.

Before operation take place, it should be making sure to closing the all knobs for cylinder, pressure "1" and amount "3" gas. At beginning operation firstly open the gas cylinder by cylinder knob, then open pressure knob (1) as shown in Fig. (14) to controlled regulator pressure (2). Therefore, open amount knob (3) to controlled regulator amount (4) of gas to flow into the furnace by nozzle "6".

2. Gas inlet controller

Gas inlet controller of ball hock used to control the rate of inlet gas. Ball hock of 5 mm diameter connected in the center of furnace door from side and the other side connected with the rubber elbow.

3. Gas outlet controller

The pipe with 5 mm diameter fitted with the outlet hole, which fixed at the furnace ceiling, used to exit gas exhaust from the activated carbon furnace. The gas outlet pipe is closed by tightly stopper to control the time of exit gas.

4. On/off and temperature controller

The controller-box is connected with activated carbon furnace by two screw bolts. The controller element is manufactured in isolated metal. The component of on/off and temperature circuit are shown in Fig. (15) and photography in Fig. (16). The figure shows that temperature and on/off control circuit consists of:

1. Thermocouple (1): K-Type thermocouples (NiCr-Ni) are selected to be enough for use at the high temperature.
2. Emergency spotlight (2).
3. Digital display screen (3).

The electronic circuit contains many flexible parts to control in temperature with relay of ±5 °C by the part "1" in Fig. (15) while, part "2" in Fig. (15) special for on/off furnace operation.

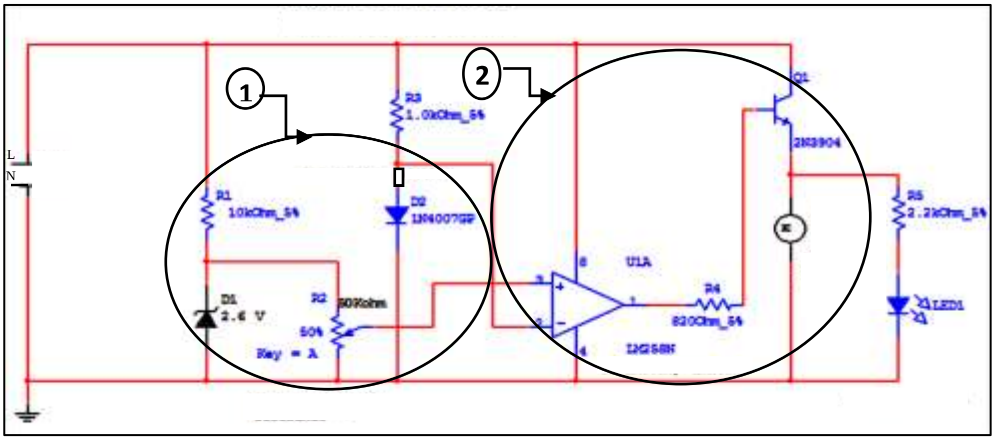


Fig. 15. The circuit of control unit for the activated carbon prototype.

(a) The conreoller components. **(b)The connection between furnace and controller.**

Fig. 16. Furnace on/off and temperature controllar box.

e. Frame for activated carbon prototype

The frame for activated carbon prototype is manufactured, identically for carry the furnace and the other components. Because of the activated carbon prototype component has about 14000g weights then the frame was constructed of 50 × 50mm iron angles. The main frame for furnace has dimensions of 1000mm height and 350 × 350mm width and length. A small iron frame of 800 × 200 × 200mm height, length and width was attached to the base of the main frame of the furnace through two iron hinges to accommodate the gas cylinder (Fig. 5). Eight caster rubber wheels were also used for free movement of the prototype. The wheel dimensions are 30 × 40mm diameter and width, respectively.

f. Source of electrical power

The electrical power can used to supply the activated carbon furnace with the cable of 7 mm diameter and the maximum carrying of 35A.

2. The laboratory unit

The laboratory unit is a standard furnace as shown in (Fig. 17) was consists of five parts namely, body shell, hearth, heating elements, control unit and nitrogen gas cylinder beside iron frame.

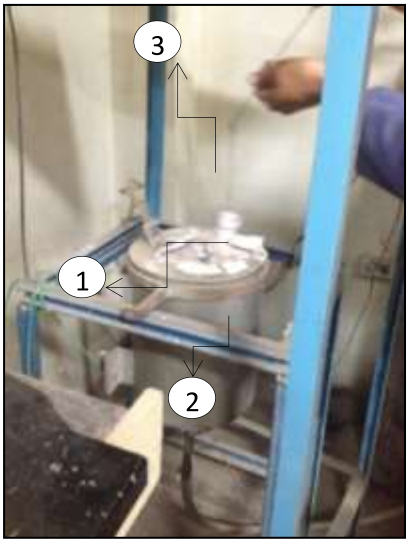


Fig. 17. Laboratory unit in Metallurgical Research Center.
1- Body shell, 2- Furnace unit and 3- Hearth.

a. Furnace

The furnace consists of body shell and hearth. The specific of them can show as follow:

1. Body shell

The furnace is made of refractory lining content is SiO_2 from the inner and from the outside made of steel, it has a diameter of 250mm and length of 500mm.

2. The hearth

The hearth is a refractory (material that retains its strength at high temperatures) cylinder has diameter of 50mm and length of 500mm as shown in (Fig. 18). The hearth put in the center of furnace which make hole to put sink containing raw material.

Fig. 18. The hearth.

3. The heating elements

Heating elements wire is surrounding the external circumference of the hearth.

b. The control unit

The furnace is equipped with an external unit of controlling the temperature as shown in (Fig. 19). The furnace consists of on/off control and up and down temperature control. The digital screen shows the current temperature.

Fig. 19. The control unit.

c. The nitrogen gas cylinder

Nitrogen is fed to the atmosphere of the furnace through an inlet open at the bottom of the furnace.

b. Agricultural residuals

Three agricultural residues from various sources included field, horticultural residues and manufacture residues were selected. These residues were shown as follow:

1. **Corn stalks** (Fig. 20): were obtained from Gimmeza Research Station- Agricultural Engineering Research Institute; the total

production solid waste of corn crops was about 758kg/feddan in the year of 2014 (Ministry of Agricultural, 2013-2014)

Fig. 20. Corn stalks collected from Gimmeza Research Station.

2. **Trimming peach trees residues** (Fig. 21): were obtained from Horticultural Research Institute in winter season. The total production solid waste of peach was about 1.5kg/feddan in the year of 2014 (Ministry of Agricultural, 2013-2014).

Fig. 21. Trimming peach trees residues collected from Horticultural Research Institute.

3. **Date kernels** (Fig. 22): were obtained from Horticultural Research Institute in summer season. The total kernel of date was about 72kg/palm tree in the year of 2014 (Ministry of Agricultural, 2013-2014).

4. Experimental procedure

The experimental procedure is divided into four parts to achieve the aim of research. The first part is important to collect data and selects the appropriate agricultural residues as pre-experiments. The second part is determined the best studied parameters suitable for produce activated carbon from the select agricultural residues in standard furnace (Laboratory unit). The third part is design and evaluates the performance of activated carbon prototype and production quality. The forth part is compare the best production quality obtained from the laboratory unit via the production obtained using the prototype. Finally the fifth part is use the produced activated carbon as applied test in drinking water treatment.

a. The first part: Pre-experiments

Collecting data of the agricultural residues are divided into many categories in the same time; data collected from the production of activated carbon researches, data collected from the amount of agricultural residues in field, garden and industries and data collected from the chemistry components of agricultural residues.

From data selected the suitable agriculture residues as sample of filed, tree trim and industry of food. Hence, the chemical components of selected residues to determine it's contain from N, C, H and ash content as a good indicator to produce high amount of the activated carbon (Hiremath, *et al*., 2012).

The amount of agricultural residues and carbon component were defined by many researches work. These data were presented in Tables (4 and 5) that showed the information mapping of the highest agricultural residue of carbon component (Hiremath *et al*., 2012) and the highest amount of agricultural residues (Ministry of Agricultural, 2013-2014).

Table 4. Summarize of carbon component of some agriculture residues (Hiremath *et al*., 2012).

Agricultural waste	Carbon, %
Peach tree pruning	53
Sun flower straw	52.9
Apricots tree	51.4
Apricot stone	50
Olive tree pruning	49.9
Peach stone	48
Barley straw	46.8
Oasts straw	46
Corn stalks	45.53
Sugar beet leaves	44.5
Corn cob	44 – 46
Date kernels	42
Rice straw	41.8
Cotton stalks	41.23
Durnm wheat straw	n.a
Almond tree	n.a

Table 5. Cultivated areas and agricultural solid waste production for major crops (Ministry of Agricultural, 2013- 2014).

Crop	Cultivated area (feddan)	Solid waste generation (tons/feddan)	Total (tons)
Rice	1,507,634	2.1	3,015,000
Corn	1,657,799	1.9	3,150,000
Wheat	2,506,178	2.56	6,415,000
Cotton	535,090	1.6	856,14,
Sugar cane	327,215	11.9	3,726,978
Peach trees	750,86	1.318 kg/f	290001
Date palm	104,851	71.81kg/ palm	1465030

b. The second part: The laboratory unit experiments

The laboratory experiments layout in Fig. (23) which carried out to determine the optimum studied variable levels.

The studied variables in this part include:

1. Three different agricultural residues (ART) of corn stalks, trimming peach trees residues and kernels of date palm.
2. Four levels of furnace temperatures (FT) of 673, 773,873 and 973ºK (400, 500, 600 and 700ºC).
3. Four levels of pyrolysis time (tF) of 1.0, 1.5, 2.0 and 2.5 h.

The test sample preparation, the all samples are cutting with manually knife about 5cm lengths (Corn stalks and trimming peach trees residues). Each sample for the different agricultural residues is weighted. Also the some samples take to determine the moisture content and bulk density. Therefore, the sample put in crucible with inner dimensions of 40 × 40 × 2mm length, width and thickness respectively and immigration in ortho phosphoric acid "H_3PO_4" 85% concentration with ratio 2 w : 1 v (raw material: H_3PO_4) about 2 hours before pyrolysis operation for each sample. The following (Table 6) showed the different ratio of (raw material: H_3PO_4) for the 48 samples.

The samples of agricultural residues were pyrolzed in laboratory unit at Metallurgical Research Center – Helwan in absence of air but in presence of nitrogen at different furnace temperatures (FT) and different pyrolysis times (tF). After pyrolysis, the samples were weighted and washed by warm distilled water several time until the pH of samples were 7, then samples were dried at 105ºC for 24 hours, (Fig. 24).

Subsequently, all pyrolysis samples tested by Methylene blue test to determine the highest carbon content for each residual.

Table 6. Volume of H_3PO_4 versus agricultural residues mass.

Sample No.	Corn stalks		Trimming peach trees		Date kernels	
	Mass (g)	Volume H_3PO_4 (ml)	Mass (g)	Volume H_3PO_4 (ml)	Mass (g)	Volume of H_3PO_4 (ml)
1	26	13	6.44	3.2	12.5	6.3
2	20	10	10.37	5.2	15.2	7.6
3	30	15	6.44	3.2	13.2	6.6
4	26	13	8.95	4.5	14.2	7.1
5	28	14	7.93	4.0	15.5	7.8
6	34	17	6.30	3.2	13.0	6.5
7	36	18	7.14	3.6	14.0	7.0
8	38	19	5.67	2.8	12.1	6.1
9	23	11.5	7.99	4.0	14.3	7.1
10	37	18.5	7.39	3.7	12.0	6.0
11	29	14.5	7.51	3.8	13.5	6.7
12	40	20	6.43	3.2	14.1	7.0
13	35	17.5	6.68	3.3	14.4	7.2
14	28	14	7.23	3.6	12.3	6.2
15	24	12	8.28	4.1	14.5	7.3
16	30	15	5.75	2.9	13.2	6.6

After tests yield and some properties of the highest carbon content for the agricultural residues are estimates as:

1. Yield, %.
2. Some properties: nitrogen-carbon-hydrogen ratios "N,C and H" ash ratio, bulk density "BD", surface area "SA", pore volume "PV" , scanning electron micrographs "SEM" and moisture contents "MC".

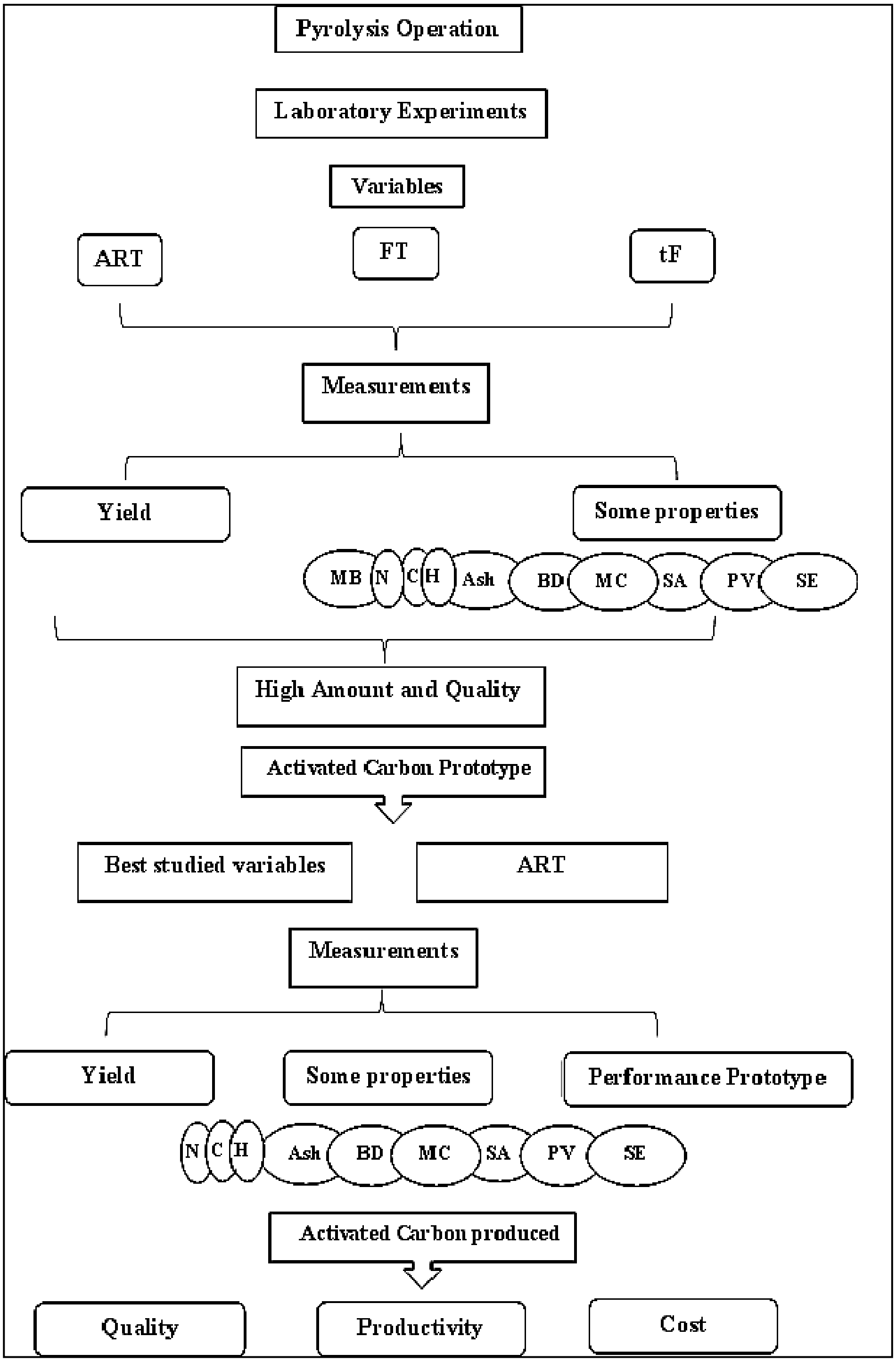


Fig. 23. Layout of the pyrolysis operations.

NB: BD: Bulk density, MC: Moisture contents, SA: Surface area, PV: Pore volume, SE: Scanning electron micrographs.

Fig. 24. Samples washing by warm distilled water.

c. The third part: The pyrolysis in activated carbon prototype.

The third part is design, evaluation performance of activated carbon prototype.

At designing prototype regarding that:

1. Simple in components and operation.
2. Cheap and safe.
3. Easy to construct and clean.

Evaluated performance was by determined:

1. Prototype productivity.
2. Cost estimation.

Through the tests used activated carbon prototype the variable factories include the optimum recommended studied parameters from the laboratory test for each of agricultural residues type "ART". The sample mass for each "ART" is about 300g for corn stalks and 1100g for peach trees trim and 3200g for date kernels. The sample put in vessel of refractory bricks has inner dimensions of 150 × 205 × 55mm length, width and thickness, respectively.

To determine the quality of activated carbon, the all above determination which done at the second part after pyrolysis operation will done except Methylene blue test were done.

d. The forth part: Comparing quality of produced activated carbon

The important evaluation to recommend the performance quality of activated carbon prototype "ACP" is compare the quality and quantity of the activated carbon produced from laboratory unit via from the prototype. The comparing items are:

3. Quantity of activated carbon (yield).
4. Quality of activated carbon; C, ash, BD, SA, PV and SEM.

e. The fifth part: Drinking water purification test (water treatment)

As applied test, the influence of used activated carbon from each agricultural residue on drinking water treatment was studied. The drinking water standard using Egyptian standard was done. The un-treatment water (Wastewater) gets from Giza Company for Water. The analysis of water before treatment are; total dissolved solid (TDS) = 350ppm, nephelometric turbidity units (NTU) = 4.5 and total microbe = 540microorganisms. ml^{-1}.

The used activated carbon bar with a constant bulk density at 1.30g/cm^{3}for corn stalks, 1.63g/cm^3 for residues of trimming peach trees and 1.75g/cm^3 for date kernels.

The studied variables are:

1. Type of activated carbon (source).
2. Activated carbon bar length of 1.0, 2.5 and 5.0cm.

The activated carbon filter prepared using injection 5ml putting two layers of medical gauze (1 mm thickness and 19 × 15mesh) to prevent activated carbon leakage to injection then putting activated carbon and pressuring it then added 40 ml waste water in injection. The treated water is extracted in test tubes (Fig. 25). To evaluate the activated carbon filtered some determination were done as: purification time, TDS, turbidity, taste, color, odor and microbial.

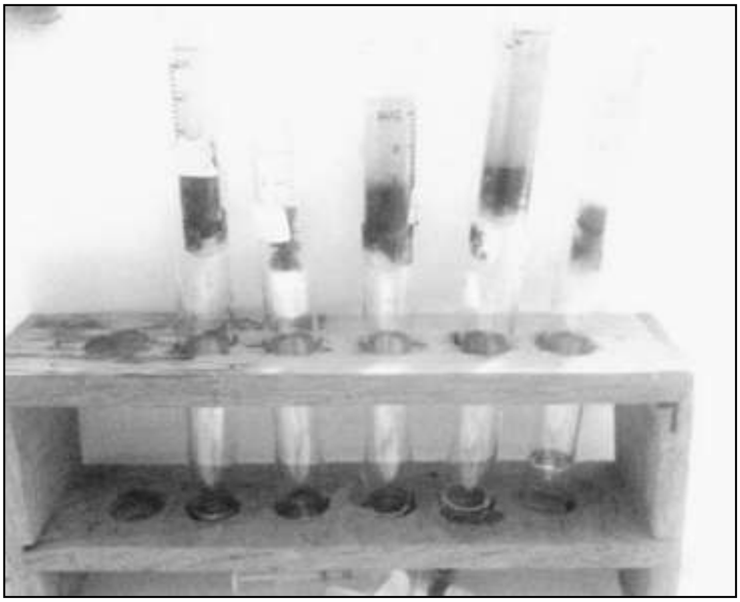


Fig. 25. Treatment of drinking water.

5. Experimental design

The randomize design for every part used in three replicates. For this reason every type of the obtained raw materials was divided into 48 + 3 samples to prepare for pyrolysis operation. Also, each type of activated carbon was divided into 48 + 3 + 9 samples to analysis the sample.

6. Methods of measurements

a. Yield of activated carbon

The activated carbon yield was calculated based on the following equation:

$$Yield = \frac{W_c}{W_o} \times 100, \% \qquad (7)$$

Where:

W_c is dry mass (g) of final activated carbon.

W_o is dry mass (g) of raw material.

b. Bulk density

Samples of the three agricultural residues after sun drying and before pyrolysis for each treatment were taken to determine mass and volume for measuring the bulk density. The volume before pyrolysis measured by cup 500cm^3 and after pyrolysis measured by a cylindrical container (115cm^3). The cup and container filled by sample above the top edge of the container. The cup and container dropped five times from a height of 15cm onto a non-resilient surface to allow setting and struck off level with the top surface. Then samples weighted (g) and the following equation was used for determination of bulk density.

$$Bulk\ density = \frac{Mass}{Volume}, (g/cm^3) \tag{8}$$

c. Moisture content

The moisture content of agricultural residues determines using the oven before pyrolysis at 70°C for mass constant. While the moisture content of samples after pyrolysis were determined at 105°C for 24 hours after washed by distilled water (Fig. 26). The following equation used to determine the moisture content:

$$MC = \frac{Weight\ of\ wet\ sample - Weight\ of\ dry\ sample}{Weight\ of\ wet\ sample} \times\ 100, wb\% \tag{9}$$

Where: MC (wb %) = Moisture content in wet basis, (%).

Fig. 26. Drying oven.

d. N, C, H ratios.

To determine the N, C, H elements percentage the automatic analyzer C, H, N and S' Vario El Ш – Elementar – Germany was used as follow (Cairo University, Faculty of Science, 2015 and 2016):

1. Helium gas (He) (200ml/ min : flow of gas) for purification.
2. Oxygen gas (for oxidation process for the samples).
3. Absorption columns (trapping for NO_2 , CO_2, SO_2, H_2O)
4. Copper (Co) for reduction process.
5. TCD (thermal conductivity detector) for detecting C, N, H and S.
6. Temperature of 2 furnaces (1150 °C, 858 °C) time of sample (15 min).
7. Pressure of gas (He gas) 1.24bar.

e. Ash ratio

To measure the ash for samples, weigh the sample before pyrolysis. Put on furnace at 550°C for 2 hours then weight the sample. The ash was calculated by the following equation:

$$Ash = \frac{Weight\ sample\ before\ burn}{Weight\ sample\ after\ burn} \times 100, \% \qquad (10)$$

f. Carbon concentration

Methylene blue test was estimate the carbon concentration for each sample after laboratory pyrolysis. A stock solution of 1.0g.L^{-1} of methylene blue was prepared by dissolving 1g of the dye in 0.1L of distilled water and then diluted of 1.0L. Adsorption of methylene blue was determined by contacting mass of the pyrolyzed samples (the activated carbon) (0.25g) with 100ml of methylene blue solution (1.0g.L^{-1}) (Fig. 27). Then it is placed on a shaker at constant temperature (±25°C) and shaking (100rpm) for a sufficient period of time (24 h) after this time the samples were centrifuged.

The concentration was determined by spectrophotometry (Fig. 28) (Model 6300 and other device specification tabulated in Appendix 2) at the wave length of maximum absorbance of the dye (λ_{max} = 668nm) and reference to the calibration curve. (Rahman *et al*., 2012). The standard relation between the blank of methylene and the absorbance at maximum wave length was illustrated in Fig (29). This relationship is used to determine the methylene blue in the sample solution concentration after treatment (mg.L^{-1}). The all sample absorbance methylene blue, then using the standard fit curve it can determine the carbon concentration.

Fig. 27. Preparation the pyrolyzed samples to determine the adsorption by methylene blue test.

Fig. 28. The spectrophotometry device.

The amount of methylene blue absorbed by each sample can be calculated from the following equation: (Jalil, 2012).

$$q = \frac{(c_o - c_e)v}{m} \tag{11}$$

Where:

c_o is the concentration of methylene blue in the sample solution before treatment (mg.l^{-1}).

c_e - the concentration of methylene blue in the sample solution after treatment. (mg.l^{-1}).

v - volume of the solution (l).

m - mass of dry adsorbent used (g).

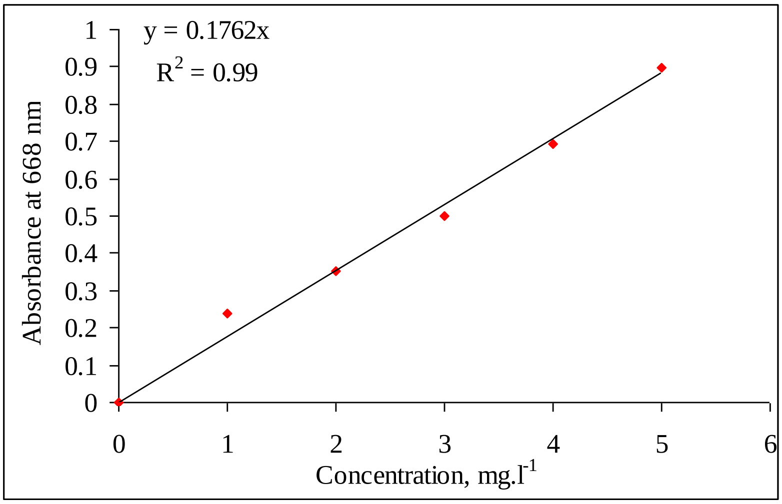


Fig. 29. The standard fit curve for absorbance methylene blue and blank concentration.

g. Surface area and pore volume

The particles of activated carbon surface area are determining using Nova 2000 series-USA device. (Metallurgical research center, 2015). Samples were carrying out degassing at 200°C under vacuum. After degassing the samples weighted, the analyze sample in a medium gas liquid N_2 at temperature of 1816°C by bet methods.

h. Scanning electron microscope (SEM)

Scanning electron micrographs (SEM) device was used to scan the thin film of dry activated carbon. The scanning electron microscope (HITACHI S-3400, Japan) (Fig. 30) adjust to photo and measure the pore shape and size. The all samples of activated carbon scanning, then the pore shape and size pictures saved in computer.

Fig. 30. The scanning electron microscope.

i. pH meter

The pH meter (Fig. 31) used to determine the pH at washing water after pyrolysis. The specifications can shows in Appendix (2).

Fig. 31. pH meter.

j.Turbidity

The samples of waste and treatment water turbidity measured using turibidmeter (Fig. 32). Turbidity unit is nephelometric turbidity units (NTU). The turibidmeter specification can show in Appendix (3).

Fig. 32. The turibidmeter®.

k. Total dissolved solids (TDS)

The total dissolved solids measured for samples of waste and treatment water, using conductivity meters (Fig. 33). The conductivity meters specification can see in Appendix (3).

Fig. 33. The conductivity meters.

l. Taste, color and odor

The samples of treatment water measured by three members working in the Giza Company for water taste, color and small odor of samples of water, the samples evaluated to acceptable or not as physical properties test.

m. Count plate

The standard plate count method is an indirect measurement of cell density and reveals information related only to live bacteria.

Calculate the number of bacteria (CFU) per milliliter of sample by dividing the number of colonies by the dilution factor multiplied by the amount of specimen added to liquefied agar.

$$No.of\ microorganism/ml = \frac{number\ of\ colonies\ (CFUs)}{dilution \times amount\ plated} \qquad (12)$$

7. Cost estimation for the activated carbon prototype production

In order to evaluate the applicability of the activated carbon prototype assumptions and equations used in cost estimation were as follows:

a. Fixed Costs (FC)

1. A capital recovery factor (CRF) was used to combine the total depreciation and interest charges into a serious of equal annual payments at compound interest (Hunt, 1983).

$$R = (P - S)CRF + Si \qquad (13)$$

Where:

R is the depreciation and interest cost, LE/year;

P - prototype purchase price, LE;

S - salvage rate (0.1 P), LE.

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \qquad (14)$$

Where:

i is the interest as compound annually, decimal (8%);

L - prototype life, years (10 years life span).

2. Taxes and insurance (THI) costs were assumed as 2% of the purchase price of the prototype (ASAE, 1983) then

$$Fixed\ cost\ (LE/year) = (P - S)CRF + 0.02P \qquad (15)$$

$$Fixed\ cost\ (LE/h) = \frac{(P-S)CRF+0.02P}{\text{yearly operating hours}} \qquad (16)$$

b. Variable Costs (VC)

1. Repair and maintenance costs (Rc) Rapier and maintenance costs are highly variable and unpredictable as to time of occurrence. The equation of Tani *et al*. (1983) was used for calculating repair and maintenance costs of the prototype as follows:

$$RC = \frac{P \times Rd}{L} \qquad (17)$$

Where

RC is the repair and maintenance cost (LE/year);

Rd - repair coefficient for prototype (17%).

2.Gas Cost (F)

$$Gas\ cost\ (LE/h) = \text{Gas consumption}\ (m^3/h) \times \text{Gas price}(LE/m^3) \qquad (18)$$

3.Electricity Cost (E)

$$E = Electrical\ consumption\ (kWh) \times Electrical\ cost\ (LE/kWh) \qquad (19)$$

4.Labor Cost (L)

Is defined as payment for operator who load, operate and unload the prototype (LE/h).

Considering the above mentioned variable parameters the following equation was used for calculating the variable costs (LE/h):

$$\text{Variable costs}\ (LE/h) = \mathrm{RC} + \mathrm{G} + \mathrm{L} + \mathrm{E} \qquad (20)$$

c. Total Costs (TC)

The total costs, (LE/h) are the summation of the total fixed costs (LE/h) and total variables costs (LE/h) as follows:

Total costs (LE/h) = Fixed costs (LE/h) + Variable costs (LE/h) (21)

8. Theoretical of activated carbon prototype

The main part of the designed prototype is the furnace unit. The mechanical operation in activated carbon prototype is basically depending on no-heat transfer from the wall, the heating circulation according to heating wire specification and distribution inside the furnace.

a. Wall structure

The furnace wall construction from materials and thickness not implemented the heat to the outside to calculate the;

(1) Heat transfer from the furnace air to the brick wall by convection the newton's law can use, (Kingsley *et al.*, 2012);

$$Q = h_{air} A(T_{air} - T_b)$$

Where:

Q = rate of heat flow

h_{air}= Convective coefficient of air (Nitrogen), W/m^2. °C

A = Total surface area of the brick, m^2

T_{air} = Convective temperature, °C

T_b = Temperature of brick wall, °C

(2) Heat transfer from the brick wall to the internal wall casing is by conduction, and it utilizes the fourier's law, (Kingsley *et al.*, 2012):

$$Q = K_b A \frac{dT}{dx} = K_b A \frac{(T_b \ - T_i)}{dx}$$

Where:

Q = Rate of heat flow

K_b = Coefficient of thermal conductivity of wall material, W/m^2°C

A_c= Total surface area of the casing, m^2

T = Convective temperature, °C

dx= Thickness of the brick, m

T_b = Temperature of brick wall, °C

T_i =Temperature of internal wall casing, °C

(3) Heat generation furnace include the first law of thermodynamics, (Incropera, 2002)

$$Q_{in} + Q_{gen} – Q_{out} = Q_{acc}$$

Where:

Q_{in}, Q_{out} = Flow of internal and external thermal energy

Q_{gen} = Related to conversion of electrical power to heat energy

Q_{acc} = Storage accumulated energy

To determine the both of Q_{gen} and Q_{acc} it must calculate heating and power for the furnace as follow:

b. Calculation of heating wire

On the design of the heating wire, the following technical /economical requirements as shown in (Fig. 34) curve (1) presents values of power for middle and high temperatures, curve (2) shows values of power of ceramic furnaces whose heat reaches to 1000ºC. curve (3, 4 and 5) show values of power of blotting furnaces whose heat reach to 300ºC point, at which value of heat of furnaces and capacity of furnaces intersect, gives power of furnaces, are taken into consideration (Bayindir, 2007; Jawad, 2010 and Esor *et al*., 2015).

1. The shape and cross section of the heating wire and the wire distribution system to ensure the allotment heating and long service life.

2. Select NiCR as the appropriate heating wire because the maximum temperature of 1200ºC, where:

   a. Electrical resistivity at maximum temperature of 1200ºC is $\rho = 1.3 \times 10^{-6}$Ohms.m.

   b. Thermal efficiency at maximum temperature of 1200ºC is $\varepsilon_h = 0.9$.

   c. Thermal efficiency at temperature of 700ºC = 973ºK is $\varepsilon_o = 0.8$.

   d. Conductivity $\sigma_0 = 5.7 \times 10^{-11}$S/m.

c. Calculation of heating power

1. Select the voltage (V) is to be the nominal rate of 220V, single phase, for the ease using at any laboratories and fields.
2. Select the working volume of 15 × 20 × 15cm equals to 4500cm^3
3. From Fig. (34), the furnace power (P) will be 2.5kW

The unit wire surface power of an ideal heater can be calculated by the equation, Bayindir (2007) (Appendix 1).

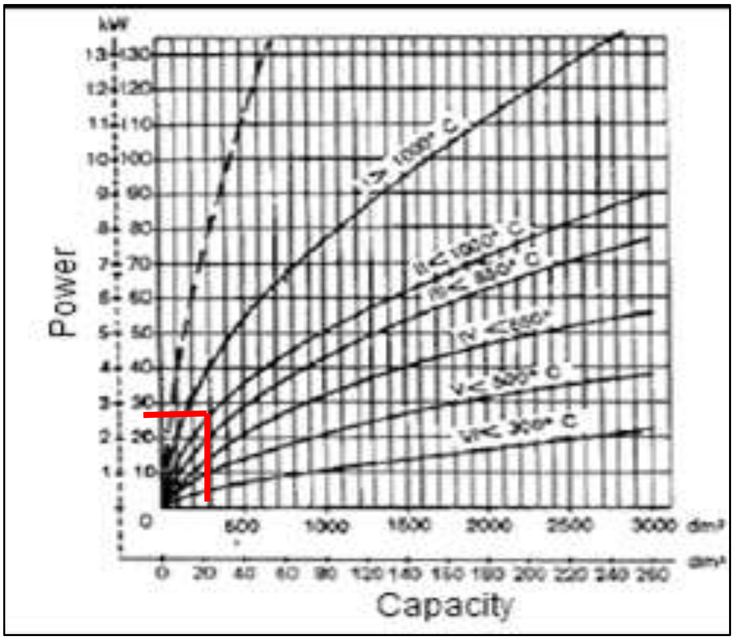


Fig. 34. Determination of furnace power. (Bayindir, 2007)

$$q_{id} = {[\sigma_o(T_h^4 - T_o^4)]}\Big/{[(1/\varepsilon_h) + (1/\varepsilon_o) - 1]} = (kW/m^2) \qquad (1)$$

For wire spiral, heat transfer coefficient = 0.3.

Then the actual power is:

$$q = q_{id} \times \text{ heat transfer coefficient } = 37kW/m^2 \qquad (2)$$

- If the diameter of the wire can be given by the equation:

$$D = 7400[\rho(P/V)^2 \times (1/q)]^{1/3}\ (mm) \qquad (3)$$

- Cross section area of the heater:

$$s = \pi/4 \times D^2\ (mm^2) \qquad (4)$$

- Resistance of the heater is given by the equation:

$$r = V^2/P \times 10^3 (ohm) \qquad (5)$$

- Length required of the wire is calculated as:

$$l = (1/\rho) \times r\ \times s\ (m) \qquad (6)$$

RESULTS AND DISCUSSION

This study aimed to carry out to performance evaluation of design activated carbon prototype productivity. For this purpose, five groups of work are done. The first group is determining some properties of the selected agricultural residues. Then, the second group is based on the use of standard laboratory unit at different furnace temperatures and pyrolysis time to evaluate the quantity and quality of activated carbon productivity such as; yield and carbon concentration for each agricultural residues type. Even more, at high carbon concentrations, some properties of activated carbon for different agricultural residues types were estimated as N, C, H ratio, ash ratio, bulk density, surface area, pore volume, shape and moisture content.

Activated carbon prototype was designed in the third group of recent study. The prototype products were evaluated. Then, evaluate the activated carbon prototype performance as productivity and cost.

In the fourth group the obtained results from laboratory and designed were compared. Finally, the fifth group is to apply activated carbon products in the purification of drinking water test using the three types of produced activated carbon at different heights of activated carbon.

1. Some properties of agricultural residues

Three agricultural residues were chosen as a raw material to produce activated carbon depending on pervious data and to proximate and ultimate analysis before pyrolysis. Some properties of agricultural residues were analyzed and illustrated in Figs. (35 through 37) and Table (7).

The chemical analyses were illustrated in (Fig. 35). The figure showed that, the nitrogen percentages were 01.59, 00.89 and 01.43% for corn stalks, trimming peach trees residues and date kernels, respectively. While, the corresponding carbon percentages were 40.70, 43.18 and 45.22% for corn stalks, trimming peach trees residues and date kernels, respectively. Also, the figure cleared that hydrogen percentages were 04.11, 07.84 and 04.40% for corn stalks, trimming peach trees residues and date kernels, respectively. Furthermore, the ash percentages as showed in Fig. (35) were 00.00, 06.67 and 13.75% for corn stalks, trimming peach trees residues and date kernels, respectively.

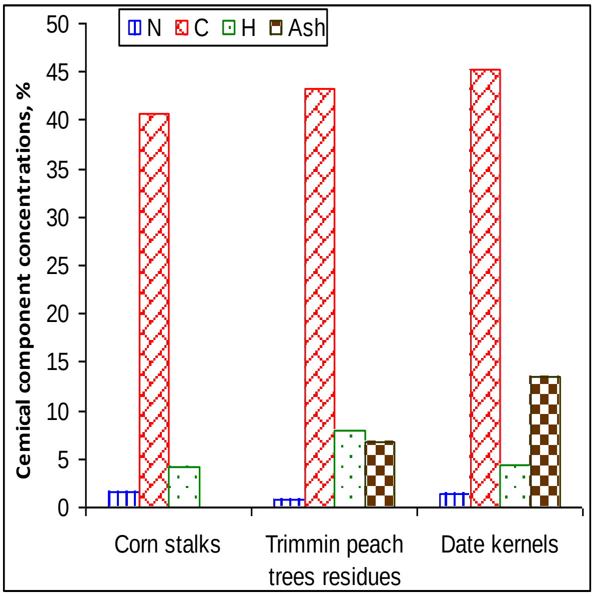


Fig. 35. Chemical components of raw materials for agricultural residues.

However, the bulk densities of corn stalks, trimming peach trees residues and date kernels as showed in Fig. (36) were 0.148, 0.263 and

$0.651 g.cm^{-3}$ for corn stalks, trimming peach trees residues and date kernels, respectively.

Table 7. Properties of residues before pyrolysis.

Residues type	Corn stalks	Trimming peach trees residues	Date kernels
N (%)	01.59	00.89	01.43
C (%)	40.70	43.18	45.22
H (%)	04.11	07.84	04.40
Ash (%)	00.00	06.67	13.75
Bulk density ($g.cm^{-3}$)	0.148	0.263	0.651
Moisture content (%)	23.30	19.30	09.10

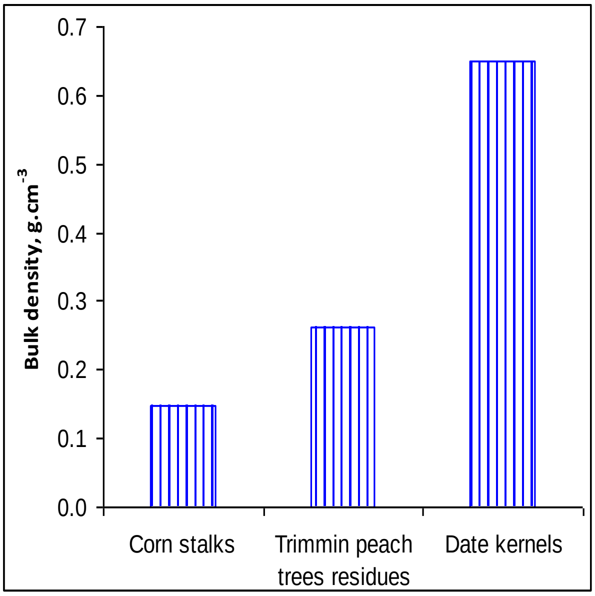


Fig. 36. Bulk density of agricultural residues.

The natural drying of agricultural residues indicated that the moisture contents were 23.3, 19.3 and 9.1% for corn stalks, trimming peach trees residues and date kernels, respectively as showed in Fig. (37).

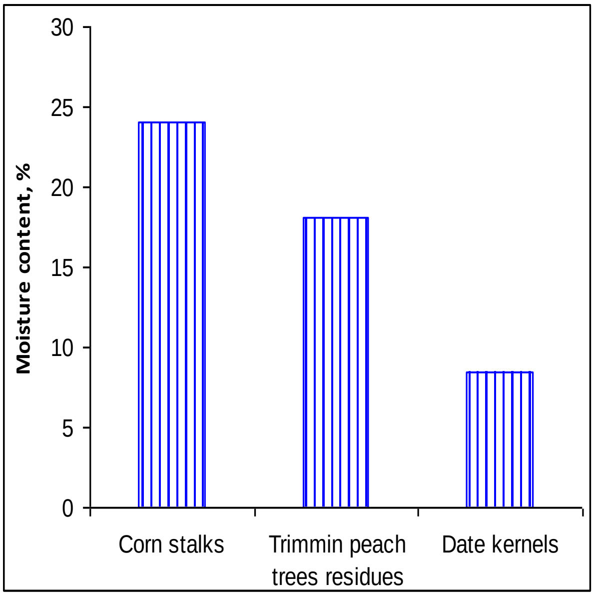


Fig. 37. Moisture content of agricultural residues.

2. the laboratory experiments

a. Mass reduction after pyrolysis

Experimental data for 16 samples of each agricultural residue were collected and tested under four furnace temperatures of 400, 500, 600 and 700°C at four pyrolysis times of 1.0, 1.5, 2.0 and 2.5 h. Mass of sample before and after pyrolysis process were showed in Tables (8 through 10) and Figs (38 through 40)

1. Corn stalks

Table (8) and Fig. (38) illustrated the effect of different furnace temperature and pyrolysis time on mass reduction of samples for corn stalks. From table (8), it can be noticed that the reduction of samples mass after pyrolysis for all samples were ranging from 12.0 to 72.0%. The lowest mass was achieved at high the both of furnace temperature and pyrolysis time. However, Fig. (38) showed that the highest mass reduction ratio for corn stalks residue was 72% obtained at furnace temperature of 700°C and pyrolysis time of 1.5 h while the lowest ratio was 12% found at furnace temperature of 500°C and pyrolysis time of 1.5 h. Generally, the steady state sample with pyrolysis time was shown at furnace temperature of 400°C.

Table 8. Mass behavior of corn stalks before and after pyrolysis.

Sample No.	Furnace temperature (°C)	Pyrolysis time (h)	Mass (g)	
			Before pyrolysis	After pyrolysis
1	400	1.0	26.00	18.20
2	400	1.5	20.00	13.20
3	400	2.0	30.00	20.70
4	400	2.5	26.00	17.68
5	500	1.0	28.00	23.24
6	500	1.5	34.00	29.92
7	500	2.0	36.00	18.72
8	500	2.5	38.00	28.88
9	600	1.0	23.00	14.72
10	600	1.5	37.00	31.08
11	600	2.0	29.00	11.60
12	600	2.5	40.00	23.20
13	700	1.0	35.00	12.60
14	700	1.5	28.00	07.84
15	700	2.0	24.00	08.88
16	700	2.5	30.00	08.70

2. Trimming peach trees residues

Table (9) and Fig. (39) showed the effect of different furnace temperatures and pyrolysis times on the mass of samples for trimming peach trees residues. All samples; mass were decreased after pyrolysis by the range from 63.1 to 80.0%. Furthermore, the lowest mass value was occurred at the low furnace temperature and high pyrolysis time. Consequently, the averages of mass reduction were 70.2, 72.5, 77.9 and

74.6%, respectively at furnace temperature of 400, 500, 600 and 700°C. On the other hand, at pyrolysis time of 1.0, 1.5, 2.0 and 2.5 h had average mass reduction of 74.9 70.3, 76.7 and 73.5%, respectively. Generally, the steady state sample with pyrolysis time was shown at furnace temperature of 600°C.

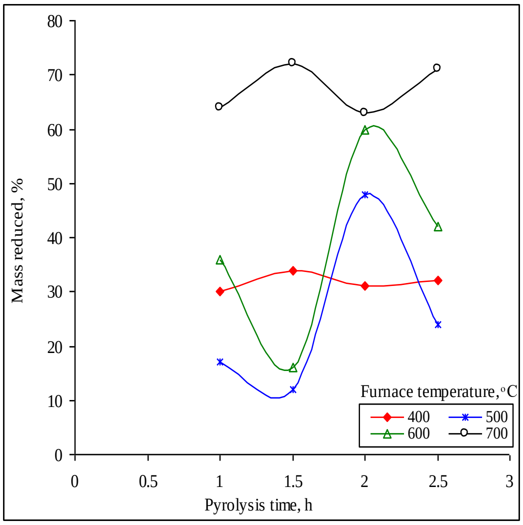


Fig. 38. Effect of pyrolysis time on mass reduction of corn stalks at different furnace temperatures.

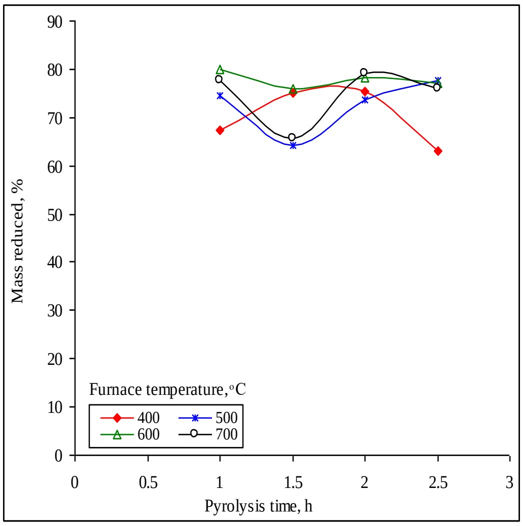


Fig. 39. Effect of pyrolysis time on mass reduction of trimming peach trees residues at different furnace temperatures.

Table 9. Mass behavior of trimming peach trees residues before and after pyrolysis.

Sample No.	Furnace temperature (°C)	Pyrolysis time (h)	Mass (g)	
			Before pyrolysis	After pyrolysis
1	400	1.0	08.95	06.79
2	400	1.5	08.28	06.45
3	400	2.0	07.93	05.84
4	400	2.5	10.37	07.72
5	500	1.0	07.14	05.59
6	500	1.5	07.99	06.34
7	500	2.0	06.44	04.87
8	500	2.5	07.39	05.20
9	600	1.0	07.51	05.01
10	600	1.5	06.44	04.19
11	600	2.0	07.23	05.13
12	600	2.5	05.75	04.75
13	700	1.0	06.68	04.37
14	700	1.5	05.67	03.87
15	700	2.0	06.43	04.2
16	700	2.5	06.30	04.22

3. Date kernels

Mass samples of all tests were decreased after pyrolysis at the ranging from 51.9 to 78.0%, the lowest mass of samples was obtained at the low furnace temperature and pyrolysis time. Consequently, with the increasing of the furnace temperature from 400 to 700°C, the mass reduction were increased from 53.9 to 55.5%. However, by increasing the pyrolysis time from 1.0 to 2.5 h, the mass reduction were increased from 60.1 to 67.6%, as showed in Table (10) and Fig. (40). Generally, the steady state sample with pyrolysis time was shown at furnace temperature of 400 and 700°C.

Table 10. Mass behavior of date kernels before and after pyrolysis.

Sample No.	Furnace temperature (C)	pyrolysis time (h)	Mass (g)	
			before pyrolysis	after pyrolysis
1	400	1.0	14.30	11.20
2	400	1.5	12.10	11.12
3	400	2.0	13.10	10.97
4	400	2.5	14.00	10.92
5	500	1.0	12.30	09.42
6	500	1.5	12.00	08.30
7	500	2.0	13.20	11.31
8	500	2.5	13.00	08.22
9	600	1.0	10.40	08.61
10	600	1.5	15.20	08.22
11	600	2.0	14.10	08.60
12	600	2.5	13.10	07.46
13	700	1.0	13.00	07.30
14	700	1.5	14.40	07.89
15	700	2.0	13.50	08.20
16	700	2.5	14.20	07.73

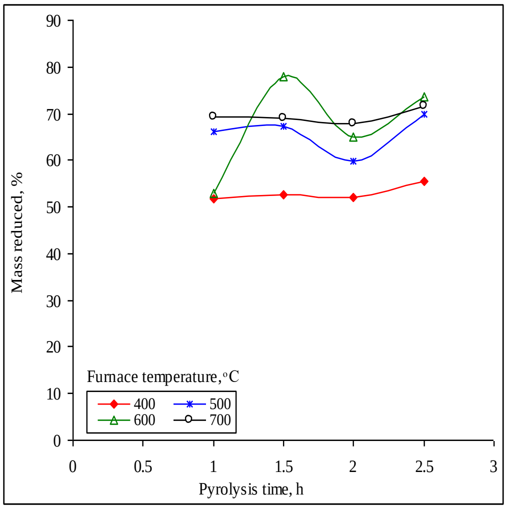


Fig. 40. Effect of pyrolysis time on mass reduction of date kernels at different furnace temperature.

It can be concluded that from previous data that, the results of pyrolysis process depending on the natural properties of the plant components including the carbohydrate, sugar and fiber. Also, the type, place and the moisture behavior in plant cells especially when encountered the high temperature.

Corn stalks and data kernels had low content of cellulose so, mass reduction increasing with increasing pyrolysis time. But in trimming peach trees residues had high content of cellulose so, mass reduction decreasing with increasing pyrolysis time.

b. Carbon concentration

All sample were tested by methylene blue dye absorbance to determine the highest carbon content for each residues after pyrolysis process, resulted data were illustrated in Figs. (41 through 43). The figures were showed that the effect of furnace temperature and pyrolysis time on carbon concentration at different agricultural residues of corn stalks, trimming peach trees residues and date kernels.

1. Corn stalks

Fig. (41) showed that the effect of furnace temperatures on carbon concentration from corn stalks at different pyrolysis time. The results indicated that when furnace temperature and pyrolysis time increase, the carbon concentration decreased. Furthermore, at furnace temperatures of 400, 500, 600 and 700°C, the carbon concentrations were 1.31, 0.51, 0.13 and 0.05mg.L^{-1}, respectively at pyrolysis time of 1.0 h.

At furnace temperatures of 400, 500, 600 and 700°C within pyrolysis time of 1.5 h, the carbon concentrations were 1.14, 0.47, 0.91 and 0.03mg.L^{-1}, respectively. Carbon concentrations showed 1.05, 0.85, 0.03 and 0.02mg.L^{-1} at furnace temperatures of 400, 500, 600 and 700°C, respectively and pyrolysis time of 2.0 h. However, at pyrolysis time of 2.5 h, the concentrations of carbon were 0.43, 0.07, 0.07 and 0.01mg.L^{-1} at furnace temperatures of 400, 500, 600 and 700°C, respectively.

The linear fit curve is the best equation by least square method to describe the carbon concentration (y) via the different furnace temperatures (x) at different pyrolysis time as follow:

At pyrolysis time 1.0 h,	$y = -0.0041x + 3.9091$	$R^2 = 0.8698$
At pyrolysis time 1.5 h,	$y = -0.0029x + 3.0023$	$R^2 = 0.5738$
At pyrolysis time 2.0 h,	$y = -0.0039x + 3.711$	$R^2 = 0.8756$
At pyrolysis time 2.5 h,	$y = -0.0012x + 1.1662$	$R^2 = 0.7124$

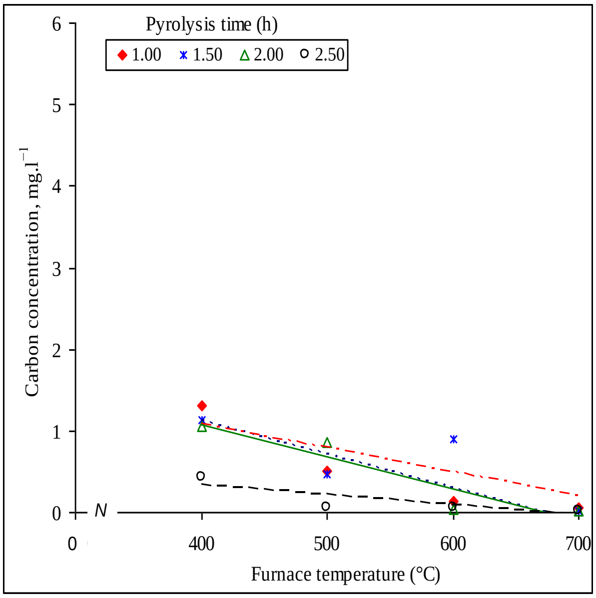


Fig. 41. Effect of furnace temperatures on carbon concentration at different pyrolysis time for corn stalks.

From previous equations it can be noticed that the carbon concentration had an inversely relationship by the furnace temperatures. Also, the high sample correlation found at pyrolysis time of 2.0 > 1.0 > 2.5 > 1.5 h.

2. Trimming peach trees residues

The effect of furnace temperatures on carbon concentration at different pyrolysis time for trimming peach trees residues was illustrated at Fig. (42). These results indicated that when furnace temperature and pyrolysis time increase, the carbon concentrations were increased.

Moreover, at furnace temperatures of 400, 500, 600 and 700°C, the carbon concentrations were 0.06, 0.14, 1.25 and 1.45mg.L^{-1}, respectively during pyrolysis time of 1.0 h. However, at the previous furnace temperatures and pyrolysis time of 1.5 h, the carbon concentrations were 0.11, 0.48, 1.11 and 2.42mg.L^{-1}, respectively.

In addition, carbon concentrations showed 0.09, 0.17, 1.48 and 3.69mg.L^{-1} at furnace temperatures of 400, 500, 600 and 700°C respectively at pyrolysis time of 2.0 h. While, at pyrolysis time of 2.5 h the concentrations of carbon recorded 0.09, 0.03, 0.96 and 2.13mg.L^{-1} at the corresponding furnace temperatures, respectively.

Increased the carbon concentrations with increase furnace temperature and pyrolysis time, this result may due to the samples of trimming peach trees residues still have some organic components lead to insufficient carbonization.

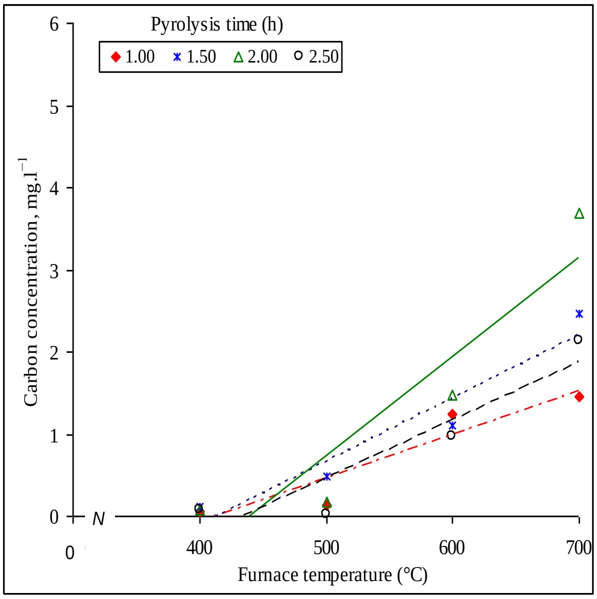


Fig. 42. Effect of furnace temperatures on carbon concentration at different pyrolysis time for trimming peach trees residues.

Applying the linear fit curve is the best equation by least square method to describe the carbon concentration (y) via the different furnace temperatures (x) at different pyrolysis time as follow:

At pyrolysis time 1.0 h, $y = 0.0053x - 3.6203$ $R^2 = 0.8804$

At pyrolysis time 1.5 h, $y = 0.0077x - 5.2861$ $R^2 = 0.9198$

At pyrolysis time 2.0 h, $y = 0.0121x - 8.6172$ $R^2 = 0.8660$

At pyrolysis time 2.5 h, $y = 0.0071x - 5.0135$ $R^2 = 0.8614$

From the equations it can clear that the carbon concentrations had a directly proportional to furnace temperatures. The high sample correlation found at pyrolysis time of 1.5 > 1.0 > 2.0 > 2.5 h.

3. Date kernels

The effect of furnace temperatures on carbon concentration at different pyrolysis time from date kernels was shown in Fig. (43). The results referred to when furnace temperature and pyrolysis time are increased, the carbon concentration were decreased.

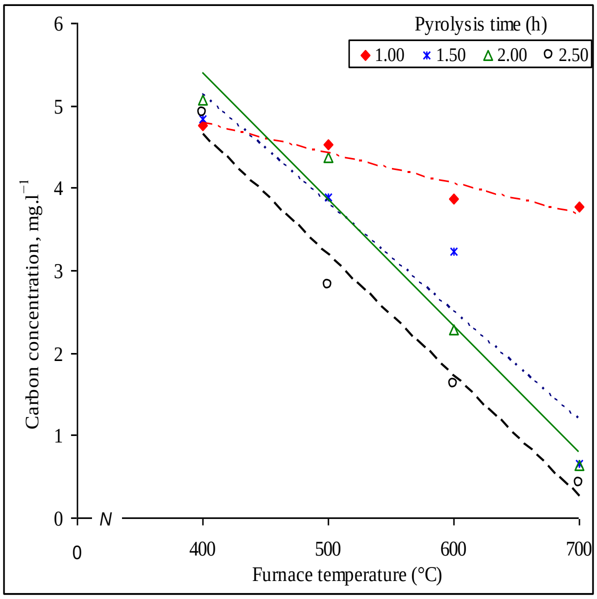


Fig. 43. Effect of furnace temperatures on carbon concentration at different pyrolysis time for date kernels.

The carbon concentrations clarified 4.7673, 4.5233, 3.8649 and 3.7741mg.L^{-1} at furnace temperatures of 400, 500, 600 and 700°C, respectively at pyrolysis time of 1.0 h. Whilst, the concentrations of carbon were 4.8297, 3.899, 3.2293 and 0.6527mg.L^{-1} at the above furnace temperatures, respectively and pyrolysis time of 1.5 h.

At furnace temperatures of 400, 500, 600 and 700°C the carbon concentrations decreased to 5.0624, 4.3757, 2.2928 and 0.6356mg.L^{-1}, respectively during pyrolysis time of 2.0 h. Whereas at the corresponding furnace temperatures and pyrolysis time of 2.5 h the carbon concentrations were 4.9092, 2.832, 1.6232 and 0.42mg.L^{-1}, respectively.

The linear fit curve is the best equation by least square method to describe the carbon concentration (y) via the different furnace temperatures (x) at different pyrolysis time as follow:

At pyrolysis time 1.0 h,	$y = -0.0036x + 7.2264$	$R^2 = 0.9846$
At pyrolysis time 1.5 h,	$y = -0.0132x + 14.017$	$R^2 = 0.9052$
At pyrolysis time 2.0 h,	$y = -0.0154x + 15.736$	$R^2 = 0.9672$
At pyrolysis time 2.5 h,	$y = -0.0147x + 14.525$	$R^2 = 0.9794$

From the equations it can be noticed that the carbon concentration was an inversely relationship by the furnace temperatures. Also, the high sample correlation found at pyrolysis time of 2.5 > 2.0 > 1.0 > 1.5h.

By increasing the furnace temperature from 400 to 700°C Figs (41 and 43), the carbon concentration decreased from 1.28 to 0.01mg.L^{-1} for corn stalks and 4.95 to 0.41mg.L^{-1} for date kernels. These results explained that the carbonizing process was completed at furnace temperature 400°C. However, for trimming peach trees residues, the data recorded a directly trend for carbon concentration with furnace temperature. So, the carbon concentration increased from 0.03 to 3.61mg.L^{-1} by increasing the temperature from 400 to 700°C, shown in Fig. (42).

Furthermore, Fig. (41) represented the effect of pyrolysis time from carbon concentration. The highest carbon concentration was 1.28mg.L^{-1} at 1.0 h pyrolysis time for corn stalks. While it was recorded as 3.61 and 4.95mg.L^{-1} during pyrolysis time of 2.0 h for trimming peach trees residues and date kernels respectively. These results showed that by increasing the pyrolysis time from 1.0 to 2.0 h the carbon concentration was increased. While it is decreased at pyrolysis time of 2.5 h, that is may be due to excessive of pyrolysis and causes carbon losses.

c. Yield percentage

All samples were weighted before and after pyrolysis to estimate the yield for each type of residue.

1. Corn stalks.

The yield percentage showed that the highest percentage was 88% at furnace temperature 500°C during pyrolysis time 1.50 h. Moreover the lowest percentage was 28.00% by using pyrolysis time of 1.50 h at furnace temperature of 700°C as showed in Fig. (44).

The quadratic fit curve is the best equation to describe the yield percentage (y) obtained from corn stalks residues via the different furnace temperatures (x) at different pyrolysis time as follow:

At pyrolysis time 1.0 h, $y = -0.0010x^2 + 0.9399x - 151.10$ $R^2 = 0.9723$
At pyrolysis time 1.5 h, $y = -0.0019x^2 + 1.9957x - 425.46$ $R^2 = 0.9842$
At pyrolysis time 2.0 h, $y = 0.0004\ x^2 - 0.5269x + 219.27$ $R^2 = 0.9996$
At pyrolysis time 2.5 h, $y = -0.0014x^2 + 1.4050x - 273.39$ $R^2 = 0.9484$

From the equations it can be cleared that the yield percentage from corn stalks had an inversely relationship by the furnace temperatures for all pyrolysis times except at 2.0 h it was direct proportional to the furnace temperatures. Also, the high regressions found at pyrolysis time of 2.0 > 1.5 > 1.0 > 2.5 h.

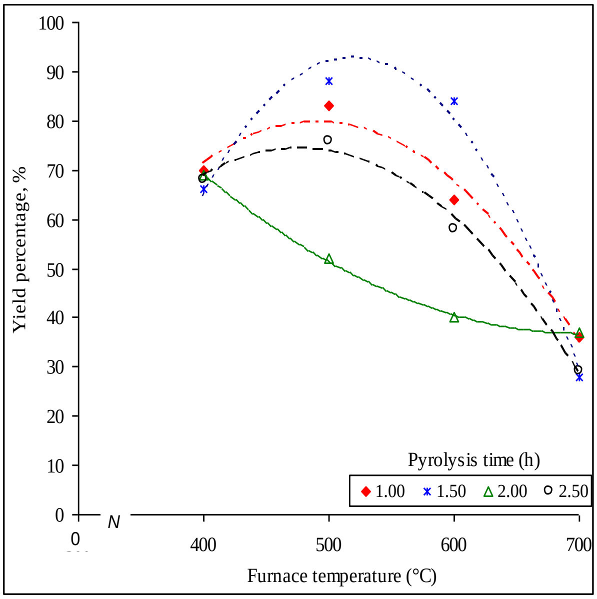


Fig. 44. Effect of furnace temperatures on yield percentage at different pyrolysis time for corn stalks.

2. Trimming peach trees residues

Fig. (45) illustrated that the average of yield percentage for trimming peach trees residues had changed from 71.38 to 73.60% at increased pyrolysis time from 2.0 to 2.5 h. While the average of yield ranging from 66.49 to 75.90% at decreased furnace temperatures from 700 to 500°C. On another side, the highest yield can obtained from trimming peach trees residues was 82.60% found at furnace temperatures of 600°C and pyrolysis time of 2.5h, while the lowest yield was 65.32% obtained at furnace temperatures of 700°C and pyrolysis time of 2.0h.

The quadratic fit curve is the best equation to describe the yield percentage (y) for the trimming peach trees residues via the different furnace temperatures (x) at different pyrolysis time as follow:

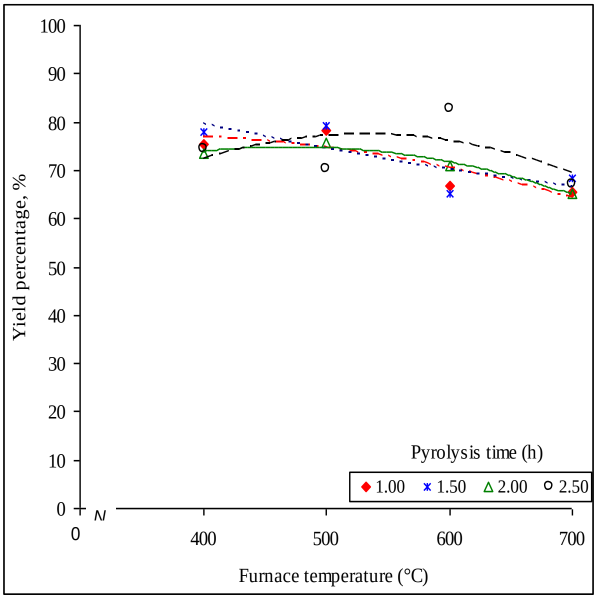


Fig. 45. Effect of furnace temperatures on yield percentage at different pyrolysis time for trimming peach trees residues.

At pyrolysis time 1.0 h, $y = -0.0001x^2 + 0.069x + 65.36$ $R^2 = 0.7526$

At pyrolysis time 1.5 h, $y = 0.00004x^2 - 0.091x + 109.01$ R2 = 0.6306

At pyrolysis time 2.0 h, $y = -0.0002x^2 + 0.180x + 32.51$ $R^2 = 0.9730$

At pyrolysis time 2.5 h, $y = -0.0003x^2 + 0.307x - 4.49$ $R^2 = 0.2825$

From the equations it can be cleared that the yield percentage from trimming peach trees residues was an inversely relationship with the furnace temperatures for all pyrolysis times except at 1.5 h it was direct proportional to the furnace temperatures. Also, the high regressions were found at pyrolysis time of 2.0 > 1.0 > 1.5 > 2.5 h.

3. Date kernels

The weighted date kernels samples showed that the lowest yield percentage was 54.44% at furnace temperature of 700°C and pyrolysis time of 2.5 h. However, the highest yield percentage was 91.90% stated at furnace temperature of 400°C during pyrolysis time of 1.50 h as illustrated in Fig. (46). Moreover, the averages of yield were ranging from 63.15 to 73.46% at pyrolysis time of 2.5 and 1.0 h, respectively. Also, the averages of yield were ranging from 56.53 to 82.99% obtained at furnace temperatures of 700 and 400°C, respectively.

The quadratic fit curve is the best equation to describe the yield percentage (y) for date kernels via the different furnace temperatures (x) at different pyrolysis time as follow:

At pyrolysis time 1.0 h, $y = -0.0006x^2 + 0.624x - 73.89 \quad R^2 = 0.8020$

At pyrolysis time 1.5 h, $y = 0.00060x^2 - 0.771x + 307.00 \quad R^2 = 0.9965$

At pyrolysis time 2.0 h, $y = -0.00005x^2 - 0.033x + 108.41 \quad R^2 = 0.7714$

At pyrolysis time 2.5 h, $y = 0.00030x^2 - 0.414x + 194.37 \quad R^2 = 0.9967$

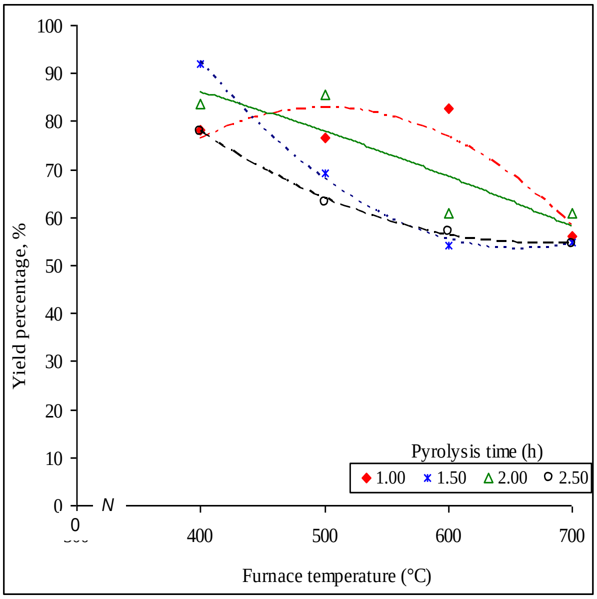


Fig. 46. Effect of furnace temperatures on yield percentage at different pyrolysis time for date kernels.

From the previous equations it can be noticed that the yield percentage from date kernels were an inversely relationship by the furnace temperatures for pyrolysis times of 1.0 and 2.0 h. But at pyrolysis times of 1.5 and 2.5 h it was direct proportional to the furnace temperatures. Also, the high sample regressions found at pyrolysis time of 2.5 > 1.5 > 1.0 > 2.0 h.

All previous results showed that the yield percentage was increased when furnace temperature decreased and pyrolysis time increased for the both of date kernels and trimming peach trees residues. The activation with phosphoric acid and its soaking time also assist to increase the yield of activated carbon. While, corn stalks yield showed the invers trend, these results were agreement with Hiremath *et al*. (2012) and Olafadehan *et al*. (2012). Generally, these results referee to the properties of lignocellulosic material component for each residue.

d. Properties of activated carbon

After pyrolysis process, the highest carbon concentration for each activated carbon that resulted from agricultural residues was chosen to perform the proximate and ultimate analysis; some properties of activated carbon were illustrated in Figs. (47 through 50) and Table (11).

Fig. (47) showed the important of chemical analysis for corn stalks trimming peach trees residues and date kernels. The carbon "C" percentages were 12.94, 64.6 and 56.4%, respectively at the above residues. From the figure it can be showed that the highest percentages of carbon established at trimming peach trees residues followed by date kernel, then corn stalks. Moreover, the nitrogen "N" percentages were 0.890, 0.050 and 2.63%, respectively at corn stalks, trimming peach trees residues and date kernels. However, the hydrogen "H" percentages were 3.08, 1.02 and 2.48%, respectively found used the previous residues. Furthermore, the ash percentages were 3.0, 10.0 and 26.0%, respectively for each activated carbon type produced from corn stalks, trimming peach trees residues and date kernels. The figure also can be illustrated that the lowest percentages of ash established at residues of corn stalks, followed by trimming peach trees residues, then date kernel.

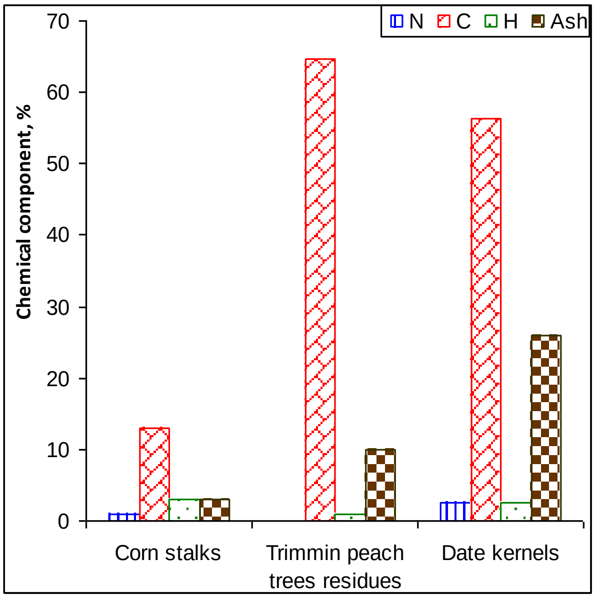


Fig. 47. Some chemical properties of activated carbon.

These results may be related to the loss in N% and H% after pyrolysis, while increase of C% was due to the good pyrolysis process and activation with H_3PO_4 for date kernels and trimming peach trees residues but the decrease of C% at corn stalks was related to excessing of pyrolysis process.

The bulk density of corn stalks, trimming peach trees residues and date kernels was showed in Fig. (48), the bulk density was 0.6, 0.7 and 1.3g.cm^{-3}. The figure showed that the highest bulk density found at date kernel followed by trimming peach trees residues, then corn stalks.

The moisture content at activated carbon produced from corn stalks, trimming peach trees residues and date kernels were showed in Fig. (49), the moisture content noted 9, 6 and 2% for the previous agricultural residues, respectively. The figure cleared that the lowest moisture content found at date kernel followed by trimming peach trees, then corn stalks.

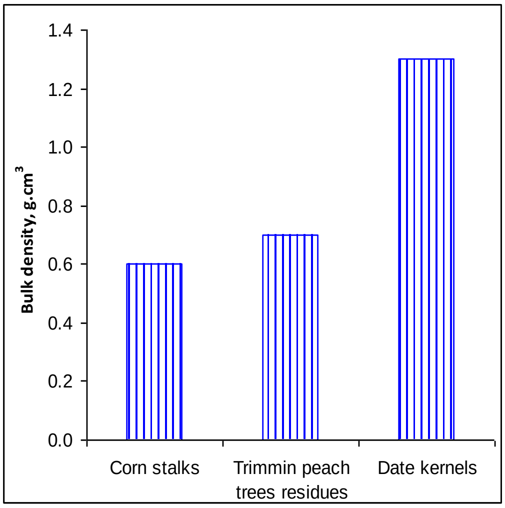


Fig. 48. Bulk density of activated carbon.

Table 11. Some properties of activated carbon.

Residues type	Corn stalks	Trimming peach trees residues	Date kernels
N (%)	0.89	0.05	2.625
C (%)	12.94	64.6	56.4
H (%)	3.08	1.02	2.48
Ash (%)	3	10	26
Bulk density (g.cm^{-3})	0.6	0.7	1.3
Moisture content (%)	9	6	2

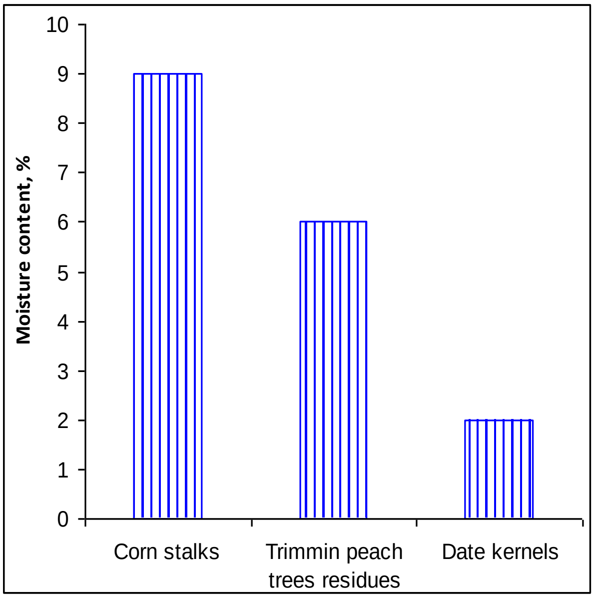


Fig. 49. Moisture content of activated carbon.

Fig. (50) illustrated the surface area of activated carbon which were 29.73, 113.88 and 95.57m^2.g^{-1} for corn stalks, trimming peach trees residues and date kernels, respectively. The figure seemed that the highest surface area was obtained for trimming peach trees residues, followed by date kernel, then corn stalks.

Meanwhile, the pore volume investigated and recorded as 7.95 × 10^{-4}, 5.33× 10^{-3} and 4.59× 10^{-3}cm^3.g^{-1}, as shows in (Fig. 51) for corn stalks, trimming peach trees residues and date kernels, respectively. Although the pore volume found in activated carbon from corn stalk was the lowest but it had a low surface area. Furthermore, the activated carbon from date kernels and trimming peach trees residues had the highest pore volumes and they had the highest surface areas. Similarly, the obtained results showed the lowest differences between the data obtained by date kernels and trimming peach trees residues which had the high surface area. These results agreement with the work of

Ioannidou and Zabaniotou (2007); Hiremath *et al*. (2012) and Brito (2017) which they reported the activation with phosphoric acid were resulted a higher surface area and pore volume of carbon.

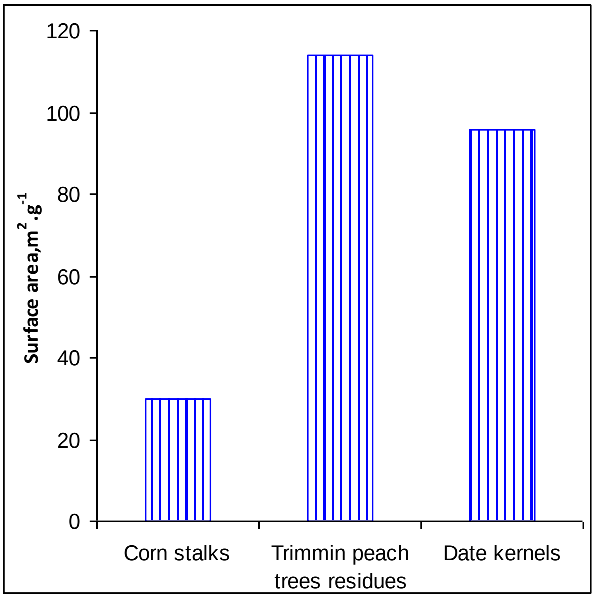


Fig. 50. Surface area for different activated carbon.

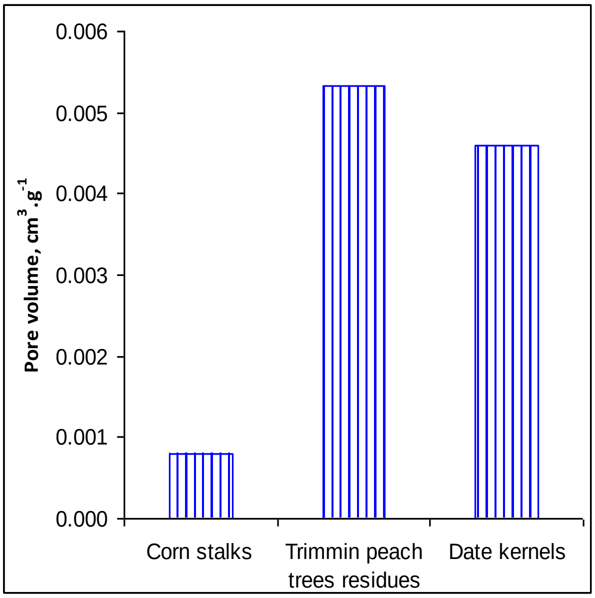


Fig. 51. Pore volume for different activated carbon.

A SEM micrographs method of identifying the pores depends on the section, Figs. (52 and 53) showed the Scanning Electron Microscope (SEM) micrographs for activated carbon produced from the agricultural residues of corn stalks according to highest and lowest carbon concentration. The all size of the pores sit in meso-porous categorize as recommended with Menéndez and Martín (2006).

Fig. (52) illustrated SEM micrographs for activated carbon produced from corn stalks according to highest carbon concentration; the scanning showed the average of pore size was 12.17µm at furnace temperature of 400°C and pyrolysis time of 1.0 h from the figure it can be showed a lot of spherical or semi-spherical pores shape with many open pores. These results may be due to the concentration process of extracting cellulose and lignocellulose. According to thermodynamic principles, the spherical shape will be more stable compared to other shapes and agreement with Kamoun *et al.* (2003) and Al-Lagtah *et al.* (2016).

Fig. (53) illustrated SEM micrographs for activated carbon produced from corn stalks at lowest carbon concentration; the scanning showed the average pore size was 2.06µm at furnace temperature of 700°C and pyrolysis time of 2.5 h. The figure showed irregular surface area could be due to a more complex network of pores; which was agreement with Wang *et al.* (2010).

Figs. (54 and 55) showed SEM micrographs for activated carbon produced from trimming peach trees residues as a maximum and minimum carbon concentration.

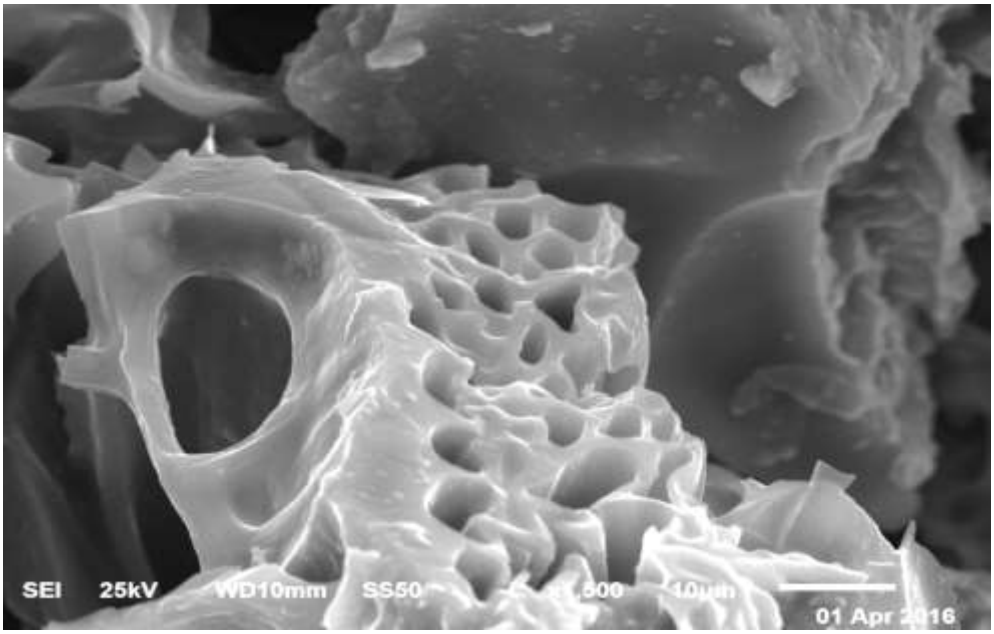


Fig. 52. Scanning electron micrographs for activated carbon produced from corn stalks at 400°C in 1 h.

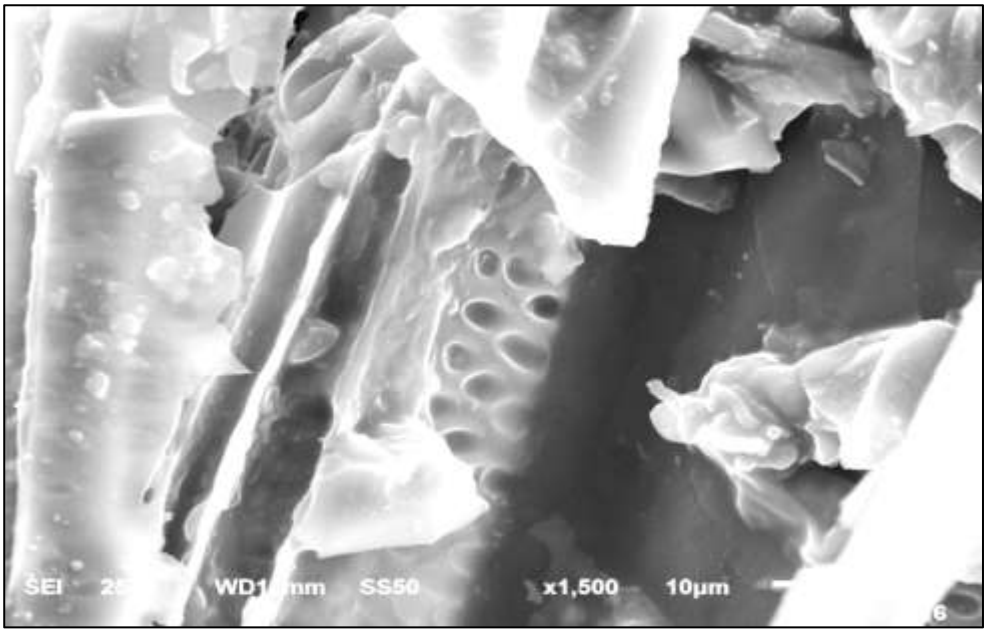


Fig. 53. Scanning electron micrographs for activated carbon produced from corn stalks at 700℃ in 2.5 h.

Fig. (54) showed SEM micrographs for activated carbon produced from trimming peach trees residues at maximum carbon concentration. The scanning showed that average of pore sizes was 9.017µm at furnace temperature of 700°C and pyrolysis time of 2 h. The scanning had a lot of spherical or semi-spherical pores shapes with many open pores, and the much particles surfaces. These results may be due to the concentration process of extracting cellulose and lignocellulose which agreement with the obtained results from Kamoun *et al*. (2003) and Al-Lagtah *et al*. (2016).

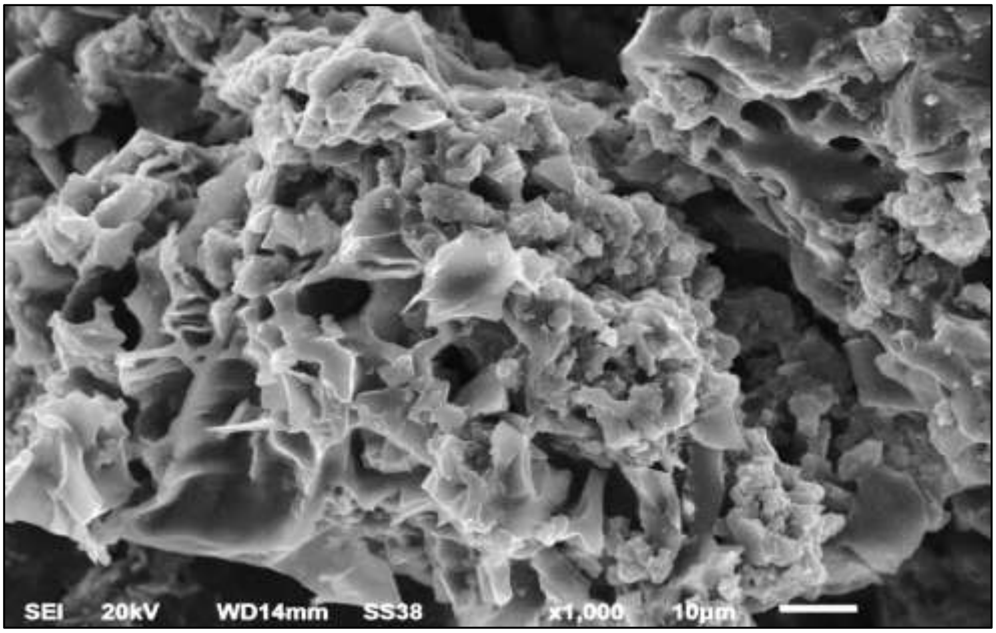


Fig. 54. Scanning electron micrographs for activated carbon produced from trimming peach trees residues at 700°C in 2 h.

Fig. (55) illustrate SEM micrographs for activated carbon produced from trimming peach trees residues at the lowest carbon concentration. The scanning showed the particles hadn't a rounded shape at furnace temperature of 500°C and pyrolysis time of 2.5 h but had more surface area. Al-Lagtah *et al*. (2016) elucidated that could be noticed the deposition of H_3PO_4 almost all over the surface.

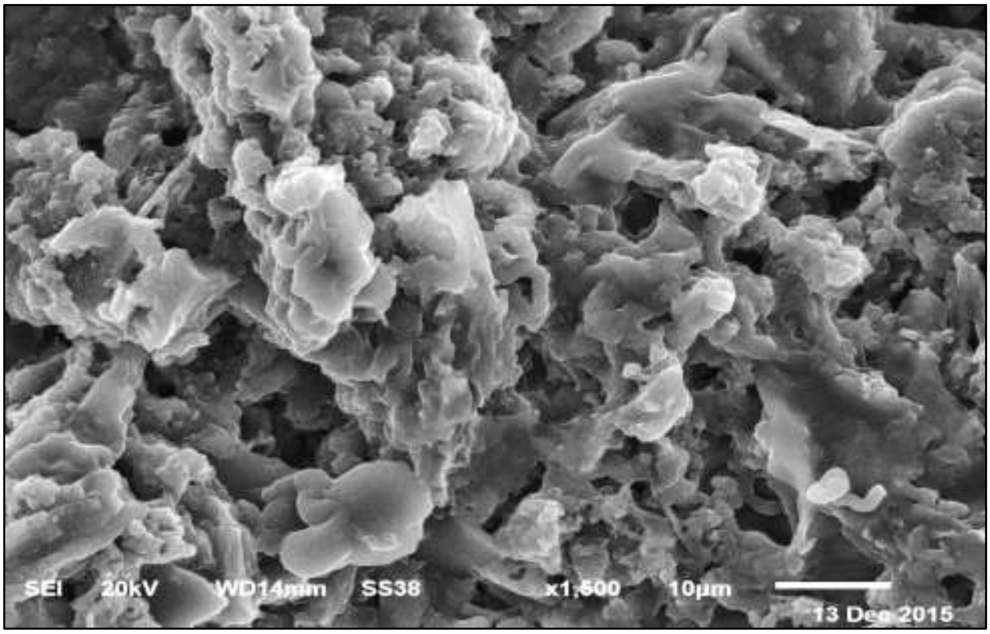


Fig. 55. Scanning electron micrographs for activated carbon produced from trimming peach trees residues at 500°C in 2.5 h.

Fig. (56 and 57) showed SEM micrographs for activated carbon produced from date kernels as a highest and lowest carbon concentration.

Fig. (56) showed SEM micrographs, for highest activated carbon produced from date kernels. The scanning showed average pore size was 10.27µm at maximum carbon concentration using furnace temperature of 400°C and pyrolysis time of 2.0 h. The scanning had a lot of a spherical or semi-spherical pores shape with many deeply open pores and much particles surfaces area. These results may be due to the concentration process of extracting lignin which was agreement with the results obtained from Kamoun *et al*. (2003) and Al-Lagtah *et al*. (2016).

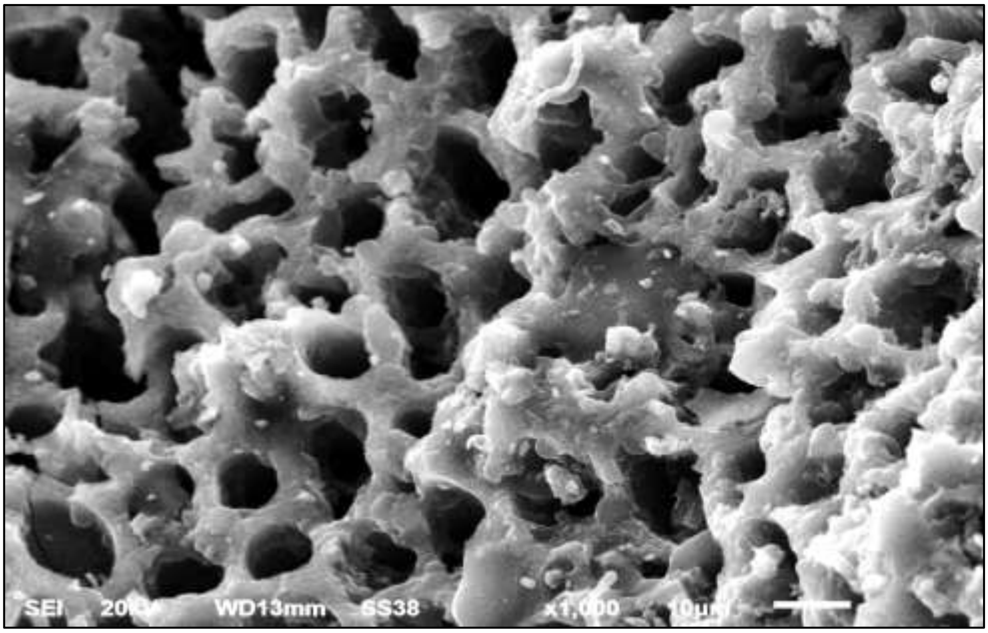


Fig. 56. Scanning electron micrographs for activated carbon produced from date kernels at 400°C in 2 h.

Meanwhile, Fig. (57) showed SEM micrographs, for lowest activated carbon produced from date kernels. The scanning illustrated average pores size was 2.789µm at furnace temperature of 700°C and pyrolysis time of 2.5 h. It was irregular size and shape and more particles surfaces area have a rounded shape. These results agree with these recommended by Wang *et al*. (2010) and may be due to a more complex network of pores. This supports the notion that increase temperature with impregnation of H_3PO_4 intensifies the attack of the acid on the botanical structure, altering the surface morphology of shoot-based activated carbon. Also, the deposition of H_3PO_4 almost all over the surface as concluded by Al-Lagtah *et al*. (2016).

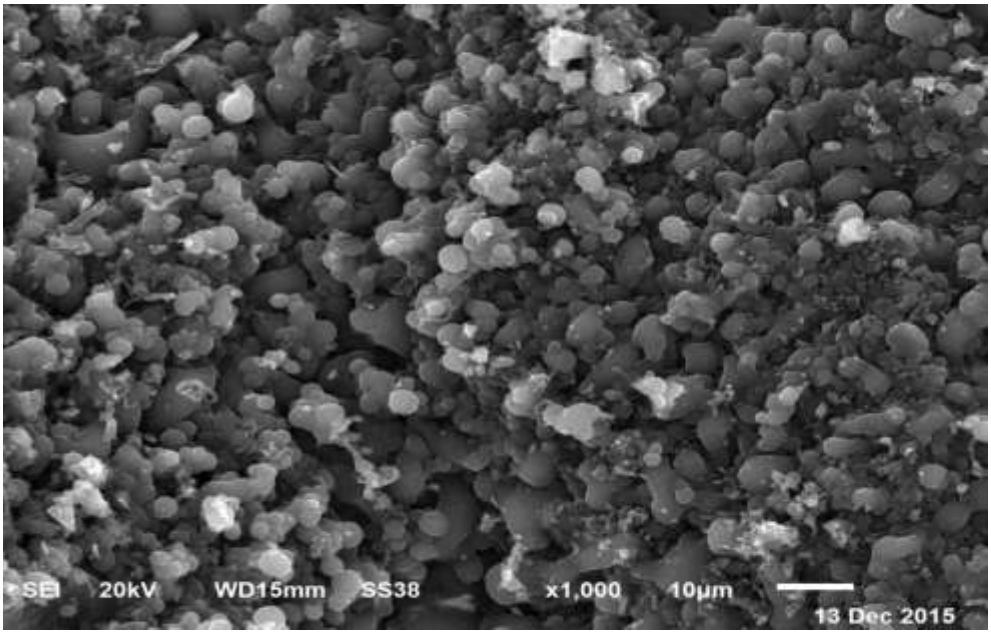


Fig. 57. Scanning electron micrographs for activated carbon produced from date kernels at 700°C in 2.5 h.

Generally, from the laboratory tests, results conclude that; the best activated carbon obtained at furnace temperature of 700°C and pyrolysis time of 2 h using trimming peach trees, then at furnace temperature of 400°C and pyrolysis time of 2 h using date kernels finally at furnace temperature of 400°C and pyrolysis time of 1.0 h using corn stalks as shown in table 12.

Table 12. Recommended optimum variables for each type of agricultural residue.

Agricultural residues	Furnace temperature (°C)	Pyrolysis time (h)
Corn stalk	400	1
Trimming peach trees residues	700	2
Date kernels	400	2

3. Evaluation performance of prototype

a. Evaluation the activated carbon

The activated carbon prototype tested at the optimum studied variables for each agricultural residue recommended from the laboratory unit to evaluate the qualification of prototype as shown in table (12). The activated carbon prototype evaluation is depending on the quality and quantity and net profit economically of production.

1. Effect of pyrolysis operation on yield

Fig. (58) illustrated the effect of pyrolysis operation on yield for each type of agricultural residual. Fig. (58) showed the percentages of yield were 79.63, 73.33 and 89.76% for corn stalks, trimming peach trees residues and date kernels, respectively. Moreover, the highest yield obtained by using the pyrolized date kernels while the lowest yield obtained by using the pyrolized trimming peach trees. These results are in agreement with Prahas *et al*. (2008).

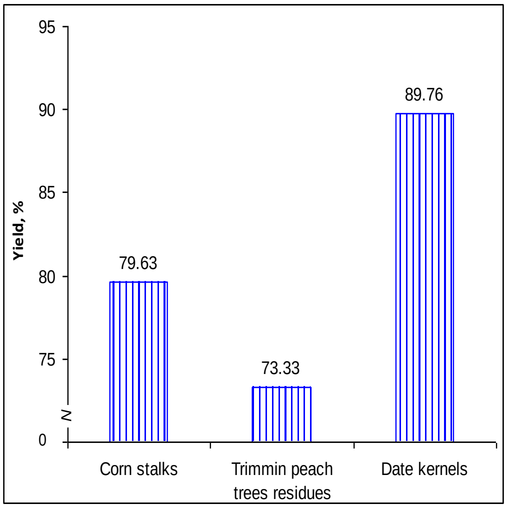


Fig. 58. Effect of pyrolysis operation on activated carbon yield.

2. Effect of pyrolysis operation on some properties

Fig. (59) described the effect of pyrolysis operation on some chemical component as N, C, H and ash for each type of activated carbon. N, C, H and ash percentages of the activated carbon obtained from corn stalks which were 1.22, 10.54, 4.28 and 2.67%, respectively. However, N, C, H and ash percentages of the activated carbon obtained from trimming peach trees residues recorded 0.00, 76.80, 0.87 and 8.89%, respectively. Nevertheless, it were recorded 1.52, 61.3, 1.05 and 27.56% of the activated carbon obtained from date kernels for N, C, H and ash, respectively. Moreover, it can conclude that the highest carbon percentage of 76.8% and the lowest ash percentage of 8.89% gained by using trimming peach trees residues residue. On the other hand, the lowest carbon percentage obtained by using corn stalks. While, the highest ash percentage found with date kernels.

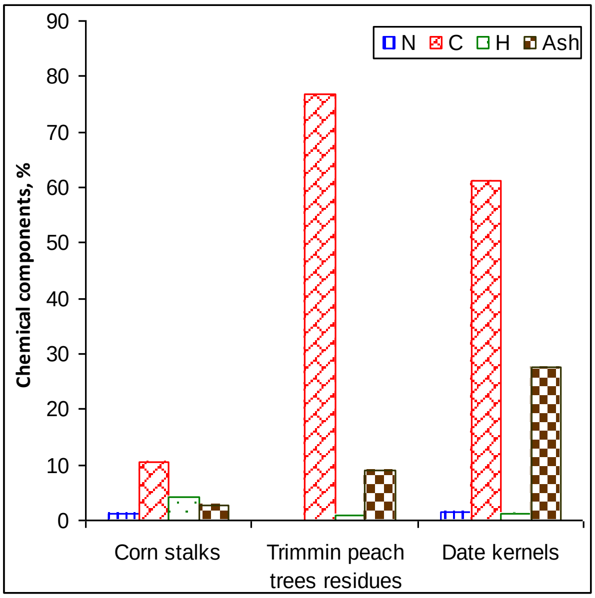


Fig. 59. Effect of pyrolysis operation on some chemical components of activated carbon.

Fig. (60) illuminated the effect of pyrolysis operation on bulk density for each type of activated carbon. The figure cleared that the bulk densities were 0.35, 0.36 and 0.52g.cm^{-3} for activated carbon produced from corn stalks, trimming peach trees residues and date kernels, respectively. So, the highest bulk density obtained using date kernels, while the lowest bulk density obtained from corn stalks.

Fig. (61) illustrate the effect of pyrolysis operation on surface area for each type of activated carbon. The figure showed that the surface area were 28.56, 142.39 and 123.65m^{2}.g^{-1} for activated carbon produced from corn stalks, trimming peach trees residues and date kernels, respectively. Moreover, it can be concluded that the highest surface area was 142.39m^{2}.g^{-1} obtained from trimming peach trees residues, while the lowest value was 28.56m^{2}.g^{-1} which obtained from corn stalks. These results agreement with Tsai *et al*. (2001).

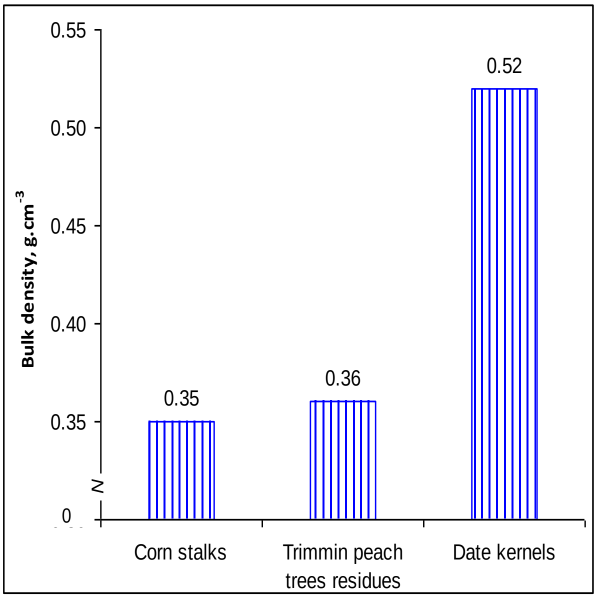


Fig. 60. Effect of pyrolysis operation on bulk density of activated carbon.

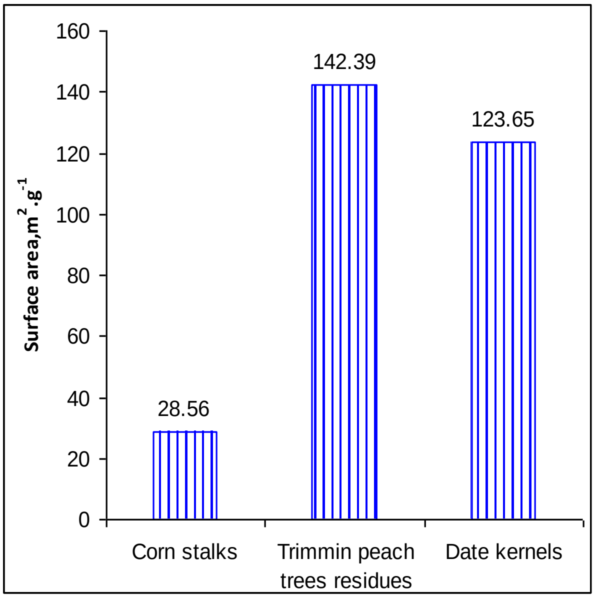


Fig. 61. Effect of pyrolysis operation on surface area of activated carbon.

Fig. (62) conducted the effect of pyrolysis operation on pore volume for each type of activated carbon. The figure realized that the pore volumes were 5.23×10^{-4}, 6.62×10^{-3} and 5.75×10^{-3}cm^3.g^{-1} for activated carbon produced from corn stalks, trimming peach trees residues and date kernels, respectively. From the figure the highest pore volume obtained from trimming peach trees residues, whilst the lowest pore volume obtained from corn stalks.

Generally, the obtained results show the lowest differences between the data obtained by date kernels and trimming peach trees residues which have the high surface area. These results clear that the high pore volume has the benefit surface area. The obtained results were agreement with Tsai *et al*. (2001); Demiral *et al*. (2007); Ioannidou and Zabaniotou (2007); Hiremath *et al*. (2012) and Abechi *et al*. (2013) for date kernels.

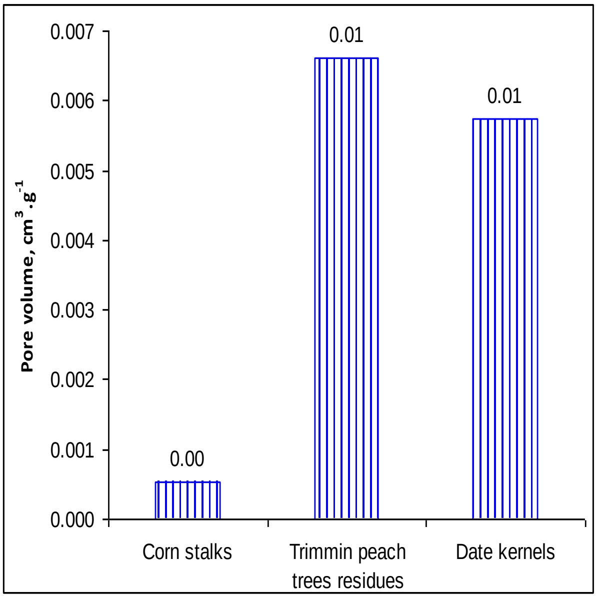


Fig. 62. Effect of pyrolysis operation on pore volume of activated carbon.

Figs. (63 through 65) illustrated the effect of pyrolysis operation on pore size and shape for each type of activated carbon. Fig. (63) showed SEM micrographs for the activated carbon from corn stalks. It was irregular shape surface and more particles surfaces area hadn't a rounded shape. These results which may be due to a more complex network of pores which agreement with the recommended from Wang *et al*. (2010).

Fig. (64) showed SEM micrographs for the agricultural trimming peach trees residues. The pore size was ranging from 4.308 to 46.819µm for activated carbon. The structure had a lot of open, deeply spherical and elliptic pores and a structure pores with different diameters. This result may be due to the concentration process of extracting lignin from liquor and according to thermodynamic principles; the spherical shape will be more stable compared to other shapes. These results were agreement with the concluded by Kamoun *et al*. (2003) and Al-Lagtah *et al*. (2016).

Fig. (65) showed SEM micrographs for activated carbon produced from date kernels. From the figure pore sizes were ranging from 4.219 to 16.648µm for activated carbon particles. The results cleared that the all sizes of the pores sit in meso-porous categorize as Menéndez and Martín (2006).

The scanning had a lot of regularity of spherical shape pores with all open. This spherical shape may be due to the concentration process of extracting lignin from liquor. These results were agreement with the results from Kamoun *et al*. (2003) and Al-Lagtah *et al*. (2016).

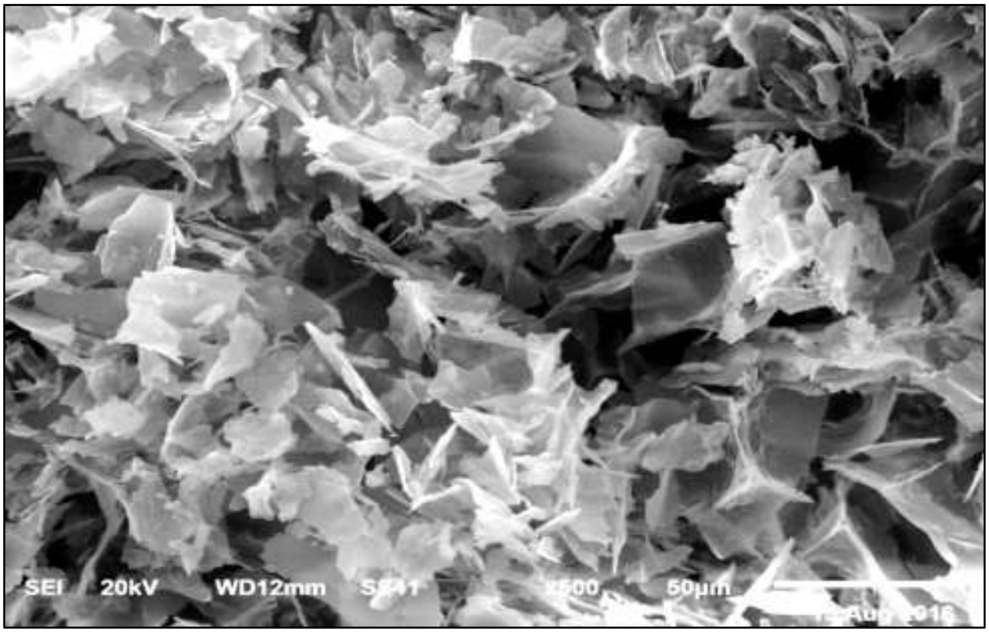


Fig. 63. The scanning electron micrographs (SEM) for activated carbon produced from corn stalks.

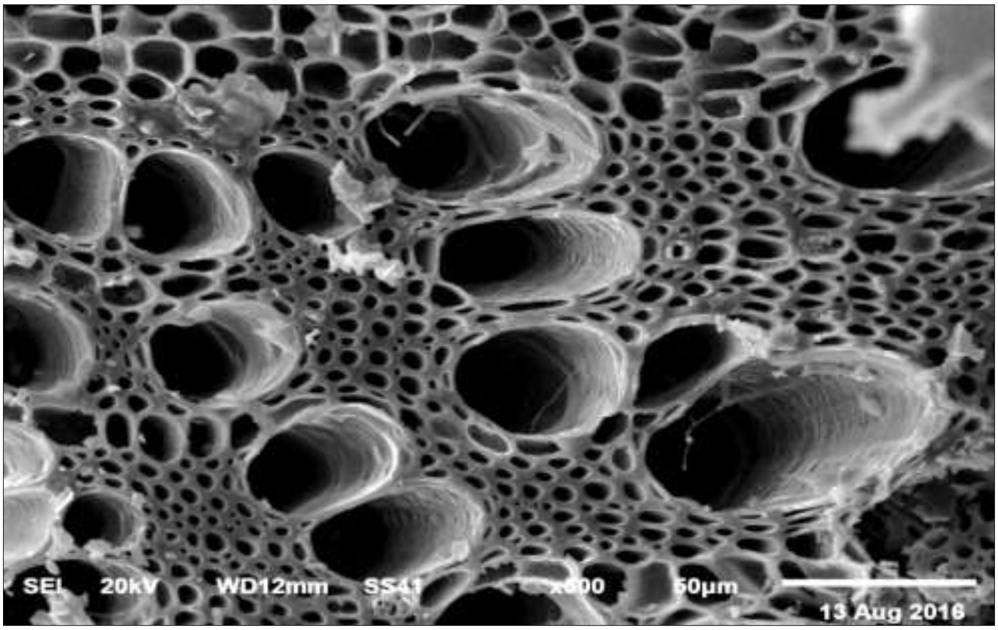


Fig. 64. The scanning electron micrographs (SEM) for activated carbon produced from trimming peach trees.

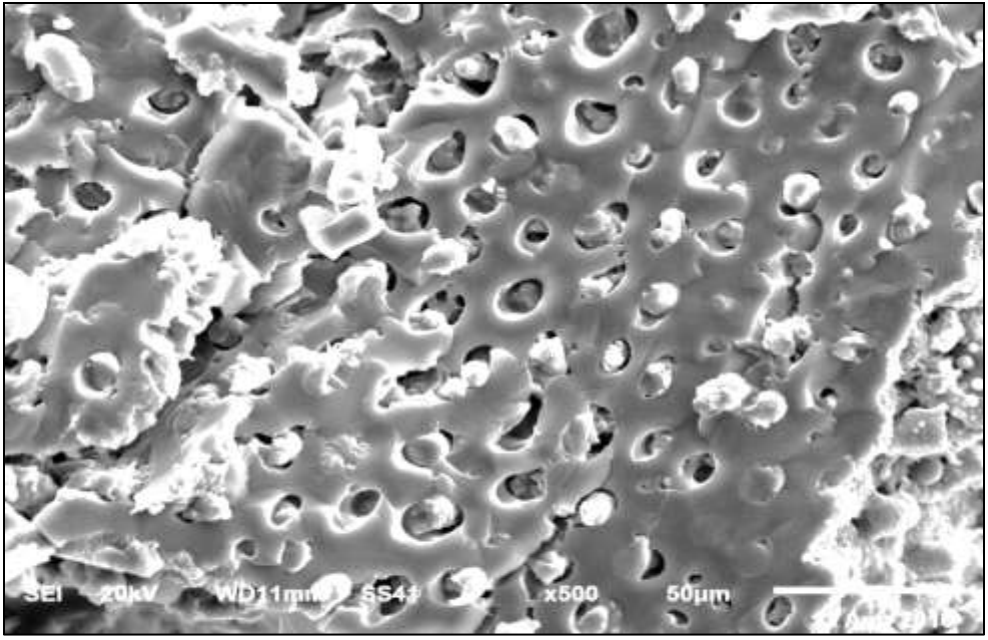


Fig. 65. The scanning electron micrographs (SEM) for activated carbon produced from date kernels.

Fig. (66) presented the effect of pyrolysis operation of moisture content for each type of activated carbon. The figure clarified that the moisture content percentage were 9.0, 6.0 and 2.0% for corn stalks, trimming peach trees residues and date kernels, respectively. From the figure the highest moisture content was 9.0% obtained from corn stalks. Then the lowest moisture content was 2.0% obtained from date kernels.

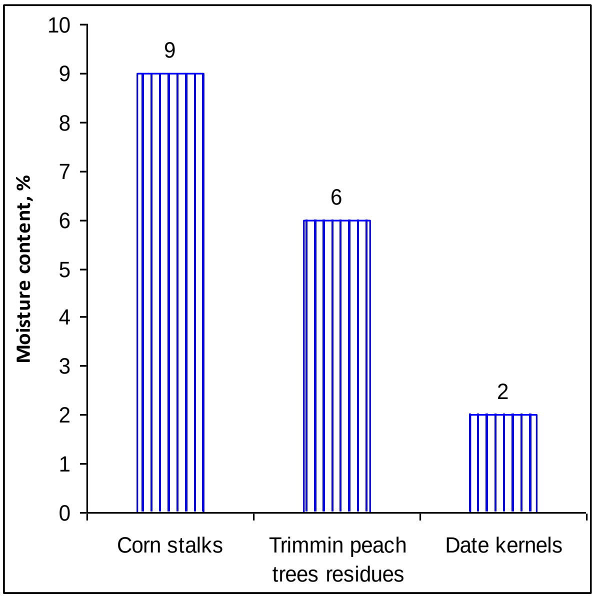


Fig. 66. Effect of pyrolysis operation on moisture content of activated carbon.

b. Performance of activated carbon prototype

1. Productivity of activated carbon prototype

Fig. (67) cleared that the productivity of activated carbon from the prototype for corn stalks, trimming peach trees residues and date kernels were 0.282, 1.130 and 3.17kg.h^{-1}. This mean that the production of activated carbon obtained from trimming peatch trees residues and date kernel using the designed prototype were high amount about 4.01 and 11.23 times for the production using activated carbon from corn stalks.

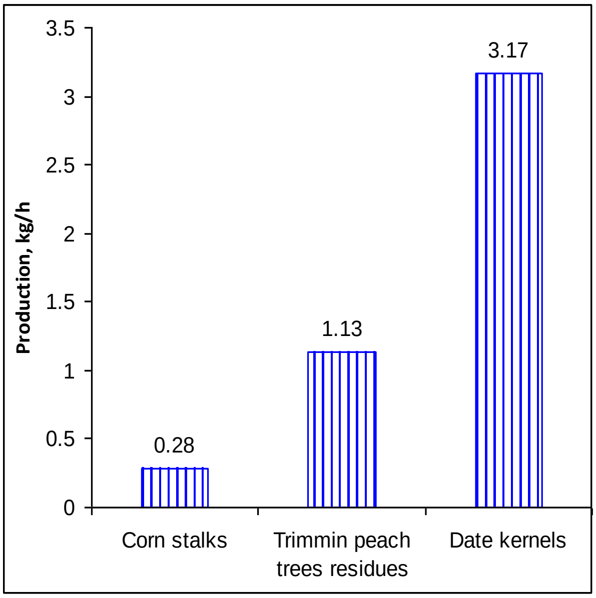


Fig. 67. Productivity of activated carbon.

2. Cost estimation for the production of activated carbon prototype

Pyrolysis operation cost for the activated designed prototype was estimated for exchange of corn stalks, trimming peach trees residues and date kernels residues to activated carbon at the furnace temperature of 400, 700 and 400°C and pyrolysis time of 1.0, 2.0 and 2.0 h, respectively. The assumptions used in cost estimation and the obtained results are presented in Table (13).

As shown in the table, the estimated total cost of residue pyrolysis using the prototype was 56.73LE/h while the pyrolysis cost/kg of raw pyrolysis was 201.18, 50.20 and 17.92LE, respectively for corn stalks, trimming peach trees residues and date kernels. Since, the total capacity of the prototype unit was about 0.355, 1.541 and 3.526kg of producing about 0.28, 1.13 and 3.17kg of activated carbon, the calculated operation cost of the prototype about 51.73LE/kg of activated carbon. Considering the price of raw residue is about 10LE/Mg. This means that the pyrolysis could gain about 56.73LE/kg of activated carbon or -86.16, 15.62 and 259.86LE/kg as a net profit, respectively for the previous agricultural residues as shown in fig. (68). From these results it can be recommended that corn stalks not suitable economic to obtain activated carbon this may be due to volatilize corn stalks through pyrolysis process. On the other side the best economical residues can use to produce the activated carbon were date kernels which resulted in about 361.94LE/h as a net profit. These results conducted that the activated carbon prototype can be used as a success small project to produce activated carbon.

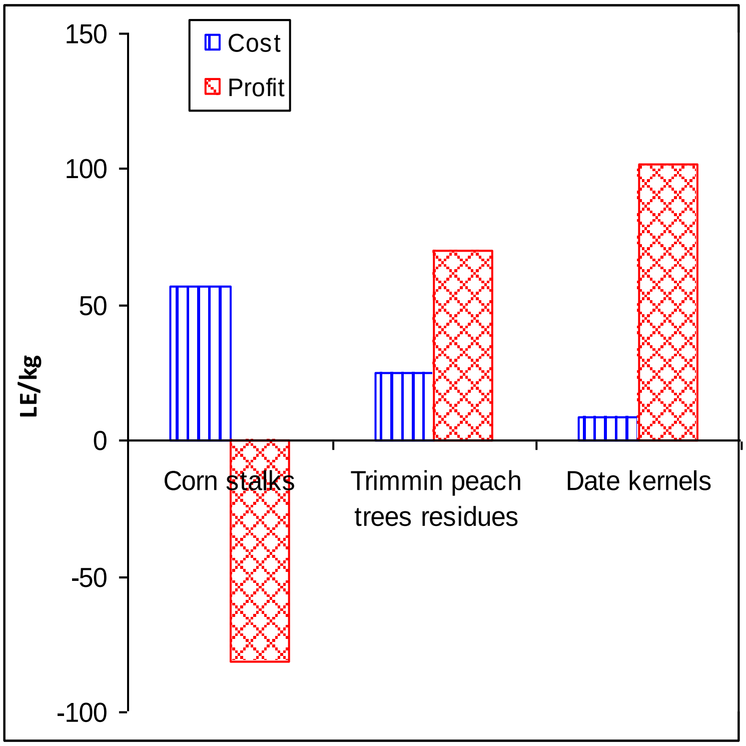


Fig. 68. Cost estimation for the activated carbon prototype.

Table 13. Cost estimation for the activated carbon prototype.

Assumptions	**Values**
Price of activated carbon prototype (LE)	4000
prototype capacity raw residues (kg)	Corn stalks, 0.28 Trimming peach trees, 1.13 Palm kernels , 3.17
Pyrolysis time (h)	1
Operation hours per year	2400
Operation life of the prototype (year)	10
Total mass of raw residues (kg/year)	672, 2712, 7608
Number of pyrolysis runs (run/year)	2400
Fixed costs:	
Depreciation and interest cost, LE/h	5.37
Taxes and insurance, LE/h	80
Variable costs:	
Repair and maintenance cost (LE/h)	68
Gas cost (LE/h)	20
Pre-treatment cost (LE)	0.01
Electricity cost (LE/h)	0.03
Labour cost (LE/h)	20
Total cost	
(LE/h)	56.73, 25.10, 8.96
(LE/kg) raw residues	10
(LE/kg) activated carbon	120
(LE/run)	56.73

4. Comparison among the qualities of activated carbon produced by laboratory unit and prototype

The qualities of products from activated carbon prototype comparing with the optimum parameters from the laboratory unit sit to determine the activated carbon prototype performance.

a. Activated carbon yield

The data in Fig. (69) cleared that prototype design gave higher activated carbon yield than laboratory furnace. In this respect, using the activated carbon prototype the yield had an increase compared to that produced from laboratory unit as about 13.76, 12.26 and 7.19%, respectively for corn stalks, trimming peach trees residues and date kernels.

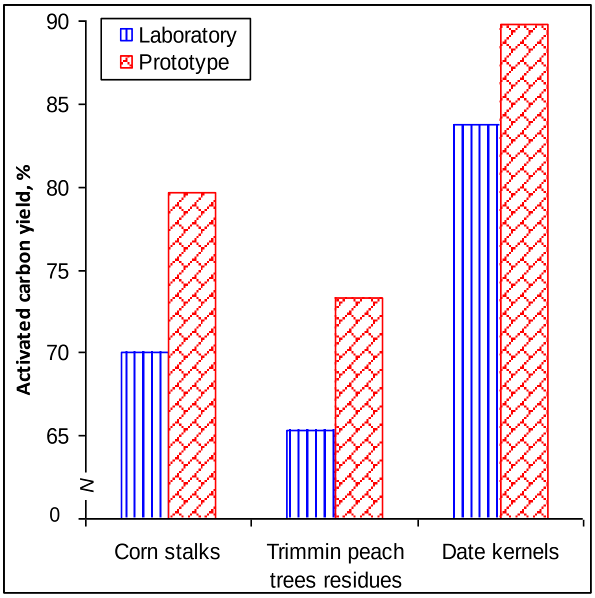


Fig. 69. Comparative between laboratory unit and prototype production in activated carbon yield.

b. Chemical components

The data from Fig. (70) illustrated a fluctuated trend between activated carbon prototype design and laboratory unit for carbon content of all types of activated carbon. In this regard, data showed the carbon content produced from corn stalks decreased about 18.55% when using activated carbon prototype than using laboratory unit.

However, data showed the carbon content of activated carbon produced from trimming peach trees residues and date kernels by using activated carbon prototype gave higher than laboratory unit.

The carbon content in activated carbon increased about 18.89 and 8.69% that produced from trimming peach trees residues and date kernels, respectively using activated carbon prototype than the laboratory.

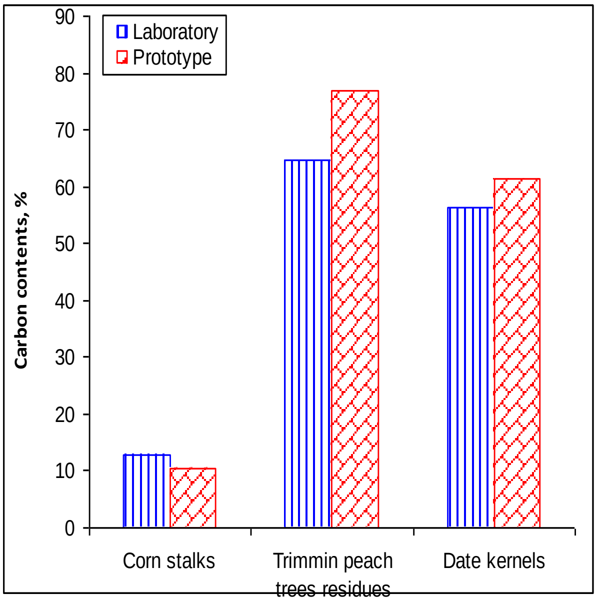


Fig. 70. Comparative between laboratory unit and prototype production in Carbon contents.

c. Bulk density

Fig. (71) obvious that the bulk density of activated carbon produced from prototype design decreased by 33.33 and 15.38% than laboratory unit for corn stalks and date kernels, respectively. On the other hand, activated carbon prototype and laboratory unit gave the same values for trimming peach trees residues.

d. Surface area

Fig. (72) indicated a fluctuated trend between activated carbon prototype and laboratory unit in all types of activated carbon. In this concern, data showed the surface area of activated carbon produced from corn stalks when using designed prototype decreased by 3.9% than laboratory unit. However, data showed the surface area of activated carbon produced from trimming peach trees residues and date kernels by using activated carbon prototype increased about 25.04 and 29.38%, respectively than laboratory unit.

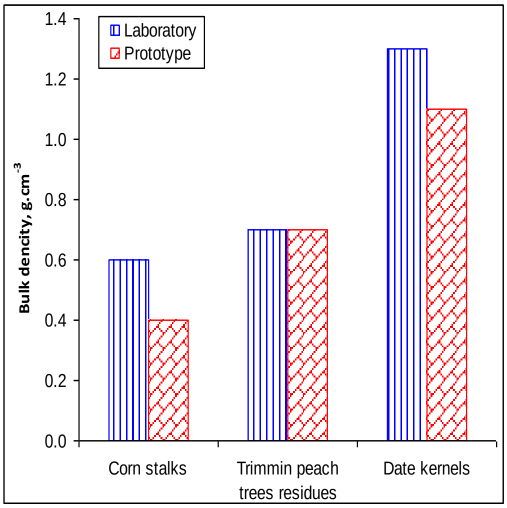


Fig. 71. Comparative between laboratory unit and prototype production in bulk density.

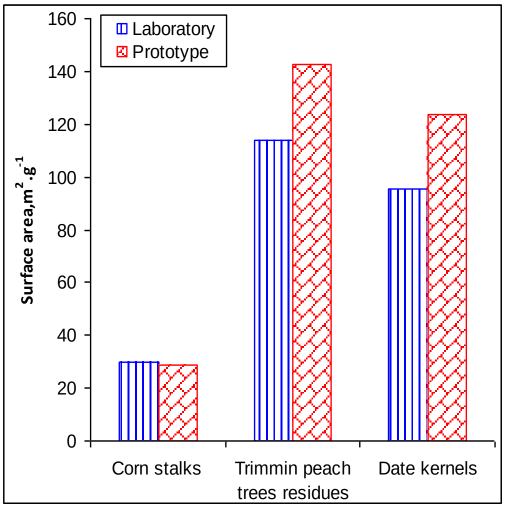


Fig. 72. Comparative between laboratory unit and prototype production in surface area.

e. Pore volume

Fig. (73) indicated a fluctuated trend between activated carbon prototype and laboratory unit in all types of activated carbon. In this concern, data showed the pore volume of activated carbon produced from corn stalks when using designed prototype decreased by 34.21% than laboratory unit. However, data showed the surface area of activated carbon produced from trimming peach trees residues and date kernels by using activated carbon prototype increased about 24.2 and 25.27%, respectively than laboratory unit.

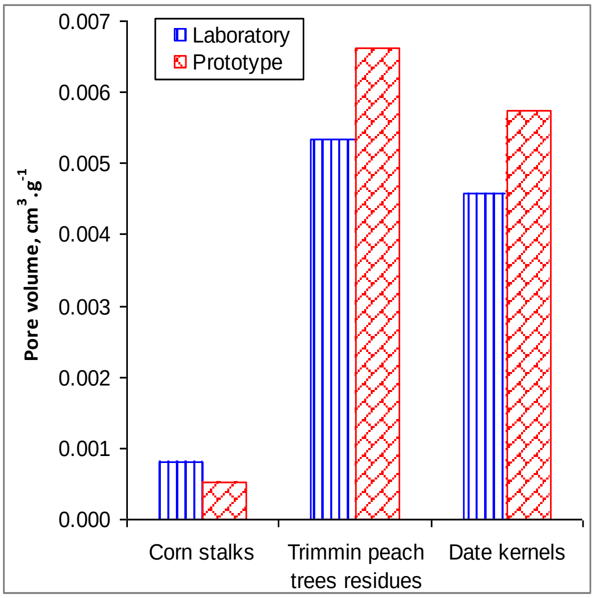


Fig. 73. Comparative between laboratory unit and prototype production in pore volume.

From the above results, the properties of activated carbon produce from trimming peach trees residues and date kernels by using prototype gave higher values than laboratory unit that due to the prototype was controlled in temperature and the air was isolated inside furnace where neitrogen gas was used. These results may be due to the solid material were not lost during pyrolsis process inside prototype as found by activated carbon from corn stalks.

5. Drinking water purification test

The influence of activated carbon produced from each agricultural residue on drinking water purification was tabulated in Table (14) and showed in Figs. (74 through 77).

Data in the Table (14) and Fig. (74) indicated that water treated using activated carbon produced from corn stalks, trimming peach trees residues and date kernels the purification time increased by increase the height of activated carbon. In this respect, activated carbon produced from corn stalks were 03.56, 16.06 and 25.27 min, while activated carbon produced from trimming peach trees residues noted 1.15, 08.21 and 15.45 min for height of activated carbon of 1.0, 2.5 and 5.0cm that used for purification, respectively. Also, the activated carbon produced from date kernels recorded the same trend for water purification times which were 2.25, 5.40 and 08.18 min for 1.0, 2.5 and 5.0cm height of activated carbon, respectively.

From the figure it can be cleared that the lowest time for purification process occurred at used activated carbon produced from trimming peach trees residues at 1.0cm height. Moreover, the highest time for purification process recorded at used activated carbon from corn stalks at 5.0cm height that may due to decreasing in bulk density increased purification time.

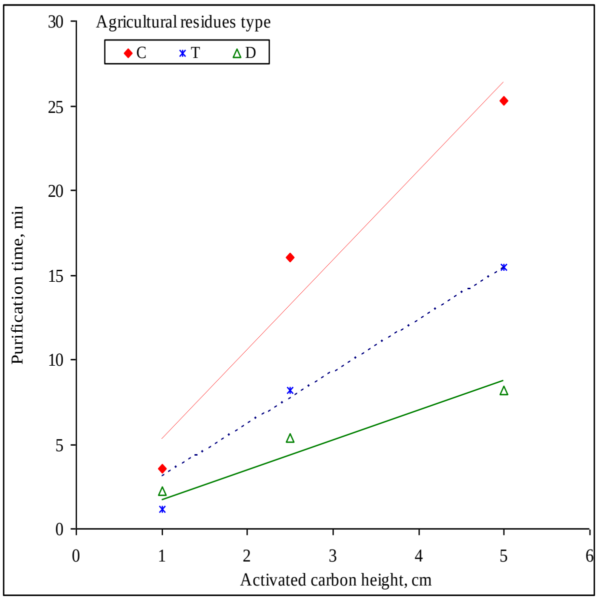


Fig. 74. Effect activated carbon height on purification time.

The linear fit curve is the best equation by least square method to describe the water purification time (y) via the activated carbon height (x) at different type of activated carbon types as follow:

At activated carbon from "C", $y = 5.2732x$ $R^2 = 0.9478$

At activated carbon from "T", $y = 3.0674x$ $R^2 = 0.9612$

At activated carbon from "D", $y = 1.7566x$ $R^2 = 0.9078$

From the equations it can be clear that the water purification time had a direct proportional to the height of activated carbon. Also, the high correlation found at activated carbon type of T > C > D.

In the other hand, data in the Table (14) and Fig. (75) stated a fluctuate trend of turbidity for all activated carbon types at different heights. In this concern, Fig. (75) showed turbidity recorded as 1.20, 0.90 and 1.60NTU when using activated carbon produced from corn stalks at different height of activated carbon 1.0, 2.5 and 5.0cm, respectively.

Nevertheless, by using activated carbon produced from trimming peach trees residues, water turbidity were noted 01.78, 01.60 and 02.85NTU at 1.0, 2.5 and 5.0cm height of activated carbon respectively. Whereas, water turbidity were 01.40, 00.70 and 00.80NTU when using activated carbon produced from date kernels at 1.0, 2.5 and 5.0 cm heights of activated carbon, respectively.

The best activated carbon used to remove the turbidity from drinking water purification that came from date kernels at 2.50 and 5.0cm height of activated carbon that’s because the properties of activated carbon of surface area and pores volume. But sample had a high NUT of turbidity when used activated carbon from corn stalks and trimming peach trees residues at 5.0cm height. The all data below 1.0 NTU can use in drinking water as the recommended from Egyptian standard (2005) and Ministry of Health and Population (2007).

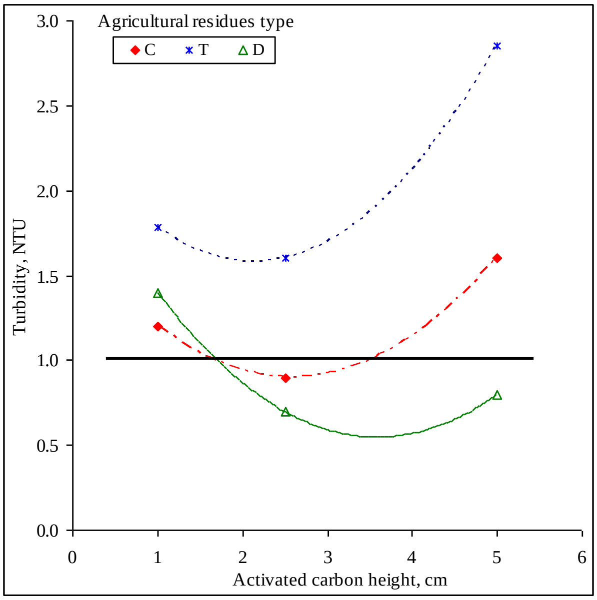


Fig. 75. Effect activated carbon height on turbidity.

Using the linear fit curve as the best equation by least square method to describe the water turbidity (y) via the activated carbon height (x) at different activated carbon as follow:

At activated carbon from "C", $y = 0.2912x + 1.2515$ $R^2 = 0.464$

At activated carbon from "T", $y = 0.2912x + 1.2515$ $R^2 = 0.7584$

At activated carbon from "D", $y = -0.1306x + 1.3367$ $r = 0.4860$

From the equations it can be cleared that the water turbidity was a directly proportional to the height of activated carbon at used activated carbon produced from corn stalks and trimming peach trees residues but it was an inversely proportional using the activated carbon produced from date kernels. Also, the high correlation found at activated carbon type of T > D > C.

With regard to total dissolved solids (TDS), data in Table (14) and Fig. (76) illustrated that the remove of total dissolved solids increased with decreasing activated carbon height. Even though, activated carbon produced from corn stalks was remove of TDS which were 3.55, 4.50 and 8.30ppm at activated carbon heights of 1.0, 2.5 and 5.0cm, respectively.

However, activated carbon produced from trimming peach trees residues noted 4.20, 11.60 and 22.70ppm at 1.0, 2.5 and 5.0cm height of activated carbon, respectively. Whilst, activated carbon produced from date kernels recorded the same trend for remove of TDS which were 05.00, 07.20 and 12.70ppm for 1.0, 2.5 and 5.0cm height of activated carbon, respectively.

The best activated carbon used to remove the TDS from drinking water purification was activated carbon from corn stalks at 1.0cm height. But sample had a high ppm of TDS by used activated carbon from trimming peach trees residues at 5.0cm of height. These results clear that the all data lower that the recommended Egyptian standard for drinking water as maximum of TDS is 50.0 ppm.

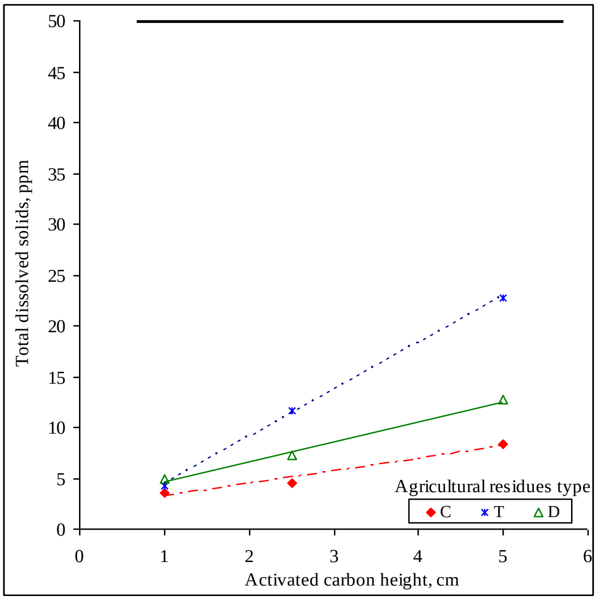


Fig. 76. Effect activated carbon height on total dissolved solids.

The linear fit curve is the best equation by least square method to describe the drinking water TDS (y) via the activated carbon height (x) at different type of activated carbon as follow:

At activated carbon from "C", $y = 1.2214x + 1.9893$ $R^2 = 0.9644$

At activated carbon from "T", $y = 4.6061x - 0.2173$ $R^2 = 0.9992$

At activated carbon from "D", $y = 1.9531x + 2.7663$ $R^2 = 0.9902$

From the equations it can be clear that TDS had a direct proportional to the height of activated carbon at used activated carbon from corn stalks and trimming peach tress residues and date kernels. Also, the high correlation found at activated carbon type of T > D > C.

The number of microorganism data in Table (14) and Fig. (77) illustrated the high no. of microorganism remove by increasing activated carbon height. Even though, by using activated carbon produced from corn stalks, the no. of microorganism was 3.69, 3.39 and 3.32microorganism.mL^{-1} at activated carbon height of 1.0, 2.5 and 5.0cm, respectively. However, activated carbon produced from trimming peach trees residues noted 0.415, 0.145 and 0.135microorganism.mL^{-1} at 1.0, 2.5 and 5.0cm activated carbon height, respectively. Whilst, activated carbon produced from date kernels recorded the same trend for remove microorganism which were 0.21, 0.055 and 0.06microorganism.mL^{-1} at 1.0, 2.5 and 5.0cm height of activated carbon, respectively.

The best activated carbon can be used to remove the microorganism from drinking water purification that activated carbon produced from date kernels at 2.5cm of activated carbon height. But sample had a highest microorganism when used activated carbon produced from corn stalks at 1.0cm of activated carbon height.

No. of microorganism of fresh water which recommended from Egyptian standard was not more than 2 microorganism.mL^{-1} so, activated carbon produced from trimming peach trees residues and date kernels can used. But can't be used activated carbon produced from corn stalks that’s because had unsuitable surface are and pores volumes.

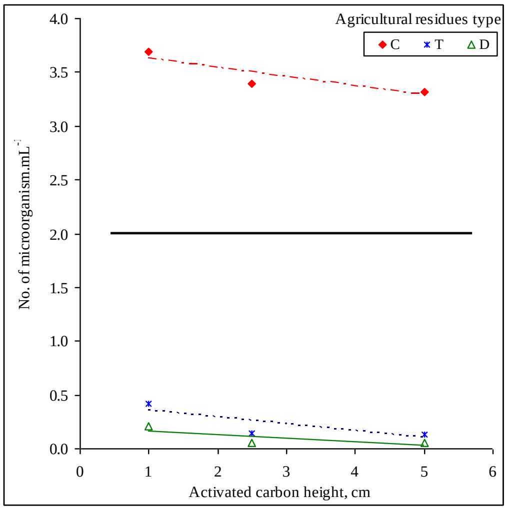
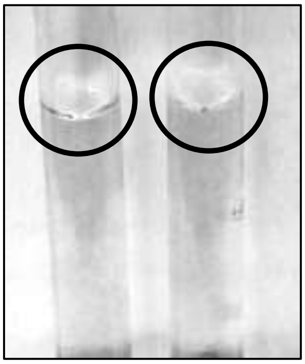


Fig. 77. Effect activated carbon height on No. of microorganism.

Furthermore, it was observed a nil color, treated and odor of the drinking water which treated with all types of activated carbon as shown in Figs. (78 and 79) the figures showed the color of drinking water before and after purification.

As well as, the percentage of removal of the color increased as the activated carbon dose was increased. The increased removal at high dosages is expected, because of the increased adsorbent surface area and availability of more adsorption sites. These results are in agreement with Aidan (2012) and El-Sayed *et al*. (2011).



Before After

Fig. 78. Drinking water before and after purification

Fig. 79. Drinking water after purification

Table 14. Effect of activated carbon type on water quality

Type of activated carbon	Mass	Height, cm	Purification time, min	Turbidity, NUT	TDS, ppm	Microbial, No of microorganism /mL
Corn stalks	0.143	1.0	03.56	01.20	03.55	3.69
	0.293	2.5	16.06	00.90	04.50	3.39
	0.659	5.0	25.27	01.60	08.30	3.32
Trimming peach trees	0.334	1.0	01.15	01.78	04.20	0.415
	0.759	2.5	08.21	01.60	11.60	0.145
	1.676	5.0	15.45	02.85	22.70	0.135
Date kernels	0.448	1.0	02.25	01.40	05.00	0.21
	1.196	2.5	05.40	00.70	07.20	0.055
	2.211	5.0	08.18	00.80	12.70	0.06

SUMMARY AND CONCLUSION

Agricultural residues are considered as a national wealth untapped. It can be caused pollution of all environmental elements, because of burning and disposing in different ways. These residues can be used in many products such as organic fertilizer, animal feed, bricks, bioenergy, coal organic, and many of innovative products such as bio-char, activated carbon, polymers, furfural and etc....

Activated carbon is materials frequently used in many fields. It is a form of carbon that has been processed to make it extremely pores and thus to have a very large surface area available for adsorption. Adsorption capacity of activated carbons depends essentially on its initial structural properties, pre-preparation and preparation methods. Therefore, activated carbon is widely used in gas purification, gold purification, metal extraction, medicine, sewage treatment, air filters in gas masks and filter masks, along with water and wastewater treatment also as catalyst support and many other applications.

Activated carbon is almost non-existent in Egypt. Although normally used, the activated carbon is imported from abroad (Ministry of Industry and Trade, 2016) and a few quantities that are produced locally does not exceed production laboratory, which is used in the experiments and researches.

So, the aim of the study is to performance evaluation of design activated carbon prototype productivity.

To achieve the aim of the research the following steps were followed:

1. Agricultural residues data were collected upon; the amount of agricultural residues, un-usage and carbon contents.
2. Activated carbon was produced in laboratory unit (Metallurgical Research Center) at different studied variables for each agricultural residue to determine the optimum parameters of each residual type.
3. Analyzed the solid materials were obtained from laboratory unit and quantity and quality of activated carbon were identified.
4. Designed an activated carbon prototype.
5. Performance evaluation the designed prototype at optimum recommends parameters for each agricultural residue. Then compere the obtained results from the laboratory unit
6. Applied the obtained activated carbon in drinking water treatment.

This study was carried out at the laboratory of Agricultural Engineering department, Faculty of Agriculture, Cairo University and laboratory of Agricultural Engineering Research Institute, Agricultural Research Center during 2013 to 2016; the work was divided into five main parts:

1. The first part: Agricultural residues data and the chemistry components of agricultural residues were collected. Three agricultural

residues were selected upon the highest production, un-usage and carbon content such as in field, horticultural and industries.

2. The second part: Agricultural residues were dried naturally and cut manually at 50mm length, then impregnated in H_3PO_4 about 2 h with ratio of 2 w : 1 v (raw material : H_3PO_4). Then, these were pyrolyzed in laboratory unit under nitrogen atmosphere with 100cm^3/h flow rate at variables studies of:

   a. Pyrolysis temperatures (400, 500, 600 and 700) °C.
   b. Pyrolysis time (1.0, 1.5, 2.0 and 2.5) h.
   c. Agricultural residues (corn stalks, residues of trimming peach trees residues and date kernels).

To evaluate the produced solid materials from laboratory unit, some properties of agricultural residues before and after pyrolysis were studied:

Evaluation pyrolysis process after pyrolysis

a. Yield of activated carbon.
b. Properties of pyrolized solid material as carbon concentration and ratios of carbon, nitrogen, hydrogen, ash, bulk density surface area, pore volume, SEM and moisture contents.

Properties of the solid materials after pyrolysis were evaluated and identified at the recommended optimum variables for each agricultural residue.

3. The third part: design an activated carbon prototype, constructed and evaluated where it described that simplicity operation, cheap, safe and easy to construct and clean.

The prototype was manufactured with the main components of furnace unit, nitrogen gas unit and control units besides the frame and the electrical power system. At the obtained high quality of activated carbon from the laboratory unit the recommended studied parameters used to evaluate the performance of activated carbon prototype.

4. The forth part: The obtained activated carbons quality were evaluated and compared with the quality of it obtained from the laboratory unit.

5. The fifth part: Drinking water treatment as applied test in drinking water treatment which collected from Drinking Water Company in Giza.

The results concluded that:

1. The properties of agricultural residues were presented as (carbon, nitrogen; hydrogen, ash, bulk density and moisture contents for corn stalks were 40.70, 01.59, 04.11, 00.00 % , 0.148 g.cm^{-3} and 23.3%, respectively. While for trimming peach trees residues were 43.18, 00.89, 04.40, 06.67%, 0.263g.cm^{-3} and 19.3%, respectively. Moreover, the properties of date kernels were 45.22, 01.43, 07.84, 13.75%, 0.651 g.cm^{-3} and 9.1%, respectively.

2. Evaluation of activated carbon produced by laboratory unit.

a. The highest yield of solid component obtained for corn stalks was 88.00% at furnace temperature of 500°C during pyrolysis time of 1.50 h. Furthermore, the highest yield for trimming peach trees residues recorded was 82.60% at furnace temperature of 600°C and pyrolysis time of 2.5 h. In addition date kernels had the highest yield of 91.90% at furnace temperature of 400°C and pyrolysis time of 1.50 h.

b. The highest carbon concentration was 1.31mg.l^{-1} at furnace temperature of 400ºC during 1 h pyrolysis time for corn stalks. Though it was recorded for trimming peach trees residues 3.69mg.g^{-1}at furnace temperature of 700ºC during pyrolysis time of 2 h and 5.062mg.g^{-1} at furnace temperature of 400ºC during pyrolysis time of 2h for date kernels. This test is indicator to the quantity of activated carbon in each test. Thus selected the highest carbon concentration for best the activated carbon obtained.

c. Some properties of activated carbon such as carbon, nitrogen, hydrogen, ash ratios, bulk density, surface area, pore volume and moisture contents for corn stalks were 12.94, 0.89, 3.08, 3%, 0.6g.cm^{-3}, 29.73m^{2}.g^{-1}, 7.95 × 10^{-4}cm^{3}.g^{-1} and 9%, respectively. Furthermore, for trimming peach trees residues were 64.6, 0.05, 1.02, 10%, 0.7g.cm^{-3}, 113.88 m^{2}.g^{-1}, 5.33 × 10^{-3}cm^{3}.g^{-1} and 6%, respectively at the previous properties. While, for date kernels were 56.4, 2.625, 2.48, 26%, 1.3 g.cm^{-3}, 95.57 m^{2}.g^{-1}, 4.59 × 10^{-3} cm^{3}.g^{-1} and 2%, respectively at the above properties.

In addition to, SEM for each produced activated carbon was recorded as uniformity pores and multiple sizes average from 12.17, 9.017 and 10.27µm for corn stalks, trimming peach trees residues and date kernels, respectively. It was indicated the surface area increased in trimming peach tress than date kernel and corn stalks,

3. Evaluation of activated carbon prototype:

a. The produced of activated carbon properties showed yield, N, C, H, ash, surface area and pore volume were recorded 79.63%, 1.22%, 10.54%, 4.28 %, 2.67 %, 28.56$m^2.g^{-1}$ and 5.23 x $10^{-4}cm^3.g^{-1}$, respectively for corn stalks. However, it were 73.33%, 0.0%, 76.8%, 0.87%, 8.89%, 142.39$m^2.g^{-1}$ and 6.62 x$10^{-3}cm^3.g^{-1}$ respectively for trimming peach trees. Furthermore, it recorded 89.76 %, 1.52, 61.3, 1.05 and 27.56 %, 123.65$m^2.g^{-1}$ and 5.75 x$10^{-3}cm^3.g^{-1}$, respectively for date kernels. In addition to SEM for each type activated carbon was recorded as uniformity pores and multiple sizes ranging from 0.0, 4.308- 46.819 and 4.219 - 16.648µm for corn stalks, trimming peach trees residues and date kernels, respectively. It was indicated the surface area increased in trimming peach tress than date kernel and corn stalks.

b. Performance of activated carbon prototype: The average production of activated carbon from activated carbon prototype were 0.282, 1.130 and 3.166$kg.h^{-1}$ for corn stalks, trimming peach trees residues and date kernels activated carbon, respectively. However, the cost of activated carbon from designed unit were about 201.18, 50.20 and 17.92$LE.kg^{-1}$ for corn stalks, trimming peach trees residues and date kernels activated carbon, respectively. Also, the net profits were

-86.16, 15.62 and 259.86LE.h^{-1}, respectively for the previous agricultural residues.

4. Quality of activated carbon produced from designed unit compered to quality of activated carbon produced from laboratory. The results showed that the properties of activated carbon in carbon percentage and surface area and pore volume increased when using designed unit for produce activated carbon from trimming peach trees residues and date kernels, but they were imperceptibly decreased when using designed unit for produce activated carbon from corn stalks. So, activated carbon produced from designed unit had a high quality.

5. Drinking water treatment as applied test in drinking water treatment which collected from Drinking Water Company in Giza and the results were recorded:

a. Purification time increased with decreased the highest of activated carbon, The highest purification time were 25.27, 15.45 and 8.18min and the lowest purification time were 3.56, 1.15 and 2.25min recorded at used corn stalks trimming peach trees residues and date kernels, respectively.

b. The characteristics of the treated water, the lowest total dissolved solids (TDS) was recorded 3.55, 4.20 and 05.00ppm when using corn stalks, trimming peach trees residues and date kernels activated carbon at 1.0 cm high of activated carbon. Furthermore, color, taste and odor was tested and recorded it was acceptable for all type of activated carbon used.

From the above results it can concluded can that:

1. Activated carbon production from using activated carbon prototype had the same quality or better than activated carbon production from using laboratory unit, so can be used activated carbon prototype to produce activated carbon.
2. It can use the activated carbon prototype at furnace temperature of 400, 700 and 400ºC and pyrolysis time of 1.0, 2.0 and 1.0 hour for corn stalks, trimming peach trees residues and dates kernels, respectively to produce about 0.282, 1.130 and $3.166kg.h^{-1}$; surface area of $28.56m^2.g^{-1}$, $142.39m^2.g^{-1}$ and $123.65m^2.g^{-1}$ and pore volume of $5.23 \times 10^{-4}cm^3.g^{-1}$, $6.62 \times 10^{-3}cm^3.g^{-1}$ and $5.75 \times 10^{-3}cm^3.g^{-1}$for corn stalks, trimming peach trees residues and date kernels activated carbon, respectively.
3. Pyrolyzed corn stalks not suitable at furnace temperature of 400ºC and pyrolysis time of 1.0 h. It can produce at less than 400ºC to obtained high quality of activated carbon.

Recommendation**:**

a. The produced activated carbon has a high efficiency to purification of drinking water. It can use in agricultural and industrial wastewater treatment.

b. To raise the designed prototype performance and its commercial, it can use grinding or powder raw- material and/or maximize the size of prototype.

REFERENCES

Abbaszadeh, S.; Alwi, S. R. W.; Webb, C.; Ghasemi, N. and Muhamad, I. I. (2016). Treatment of lead-contaminated water using activated carbon adsorbent from locally available papaya peel biowaste. Journal of Cleaner Production, 118: 210-222.

Abechi, S. E.; Gimba, C. E.; Uzairu, A. and Dallatu, Y. A. (2013). Preparation and characterization of activated carbon from palm kernel shell by chemical activation. Research Journal of Chemical Sciences, 3 (7): 54-61.

Acikyildiz, M.; Gurses, A. and Karaca, S. (2014). Preparation and characterization of activated carbon from plant wastes with chemical activation. Microporous and Mesoporous Materials, 198: 45-49.

Ahmadroup, A. and Do, D. D. (1997). The preparation of activated carbon from Macadamia nutshell by chemical activation. Carbon, 35 (1): 723-732. [C.f. Tsai, W. T.; Chang, C. Y.; Wang, S. Y.; Chang, C. F.; Chien, S. F. and Sun, H. F. (2001). Cleaner production of carbon adsorbents by utilizing agricultural waste corn cob. Resour. Conserv. Recy., 32: 43-53].

Ahmedna, M.; Marshall, W. E. and Rao, R. M. (2000). Production of granular activated carbons from select agricultural byproducts and evaluation of their physical, chemical and dsorption properties. Bioresource Technol., 71: 113-23.

Ahmedna, M.; Marshall, W. E.; Husseiny, A. A.; Rao, R. M. and Goktepe, I. (2004). The use of nutshell carbons in drinking water filters for removal of trace metals. Water Res., 38: 1062-1068.

Aidan, G. (2012). Agricultural wastes and activated carbon from them for furfural removal from water solutions. Life Science Journal, 9 (3): 2501- 2505.

Alhamed, Y. A. (2002). Preparation and characterization of activated carbon from dates stones, The 6th Saudi Engineering Conference, King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia. Proceedings, Volume 2, Chemical engineering: 441-450.

Alhamed, Y. A. (2006). Activated carbon from dates' stone by $ZnCl_2$ activation. JKAU: Eng. Sci., 17 (2): 75 -100.

Al-Lagtah, N. M. A; Al-Muhtaseb, A. H.; Ahmad, M. N. M. and Salameh, Y. (2016). Chemical and physical characteristics of optimal synthesised activated carbons from grass-derived sulfonated lignin versus commercial activated carbons. Microporous and Mesoporous Materials, 225: 504-514.

Al-Qodah, Z. and Shawabkah, R. (2009). Production and characterization of granular activated carbon from activated sludge. Brazilian Journal of Chemical Engineering, 26 (1): 127-136.

Amaya, A.; Tancredi; N.; Sardella, F.; Aguilar, E.; Deiana, C. and Silva, H. (2005). Use of grape stalk to obtain activated carbon. 2nd Mercosur Congress on Chemical Engineering. 4th Mercosur Congress on Process Systems Engineering.

ASAE Yearbook Standard (1983). Agricultural engineers year-book. ASAE. St. Joseph, MI, USA.

Aygun, A.; Yenisoy, S. and Duman, I. (2003). Production of granular activated carbon from fruit stones and nutshells and evaluation of their physical, chemical and adsorption properties. Microporous and Mesoporous Materials, 66 (1): 89 -95.

Bacaoui, A; Yaacoubi, A.; Dahbi, A.; Bennouna, C.; Phan, T. L. R. and Maldonado, H. F. J. (2001). Optimization of conditions for the preparations of activated carbons from olive-waste cakes. Carbon, 39: 425-32.

Baseri, J. R.; Palanisamy, P. N. and Sivakumar, P. (2012). Preparation and characterization of activated carbon from Thevetia peruviana for the removal of dyes from textile waste water. Advances in Applied Science Research, 3 (1): 377-383.

Bayindir, R. (2007). Design and construction of an electrical furnace to fire ceramic products Faculty of technical education. Journal of Scientific and Industrial Research, 77: 135-140.

Becnaddi, H.; Gras, D. l. E.; Rouzaud, J. N. and Begun, F. (1998). Influence of the atmosphere in the chemical activation of wood by phosphoric acid. Carbon, 36 (3): 306-309.

Bostancioglu, M. and Oruç, S. (2012). Preparation and characterization of activated carbons from furfural production wastes. Journal of Civil Engineering and Urbanism, 2 (1): 01-05.

Bouchelta, C.; Medjram, M. S.; Bertrand, O. and Bellat, J. (2008). Preparation and characterization of activated carbon from date stones by physical activation with steam. J. Anal. Appl. Pyrolysis, 82: 70-77.

Bousher, A.; Shen, X. and Edyvean, R. G. J. (1997). Removal of colored organic matter by adsorption on to low cost waste materials. Water Res., 31: 2084-2092**.**

Brito, M. J. P. ; Veloso, C. M.; Bonomo, R. C. F.; Fontan, R. d. C. I.; Santos, L. S. and Monteiro, K. A. (2017). Activated carbons preparation from yellow mombin fruit stones for lipase immobilization. Fuel Processing Technology, 156: 421- 428.

Buah, W. K. and Kuma, J. S. Y. (2016). Design of a novel gas fired static bed pyrolysis-gasification reactor for the production of activated carbons. Process Safety and Environmental Protection, 102: 353-360.

Cao, Y.; Wang, K.; Wang, X.; Gu, Z.; Fan, Q.; Gibbons, W.; Hoefelmeyerd, J. D.; Kharel, P. R. and Shrestha, M. (2016). Hierarchical porous activated carbon for supercapacitor derived from corn stalk core by potassium hydroxide activation. Electrochimica Acta, 212: 839-847.

Chang, C. F.; Chang, C. Y.; Lee, S. L.; Wang, S. Y.; Chiang, P. C.; Tseng, S. K. and Tsai, W. T. (1998). Effect of physical carbonization and activation methods on the preparation of activated carbon from corn cob. J. Chin Inst. Environ Eng., 8: 227-232. [C.f. Tsai, W. T.; Chang, C. Y.; Wang, S. Y.; Chang, C. F.; Chien, S. F. and Sun, H. F. (2001). Cleaner production of carbon adsorbents by utilizing agricultural waste corn cob. Resour. Conserv. Recy., 32: 43-53].

Chang, C. F.; Chang, C. Y. and Tsaiy, W. T. (2000). Effects of burn-off and activation temperature on preparation of activated carbon from corn cob agro-waste by co_2 and steam. Journal of Colloid and Interface Science, 232: 45-49.

Cobb, A.; Warms, M.; Maurer, E. P. and Chiesa, S. (2012). Low-tech coconut shell activated charcoal production. International Journal for Service Learning in Engineering, 7 (1): 93-104.

Cuhadaroglu, D. and Uygun, O. A. (2008). Production and characterization of activated carbon from a bituminous coal by chemical activation. African Journal of Biotechnology, 7 (20): 3703-3710.

Diao, Y.; Walawender, W. P. and Fan L. T. (2001). Activated carbons prepared from phosphoric acid activation of grain sorghum. Bioresource Technology, 81: 45-52.

Demiral, H.; Demiral, I.; Tumsek, F. and Karabacakoglu, B. (2007). Pore structure of activated carbon prepared from hazelnut bagasse by chemical activation. Surface and Interface Analysis, 40: 616-619.

Demiral, H. and Güngor, C. (2016). Adsorption of copper (II) from aqueous solutions on activated carbon prepared from grape bagasse. Journal of Cleaner Production, 124: 103-113.

Dolas, H.; Sahin, O.; Saka, C. and Demir, H. (2011). A new method on producing high surface area activated carbon: The effect of salt on the surface area and the pore size distribution of activated carbon prepared from pistachio shell. Chemical Engineering Journal, 166: 191-197.

Duran,V. C. J.; Gomez, C. M.; Pastor, V. J. and Gomez, S. V. (2005). Study of cherry stones as raw material in preparation of carbonaceous adsorbents. J. Anal. Application Pyrolysis, 73 (1): 59- 67.

Dvorak, B. I. and skipton, S. O. (2013) Drinking water treatment: Activated carbon filtration. Neb Guide. G1489.

Egyptian Organization for Standardization and Quality Control. (2005). Egyptian standards " Bottled/ packaged drinking water" E. S 1589/2005, ICS: 13.060010.

El-Hendawy, A. N. A.; Samra, S. E. and Girgis, B. S. (2001). Adsorption characteristics of activated carbons obtained from corncobs. Colloid Surface A: Physicochem Eng. Aspects, 180: 209-221.

El-Said, S. M. (2004). Revealed that the adsorptive removal of some detergents from waste water using friendly environmental materials. Ass. Univ. Bull. Environment Research, 7 (2): 137-147.

El-Sayed, G. O.; Moustafa, M. E. and Mahrous, M. F. (2011). Removal of disperse 2BLN dye from industrial water onto activated carbon prepared from sugar can stalks. International Journal of ChemTech Research, 3 (3): 1604-1611.

El-Shafey, E. I.; Syeda, N. F. A.; Al-Busafi, S. and Al-Lawati, H. A. J. (2016). Preparation and characterization of surface functionalized activated carbons from date palm leaflets and application for methylene blue removal. Journal of Environmental Chemical Engineering, 4: 2713-2724.

Esor, E. E; Babatunde, S. Y.; Felix, A. C. and Mustapha, F. O. (2015). Design and fabrication of aluminium melting furnace using locally available materials. Journal of Scientific and Engineering Research, 2 (3): 36-43.

Fan, M.; Marshall, W.; Daugaard, D. and Brown, R. C. (2004). Steam activation of chars produced from oat hulls and corn stover. Bioresource Technology, 93: 103-107.

Farah, J. Y. (2001). Technical performance evaluation of industrial adsorption columns using locally prepared activated carbon. Ph.D thesis. Faculty of Engineering, Cairo University. Giza. Egypt.

Foo, P. Y. L. and Lee, L. Y. (2010). Preparation of activated carbon from parkia speciosa pod by chemical activation. Proceedings of the World Congress on Engineering and Computer Science. Vol II.

Gamage , S. M. K. and Sathasivan, A. (2017). A review: Potential and challenges of biologically activated carbon to remove natural organic matter in drinking water purification process. Chemosphere, 167: 120-138.

GCC Standardization Organization (GSO) (2008). Boteled drinking water. GSO5/FDS/1025/2008, Final report. ICS:76.13.06.

Girgis, B. S.; Yunis, S. S. and Soliman, A. M. (2002). Characteristics of activated carbon from peanut hulls in relation to conditions of preparation. Mater. Lett., 57: 164-72.

Gonsalvesh, L.; Marinov, S. P.; Gryglewicz, G.; Carleer, R. and Yperman, J. (2016). Preparation, characterization and application of polystyrene based activated carbons for Ni (II) removal from aqueous solution. Fuel Processing Technology, 149: 75-85.

Haykiri, A. H.; Yaman, S. and Kucukbayrak, S. (2006). Gasification of biomass chars in steam-nitrogen mixture. Energy Conversion Management, 47 (7-8): 1004-1013.

Hiremath, M. N.; Shivayogimath, C. B. and Shivalingappa, S. N. (2012). Preparation and characterization of granular activated carbon from corn cob by KOH activation. Int. Journal of Research Chemical Environment, 2 (3): 84-87.

Hunt, D. (1983). Farm power and machinery management. 8th Ed. Iowa State Univ. Press, Ames, U.S.A. pp. 59-76.

Incropera, F. P. (2002). Introduction to Heat Transfer. John Wiley and Sons, Inc., ISBN: 13: 978-0471386490, pp: 912.

Ioannidou, O. and Zabaniotou, A. (2007). Agricultural residues as precursors for activated carbon production- A review. Renewable and Sustainable Energy Reviews, 11: 1966-2005.

Jalil, (2012). Surface area determination of activated carbons produced from waste tires using adsorption from solution. Tikrit Journal of Pure Science, 17 (2): 1813-1662.

Jambulingam, M.; karthikeyan, S.; Sivakumar, P.; Kiruthika, J. and Maiyalagan, T. (2007). Characteristic studies of some activated carbons from agricultural wastes. Journal of Scientific and Industrial Research, 66: 495-500.

Jawad, S. K. (2010). Investigation of the dimensions design components for the rectangular indirect resistance electrical furnaces. American Journal of Engineering and Applied Sciences, 3 (2): 350-354.

Jun, T. Y.; Arumugam, S. D.; Latip, N. H. A.; Abdullah, A. M. and Latif, P. A. (2010). Effect of activation temperature and heating duration on physical characteristics of activated carbon prepared from agriculture waste. Environment Asia, 3 (special issue): 143-148.

Kingsley, U. O.; Silas, A. U.; Samson, I. A.; Oluwafemi, O. A.; Adgidzi, D.; Raymond, R. and Olunsule, S. O. O. (2012). Development of low heat treatment furnace. International Journal of Applied Science and Technology, Vol. 2 (7):188-194.

Kadirvelu, K.; Palanivel, M.; Kalpana, R. and Rajeshwari, S. (2000). Activated carbon from an agricultural by-product, for the treatment of dyeing industry wastewater. Bioresource Technology, 74: 263-265.

Kamoun, A.; Jelidi, A. and Chaabouni, M. (2003). Evaluation of the performance of sulfonated esparto grass lignin as a plasticizer-water reducer for cement .Cem. Concr. Research, 33 (7): 995-1003.

Ketcha, J. M.; Dina1, D. J. D.; Ngomo, H. M. and Ndi1, N. J. (2012). Preparation and characterization of activated carbons obtained from maize cobs by zinc chloride activation. American Chemical Science Journal, 2 (4): 136-160.

Kwaghger, A. and Adejoh, E. (2012). Optimization of conditions for the preparation of activated carbon from mango nuts using $ZnCl_2$. International Journal of Engineering Research and Development, 1 (8): 01-07.

Kwaghger, A. and Ibrahim, J. S. (2013). Optimization of conditions for the preparation of activated carbon from mango nuts using HCl. American Journal of Engineering Research (AJER), 2 (7): 74-85.

Laginhas, C.; Nabais, J. M. V. and Titirici, M. M. (2016). Activated carbons with high nitrogen content by a combination of hydrothermal carbonization with activation. Microporous and Mesoporous Materials, 226: 125-132.

Lua, A. C.; Yang, T. and Guo, J. (2004). Effects of pyrolysis conditions on the properties of activated carbons prepared from pistachio-nut shells. J. Anal. Application Pyrolysis, 72: 279-87.

Malik, P. K. (2003). Use of activated carbons prepared from sawdust and rice-husk for adsorption of acid dyes: a case study of acid yellow 36. Dyes Pigments, 56: 239-249.

Marcilla, A.; Garcıa, G. S.; Asensio, M. and Conesa, J. A. (2000). Influence of thermal treatment regime on the density and reactivity of activated carbons from almond shells. Carbon, 38:429-40.

Marouli, A. Z. and Maroulis, Z. B. (2005). Cost data analysis for the food industry. Journal of Food Engineering, 67: 289-299.

Menéndez, D. J. A. and Martín, G. I. (2006). Types of carbon adsorbents and their production. Activated carbon surfaces in environmental remediation, (ISBN: 0-12-370536-3) 1-48.

Ministry of Agricultural and Land Reclamation Affalrs Sectors (EAS). (2013-2014). Study of the indicators agricultural Statistics.

Ministry of Health and Population. (2007). Resolution of Ministry of Health and Population No. (458) for the availability of drinking water.

Ministry of Industry and Trade. (2015-2016). Exports and imports data**.**

Minkova, V.; Marinov, S. P.; Zanzi, R.; Bjornbom, E.; Budinova, T. and Stefanova, M. (2000). Thermochemical treatment of biomass in a flow of steam or in a mixture of steam and carbon dioxide. Fuel Process Technology, 62: 45-52.

Minkova, V.; Razvigorova, M.; Bjornbom, E.; Zanzi, R.; Budinova, T. and Petrov, N. (2001). Effect of water vapour and biomass nature on the yield and quality of the pyrolysis products from biomass. Fuel Production Technology, 70:53-61.

Mohamed, A. G.; El Safty, A. M. and Siha, M. S. (2013). Current situation of water pollution and its effect on aquatic life in Egypt. Egyptian Journal of Occupational Medicine, 37 (1): 95-119.

Mohammad, K. A. and Ansari, R. (2009). Activated charcoal: preparation, characterization and applications: A review article. International Journal of ChemTech Research, 1 (4): 859-864.

Munir, T.; Hussain, M. and Naseem, S. (2016). Water pollution-A menace of freshwater biodiversity: A Review. Journal of Entomology and Zoology Studies, 4 (4): 578-580.

Mussatto, S. I.; Teixeira, J. A. (2010). Lignocellulose as raw material in fermentation processes. IBB- Institute for Biotechnology and Bioengineering, Centre of Biological Engineering, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.

Mussatto, S. I.; Fernandes, M.; Rocha, G. J. M.; Qrfao, J. J. M.; Teixeira, J. A. and Roberto, I. C. (2010). Production, characterization and application of activated carbon from brewer’sspent grain lignin. Bioresource Technology, 101: 2450-2457.

Nasser, R. A.; Salem, M. Z. M.; Hiziroglu, S.; Al-Mefarrej, H. A.; Mohareb, A. S.; Alam, M. and Aref, I. M. (2016). Chemical analysis of different parts of date palm (phoenix dactylifera l.) Using ultimate, proximate and thermo-gravimetric techniques for energy production. Energies, 9 (374): 1-14.

Oh, G. H. and Park, C. R. (2002). Preparation and characteristics of rice-sraw-based pores carbons with high adsorption capacity. Fuel, 81: 327-336.

Okibe, F. G.; Gimba, C. E.; Ajibola, V. O. and Ndukwe, I. G. (2013). Preparation and surface characteristics of activated carbon from brachystegia eurycoma and prosopis africana seed hulls. International Journal of ChemTech Research, 5 (4): 1991-2002.

Olafadehan, O. A.; Jinadu, O. W.; Salami, L. and Popoola, O. T. (2012). Treatment of brewery wastewater effluent using activated carbon prepared from coconut shell. International Journal of Applied Science and Technology, 2 (1): 165-178.

Olivares, M. M.; Fernandez, G. C.; Macıas, G. A. and Gomez, S. V. (2006). Preparation of activated carbon from cherry stones by chemical activation with $ZnCl_2$. Applied Surface Science, 252: 5967-5971.

Patil, B. S. and Kulkarni, K. S. (2012). Development of high surface area activated carbon from waste material. International Journal of Advanced Engineering Research and Studies, I (ii): 109-113.

Pérez, J. T.; Gérente, C. and Andrès, Y. (2012). Sustainable activated carbons from agricultural residues dedicated to antibiotic removal by adsorption. Chinese Journal of Chemical Engineering, 20 (3): 524-529.

Prahas, D.; Kartika, Y.; Indraswati, N. and Ismadji, S. (2008). Activated carbon from jack fruit peel waste by H_3PO_4 chemical activation: Pore structure and surface chemistry characterization. Chemical Engineering Journal, 140: 32-42.

Putun, A. E.; Ozbay, N.; Onal, E. P. and Putun, E. (2005). Fixed-bed pyrolysis of cotton stalk for liquid and solid products. Fuel Process Technol., 86: 1207-1219.

Rahman, M. A.; Ruhul, S. M. A. and Shafiqul, A. M. A. (2012). Removal of methylene blue from waste water using activated carbon prepared from rice husk. Dhaka Univ. J. Sci., 60 (2): 185-189.

Rengaraj, S.; Banumathi, A. and Murugesan, B. (1999). Preparation and characterization of activated carbon from agricultural wastes. Indian J. Chem. Technol., 6: 1-4.

Savova, D.; Apak, E.; Ekinci, E.; Yardim, F.; Petrova, N. and Budinova, T. (2001). Biomass conversion to carbon adsorbents and gas. Biomass Bioenergy, 21: 133-42.

Shalna, T. and Yogamoorthi, A. (2015). Preparation and characterization of activated carbon from used Tea dust in comparison with commercial activated carbon. International Journal of Recent Scientific Research, 6 (2): 2750-2755.

Skoulou, V. and Zabaniotou, A. (2005). Investigation of agricultural and animal wastes in Greece and their allocation to potential application for energy production. Renew Sustain Energy Rev., 11: 1010-1016.

Stavropoulos, G. G. and Zabaniotou, A. A. (2005). Production and characterization of activated carbons from olive-seed waste residue. Microporous and Mesoporous Materials, 82-85.

Sudaryanto, Y.; Hartono, S. B.; Irawaty, W.; Hindarso, H. and Ismadji, S. (2006). High surface area activated carbon prepared from cassava peel by chemical activation. Bioresource Technology, 97: 734-739.

Sugumaran, P.; Susan, V. P.; Ravichandran, P. and Seshadri, S. (2012). Production and characterization of activated carbon from banana empty fruit bunch and delonix regia fruit pod. Journal of Sustainable Energy and Environment, 3: 125-132.

Tani, K.; Mukai, M. and Takijima, Y. (1983). Farm mechanization in Japan. Text Book, Rice production mechanization course. Agricultural Training Center, Tsukuba, Japan.

Tsai, W. T.; Chang, C. Y. and Lee, S. L. (1997). Preparation and characterization of activated carbons from corn cob. Carbon, 35 (1): 198-200. [C.f. Tsai, W. T.; Chang, C. Y.; Wang, S. Y.; Chang, C. F.; Chien, S. F. and Sun, H. F. (2001). Cleaner production of carbon adsorbents by utilizing agricultural waste corn cob. Resour. Conserv. Recy., 32: 43-53].

____________________________________, (1998). A low cost adsorbent from agricultural waste corn cob by zinc chloride activation. Bioresource Technol., 64 (2): 11-7. [C.f. Tsai, W. T.; Chang, C. Y.; Wang, S. Y.; Chang, C. F.; Chien, S. F. and Sun, H. F. (2001). Cleaner production of carbon adsorbents by utilizing agricultural waste corn cob. Resource Conserv. Recycle, 32: 43-53].

Tsai, W. T.; Chang, C. Y.; Wang, S. Y.; Chang, C. F.; Chien, S. F. and Sun, H. F. (2001). Cleaner production of carbon adsorbents by utilizing agricultural waste corn cob. Resource Conserv. Recycle, 32: 43-53.

Wang, J.; Wu1, F. A.; Wang, M.; Qiu, N.; Liang, Y.; Fang, S. Q. and Jian, X. (2010). Preparation of activated carbon from a renewable agricultural residue of pruning mulberry shoot. African Journal of Biotechnology, 9 (19): 2762-2767.

World Health Organization (WHO). (2011). World Health Statistics.

Yalcm, N. and Sevinc, V. (2000). Utilization of bauxite waste in ceramic glazes. Ceramics International, 26: 485-493.

Yang, T. and Lua, A.C. (2003). Characteristics of activated carbons prepared from pistachio-nut shells by physical activation. Journal Colloid. Interf. Science, 267: 408-417.

Yu, J.; Yang, F. C.; Hung, W. N.; Liu, C. L.; Yang, M. and Lin, T. F. (2016). Prediction of powdered activated carbon doses for 2-MIB removal in drinking water treatment using a simplified HSDM approach. Chemosphere, 156: 374-382.

Yusufu, M. I.; Ariahu, C. C. and Igbabul, B. D. (2012). Production and characterization of activated carbon from selected local raw materials. African Journal of Pure and Applied Chemistry, 6 (9): 123-131.

Zhang, T.; Walawender, W. P.; Fan, L. T.; Fan, M.; Daugaard, D. and Brown, R. C. (2004). Preparation of activated carbon from forest and agricultural residues through CO_2 activation. Chemical Engineering Journal, 105: 53-59.

بحوث مستخرجة من الرسالة

El-Raie, A. E. S.; Abdelbary, K. M.; Ismail, N. K. and Amer, M. A. (2016). Production of activated carbon from agricultural residues. Journal of ChemTech Research 9 (8): 62 – 69.

Appendix 1

Calculation of heating energy

- Select the voltage (V) is to be the nominal rate of 220 V, single phase, for the ease using at any laboratories and fields.

- Select the working volume of 15 × 20 × 15 cm equals to 4500 cm^3

- From Fig. (24), the furnace power (P) will be 2.5 kW

  - The unit wire surface power of an ideal heater can be calculated by the equation, Bayindir (2007):

$$q_{id} = {[\sigma_o(T_h^4 - T_o^4)]}\Big/{[(1/\varepsilon_h) + (1/\varepsilon_o) - 1]} = (KW/m^2)$$

Then the ideal unit power is:

$$q_{id=123.5\ kW/m^2}$$

  - For wire spiral, heat transfer coefficient = 0.3.

Then the actual power is:

$q = 123.5X0.3 = 37\ kW/m^2$

  - If the diameter of the wire can be given by the equation:

$D = 7400[\rho(P/V)^2X(1/q)]^{1/3}\ (mm)$

Then the wire diameter is:

$$D \approx 1.5mm$$

- Cross section area of the heater:

$s = \pi/4\, X D^2 \ (mm^2)$

Then the wire cross section is:

$$s = 1.77\ X10^{-6}\ m^2$$

- Resistance of the heater is given by the equation:

$r = V^2/P\, X10^3 (ohm)$

Then the resistance of the wire is:

$r = 19.36\ \Omega$

- Length required of the wire is calculated as:

$l = (1/\rho) X\ r\ Xs\ (m)$

Then the wire length needed is:

$$l = 26\ m$$

Appendix 2

The specifications of the spectrophotometer.

Model	**6300**
Wavelength	
Range	320 to 1000nm
Resolution	1nm
Accuracy	± 2nm
Spectral bandwidth	8nm
Photometrics	
Transmittance	0 to 199.9%
Absorbance	-0.300 to 1.999A
Accuracy	±1%T, ±0.01Abs at 1.000 Absorbance
Resolution	0.1%T, 0.001A
Stability	1%/hr after 15 minute warm up
Concentration	
Range	-300 to 1999
Resolution	
Other	
Power	<50W

The specifications of pH meter.

Model	**pH100**
Temperature	
Range	-10 to +120°C
Resolution	0.1°C
Accuracy	±0.3°C ±2 digit
pH	
Range	-2 to 16 units
Resolution	0.01 unit
Accuracy	±0.1% ±2 digit

Appendix 3

Specification of turibidmeter.

Model	**2100N**
Country of Origin	U.S.A
Brand	Hach
Accuracy	± 2 % of reading plus 0.01 FNU/NTU
Display type:	8-digit LED display
Measuring mode:	FNU, NTU
Operating temperature range:	0 - 40 °C
Response time:	6.8 s with signal averaging off; 14 s with signal averaging on
Sample volume:	20 mL with 25mm sample cell

Specification conductivity meters.

Model	**4520**
Country of Origin	Germany
Brand	Genway
Conductivity	
Ranges	0 to 19.99µS / 0 to 199.9µS / 0 to 1999µS / 0 to 19.99mS / 0 to 199.9mS / 0 to 1999mS / 0 to 19.99S
Resolution	0.01µS / 0.1µS / 1µS / 0.01mS / 0.1mS / 1mS / 0.01S* *only with cell constant >5
Accuracy	±0.5%±2 digits
TDS	
Ranges	0 to 19.99mg/l / 0 to 199.9mg/l / 0 to 1999mg/l / 0 to 19.99g/l / 0 to 199.9g/l / 0 to 1999g/l
Resolution	0.01mg/l / 0.1mg/l / 1mg/l / 0.01g/l / 0.1g/l / 1g/l* *only with cell constant >5
Accuracy	±0.5%±2 digits

Appendix 4

Specifications of fresh water.

The statement	**The statement of standards and specifications (mg / L unless otherwise stated) except pH**
Color	does not exceed 100 degrees
Total solids	500
Temperature	5 degrees above normal
Dissolved oxygen	for at least 5
PH	of at least 7 and not more than 8.5
BOD	for no longer than 6
Chemical oxygen consumer	no more than 10
Organic nitrogen	is not more than 1
Ammonia	is not more than 0.5
Greases and oils	is not more than 0.1
Total alkalinity	of not more than 150 and not less than 20
Sulphate	of not more than 200
Mercury compounds	does not exceed 0.001
Iron	is not more than 1
Manganese	is not more than 0.5
Copper	is not more than 1
Zinc	no more than 1
Detergents	no more than 0.5
Nitrate	is not more than 45
Florides	no more than 0.5
Phenol	is not more than 0.02
Arsenic	is not more than 0.05
Cadmium	is not more than 0.01
Chrome	does not exceed 0.05
Cyanide	is not more than 0.1
Lead	is not more than 0.005
Silinium	no more than 0.01

الملخص العربى

تصميم وتصنيع وحدة صغيرة لإنتاج الكربون المنشط من بعض المخلفات الزراعية

تعتبر المخلفات الزراعية ثروة قومية غير مستغلة وتعد عبء لتسببها فى تلوث العناصر البيئية المختلفة, حيث يتم حرقها أوالتخلص منها بطرق غير مفيدة. فى حين أن هذه المخلفات يمكن استخدامها فى العديد من المنتجات المفيدة والحيوية وأهمها تصنيع السماد العضوى, وإنتاج الأعلاف الحيوانية، الطوب، فضلا عن استخدامها فى إنتاج الطاقة الحيوية والفحم العضوى, والعديد من المنتجات المستحدثة مثل إنتاج الكربون الحيوى والمنشط، البلمرات و الفروفورال وغيرها....

يعد الكربون المنشط من المواد التى تستخدم بكثرة فى العديد من المجالات نظراً لطبيعته حيث يمتاز بإحتواء حبيباته على مساحة سطحية كبيرة تتيح له قدرة إمتصاص عالية وتعتمد هذه القدرة على الخصائص الأولية للمواد المنتج منها والمعاملات الأولية وطرق الإنتاج. ويستخدم الكربون المنشط على نطاق واسع في جميع أنحاء العالم فى مجالات تنقية الغاز، وتنقية الذهب، واستخراج المعادن، والطب، مرشحات الهواء في الأقنعة الواقية من الغازات وأقنعة التصفية جنبا إلى جنب مع معالجة مياه الشرب ومياه الصرف الصحي والزراعي، الى جانب العديد من التطبيقات الأخرى.

إلا أن إنتاج الكربون المنشط محلياً يكاد ينعدم وبالرغم من إستخدامه بكثرة فى مصر فغالبا ما يتم إستيراده من الخارج (وزارة الصناعة والتجارة، ٢٠١٦) والكميات القليلة التى يتم إنتاجها محلياً لا تتعدى الإنتاج المعملى الذى يستخدم فى التجارب والأبحاث او من بعض المصانع الكبيرة محدودة العدد والإنتاج. كما لوحظ ان معظم الأبحاث تدرس النظم الكيميائية للإنتاج وليس المعدات المنتجة . لذا كان من الأهمية تسليط الضوء على مواصفات وشكل وحدات الإنتاج للكربون المنشط وطرق إنتاجه وكذلك إقتصاديات إنتاجه حيث تعد المعرفه أول الطريق للوصول إلى سبل الإنتاج.

وعليه فإن الهدف من الدراسة تصميم وتقييم أداء وجودة المنتج لنموذج أولى لإنتاج الكربون المنشط.

ولتحقيق الهدف من الدراسة تم إجراء الخطوات الآتية:

١. تجميع بيانات تشتمل على كميات بعض المخلفات الزراعية والتركيب الكيميائى خاصة نسبة الكربون ومدى الإستفادة منها وذلك للتمكن من تحديد المخلفات التى يمكن إستخدامها فى إنتاج الكربون المنشط.

٢. إنتاج الكربون المنشط فى وحدة معملية قياسية (بمركز بحوث الفلزات- أكاديمية البحث العلمى والتكنولوجيا) تحت متغيرات دراسية مختلفة لكل أنواع المخلفات التى تم إختيارها بهدف تحديد أفضل مستويات عوامل الدراسة لكل نوع من أنواع المخلفات تحت الدراسة وخصائص الكربون المنشط الناتج.

٣. تحليل المنتج الصلب الناتج من الإنحلال الحرارى للمخلفات معملياً وتحديد كمية وجودة الكربون المنشط الناتج.

٤. تصميم نموذج أولى لإنتاج الكربون المنشط تناسب الإنتاج التجاري.

٥. إختبار الوحدة المصممة عند أفضل عوامل دراسة معملية لكل نوع من أنواع المخلفات المحددة وتقييم الكربون المنشط الناتج زمقارنة خواصه بالمنتج معمليا وكذلك تقييم أداء الوحدة المصممة.

وقد تم إجراء التجارب بمعمل قسم الهندسة الزراعية - كلية الزراعة - جامعة القاهرة ومعمل معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية في الفترة من ٢٠١٣-٢٠١٦. حيث تم تقسيم العمل إلى ثلاث مراحل أساسية وهى:

١. تم تجميع بيانات المخلفات الزراعية والتركيب الكيميائى لها ومدى الإستفادة منها ومنه تم تحديد ثلاث أنواع مختلفة المصدر من المخلفات الزراعية النباتية ذات محتوى مرتفع من الكربون وذات إنتاج سنوى مرتفع وتم إختيارها لتمثل نماذج لمخلف حقلي (عيدان الذرة)، مخلف بستانى (مخلفات تقليم أشجار الخوخ)، مخلف تصنيع (نوى البلح).

٢. تم إجراء الإنحلال الحرارى لهذه المخلفات بمعزل عن الهواء فى وحدة إنحلال حرارى معملية قياسية (بمركز بحوث الفلزات- أكاديمية البحث العلمى والتكنولوجيا) بعد تجفيفها بالشمس (طبيعياً) وتقطيع عيدان الذرة تقليم أشجار الخوخ لأطوال ٥٠ مم ثم غمر العينات لمدة ساعتين فى حمض فوسفوريك "H_3PO_4" والذى أضيف بنسبة حجمية تعادل نصف وزن عينة المخلفات (١ لتر: ٢ كجم) وتم الإنحلال الحرارى فى وجود غاز النيتروجين. وكانت متغيرات الدراسة:

أ. أربع درجات حرارة للفرن (٤٠٠، ٥٠٠، ٦٠٠، ٧٠٠ °م).

ب. أربع أزمنة إنحلال حرارى (١,٠، ١,٥، ٢,٠، ٢,٥ ساعة).

ج. ثلاث مخلفات زراعية (عيدان الذرة، نواتج تقليم أشجار الخوخ، نوى البلح).

ولتقييم ناتج عملية الإنحلال الحرارى تم دراسة بعض خواص المخلفات قبل وبعد الإنحلال الحرارى ومنها:

١- قياسات قبل الإنحلال الحرارى وتشمل خواص المخلفات تحت الدراسة وهى:

- نسب النيتروجين، الكربون، الهيدرجين، الرماد، الكثافة الطبيعية والمحتوى الرطوبى.

٢- قياسات المواد الصلبة الناتجة بعد الإنحلال الحرارى، وتشمل:

- كمية المواد الصلبة الناتجة.
- خواص المواد الصلبة مثل السابقة بالإضافة الى:

١- مساحة السطح، حجم المسام، المسح الميكروسكوبى.

ومن خلال تحديد كمية المواد الصلبة الناتجة ونسبة الكربون المنشط فى كل العينات تحت الدراسة أمكن تحديد مستويات عوامل الدراسة المثلى لكل مخلف، عندها تمت باقى قياسات الجودة على العينات.

٣. تصميم وتنفيد وإختبار نموذج الإنحلال الحرارى (Activated carbon prototype) حيث روعى أن يكون التصميم بسيط سهل التركيب والتشغيل والتنظيف ومحكم الغلق ورخيص وآمن ويتكون من:

- وحدة الإنحلال الحرارى عبارة عن فرن إنحلال حرارى مصنوع من الطوب الحرارى المبطن من الخارج بالسيراميك والحديد ومزود بباب محكم الغلق مصنع بنفس مواصفات الفرن ويوجد فى الباب فتحة لدخول الغاز الخامل وتوجد فتحة فى الجدار العلوى للفرن لخروج غازات العادم.

- وحدة إضافة الغاز الخامل.

- وحدات التحكم فى ضبط ضغط ومعدل سريان غاز النيتروجين (الغاز الخامل)، التحكم فى دخول وخروج الغاز لوحدة الإنحلال الحرارى، التحكم فى درجة الحرارة، ووصل وفصل التيار الكهربى.

- إطار لحمل أجزاء نموذج تصنيع الكربون المنشط مزود بعجل لسهولة الحركة والتنقل.

- وقد تم إختبار النموذج المصمم عند أفضل عوامل دراسة موصى بها خلال التجارب المعملية لكل نوع من المخلفات الزراعية ثم تم إختبار جودة الكربون المنشط الناتج بنفس القياسات السابقة بالإضافة إلى إختبار تطبيقى لمعالجة مياه الشرب المأخوذة من محطة مياه الشرب بالجيزة عند إرتفاعات مختلفة للكربون المنشط (١,٠، ١,٥، ٢,٠، ٢,٥سم).

- تم مقارنة جودة الكربون المنشط المنتج من النموذج الأولى بالمنتج من الوحدة المعملية من حيث الكمية والخواص الكيميائية، الطبيعية.

- تم تقييم النموذج كوحدة إنتاجية صغيرة من حيث:

1. الإنتاجية.
2. حساب تكاليف الإنتاج.

وكانت أهم النتائج المتحصل عليها:

١. **قياسات قبل عملية الإنحلال الحرارى:**

تتمثل فى نسبة الكربون والنيتروجين والهيدروجين والرماد والكثافة الظاهرية و المحتوى الرطوبى لعيدان الذرة كالاتى ٤٠,٧٠، ١,٥٩، ٤,١١ و ٠,٠% و٠,١٤٨جرام.سم$^{-٣}$ و٢٣,٣% على التوالى. بينما لمخلفات تقليم الاشجار فكانت كالاتى ٤٣,١٨، ٠,٨٩، ٤,٤٠ و٦,٦٧%، ٠,٢٦٣ جرام.سم$^{-٣}$ و١٩,٣% على التوالى وكانت لنوى البلح ٤٥,٢٢، ١,٤٣، ٧,٨٤ و ١٣,٧٥% و ٠,٦٥١ جرام.سم$^{-٣}$ و ٩,١% على التوالى.

٢. **تقييم عملية الإنحلال الحرارى المعملية:** قياسات المواد الصلبة الناتجة بعد الإنحلال الحرارى وإشتملت على:

أ. كمية المواد الصلبة الناتجة: تم الحصول على أعلى كمية مواد صلبة بنسبة ٨٨% عند درجة حرارة للإنحلال حرارى ٥٠٠ °م خلال ١,٥ ساعة وأقل نسبة كانت ٢٨% عند درجة حرارة ٧٠٠ °م لمدة ١,٥% ساعة وذلك لعيدان الذرة. بينما نتج أن أعلى كمية للمواد الصلبة لمخلفات تقيلم اشجار الخوخ بنسبة ٨٢,٦٢% عند ٦٠٠°م لمدة ٢,٥ساعة واقل نسبة كانت ٦٥,٣٢% عند انحلال حرارى على درجات حرارة ٧٠٠ °م وزمن ٢ ساعة، فى حين ظهر أن أعلى نسبة لكمية المواد الصلبة الناتجة ٩١,٩% عند درجة حرارة ٤٠٠ °م لمدة ١,٥ ساعة واقل نسبة ٥٤,٤٤% عند درجة حرارة ٧٠٠ °م لمدة ٢,٥ ساعة عند استخدام نوي البلح.

ب. خواص المواد الصلبة

وتتمثل في حساب تركيز الكربون الموجودة فى الكربون المنشط المنتج من المخلفات المختلفة وتم الحصول على النتائج الأتية:

- أعلى تركيز للكربون ١,٣١ملجم. لتر$^{-١}$ تم الحصول عليها بإنحلال حرارى لمخلفات عيدان الذرة عند ٤٠٠° م لمدة ساعة عند كمية مواد صلبة بنسبة ٧٠%، وكان حوالى ٦٥,٣٢% و ٨٣,٧٤% عند الإنحلال الحرارى لمخلفات تقليم أشجار الخوخ و نوى البلح على التوالى. ومن هذه النتائج تم تحديد مستويات درجات الحرارة ومدة الإنحلال

حرارى المثلى لكل مخلف تحت الدراسة حيث تم عندها إختبارات الجودة الأخرى. وتشمل:

- نسب الكربون والنيتروجين والهيدروجين والرماد والكثافة الظاهرية ومساحه سطح الحبيبات وحجم المسام للكربون المنشط والمحتوى الرطوبى لعيدان الذرة كالاتى ١٢,٩٤، ٠,٨٩، ٤,٠٨ و ٣,٠% و ٠,٨ جرام.سم$^{-٣}$ و ٢٩,٧٣ م^{٢}.جرام$^{-١}$ و٧,٩٥×١٠$^{-٤}$ سم^{٣}.جرام$^{-١}$ و ٩% على التوالى. بينما لمخلفات تقليم اشجار الخوخ فكانت كالأتى ٦٤,٦، ٠,٠٥، ١,٠٢ و١٠,٠% و ٠,٧ جرام.سم$^{-٣}$ و١١٣,٨٨م^{٢}.جرام$^{-١}$ و٥,٣٣×١٠$^{-٣}$سم^{٣}.جرام$^{-١}$ و ٦% على التوالى في حين كانت القيم للكربون المنشط الناتج من نوى البلح كالاتى على التوالى ٥٦,٤، ٢,٦٢٥، ٢,٤٨ و٠,٢٦% و١,٣ جرام.سم$^{-٣}$ ٩٥,٥٧ م^{٢}.جرام$^{-١}$ و٤,٥٩×١٠$^{-٣}$ سم^{٣}.جرام$^{-١}$ و ٢%.

- وعند إجراء المسح الميكروسكوبى لعينات الكربون المنشط للمخلفات الثلاث لوحظ إنتظامية المسام وتعدد أحجامها وزيادة الحبيبات مما يشير إلى زيادة مساحة الأسطح فى صور مخلف تقليم أشجار الخوخ يليها فى الجودة مخلف نوى البح ثم مخلف عيدان.

٣. إختبار جودة الكربون المنشط الناتج من الوحدة المصممة

أ. بإستخدام الفرن المصمم تم إنتاج الكربون المشط عند مستويات عوامل الدراسة المثلى للتجارب المعملية وكانت أهم النتائج لكمية المواد الصلبة ونسب النيتروجين، الكربون، الهيدروجين، والرماد والمساحة السطحية وحجم المسام ٧٩,٦٣%، ١,٢٢%، ١٠,٥٤٪، ٤,٢٨%، ٢,٦٧٪، ٢٨,٥٦م^{٢}.جرام$^{-١}$ و٥,٢٣×١٠$^{-٤}$سم^{٣}.جرام$^{-١}$ على التوالى عند إنحلال حرارى مخلفات عيدان الذرة.

وعند الإنحلال الحرارى لمخلفات تقليم أشجار الخوخ كانت القيم ٧٣,٣٣%، ٠,٠%، ٧٦,٨٪، ٠,٨٧%، ٨,٨٩٪، ١٤٢,٣٩ م^{٢}.جرام$^{-١}$ و ٦,٦٢×١٠$^{-٣}$ سم^{٣}.جرام$^{-١}$ على التوالي. بينما كانت القيم عند الإنحلال الحرارى لنوى البلح ٨٩,٧٦%، ١,٥٢%، ٦١,٣٪، ١,٠٥%، ٢٧,٥٦٪، ١٢٣,٦٥ م^{٢}.جرام$^{-١}$ و٥,٧٥×١٠$^{-٣}$ سم^{٣}.جرام$^{-١}$ على التوالى. وعند إجراء المسح الميكروسكوبى لعينات الكربون المنشط للمخلفات الثلاث لوحظ إنتظامية المسام وتعدد

أحجامها وزيادة الحبيبات مما يشير إلى زيادة مساحة الأسطح فى صور مخلف تقليم أشجار الخوخ يليها فى الجودة مخلف نوى البح ثم مخلف عيدان الذرة.

ب.كفاءة أداء النموذج المصمم: وجد خلال الدراسة أن متوسط إنتاج النموذج المصمم فى الساعة حوالى ٠,٢٨٢، ١,١٣٠ و٣,١٦٦ كجم على التوالى لكلٍ من مخلفات عيدان الذرة، تقليم أشجار الخوخ نوى البلح، في حين تكاليف الإنتاج بالنوذج المصمم حوالى ٢٠١,١٨، ٥٠,٢٠، ١٧,٩٢ جنيه.كج$^{-١}$ على التوالى لكلٍ من مخلفات عيدان الذرة، تقليم أشجار الخوخ نوى البلح. أى أن تكلفة الساعة تبلغ حوالى ٥٦,٧٣، ٢٥,١٠ و٨,٩٦ لكلٍ من المخلفات السابقة الذكر على التوالى. وبحساب أن سعر بيع الكيلو جرام حوالى ١٢٠ جنيه فإن صافي عائد الإنتاج يكون بالخسارة للكربون المنشط الناتج من مخلف عيدان الذرة ومجزى للكربون المنشط المنتج من مخلقي تقليم أشجار الخواخ ونوي البلح.

٤. نتائج مقارنة جودة الكربون المنشط الناتج من الوحدة المعملية والنموذج المصمم وجد من خلال المقارنة زيادة نسب كلٍ من الكربون ومساحة السطح وحجم المسام عند إستخدام النموذج المصمم وإنتاج الكربون المنشط من مخلفات تقليم الأشجار ونوى البلح. فى حين إنخفضت هذه النسب بشكل غير ملحوظ عند إنتاج الكربون المنشط من عيدان الذرة عند إستخدام النموذج المصمم. ومن هذا نجد أن النموذج المصمم ذو جودة عالية ويكاد يعادل أو يزداد فى جودة الإنتاج عن الوحدة المعملية.

٥. **إختبار معالجة مياه الشرب:** تم اجراء اختبار تطبيقي للدلالة على كفاءة الكربون المنشط الناتج من المخلفات الزراعية الثلاثة بإستخدام الوحدة المصممة في عملية معالجة مياه الشرب وذلك لعينة غير معالجة مأخوذة من محطة مياه الشرب بالجيزة، وقد تبين أن:

أ. زمن المعالجة يزيد مع إنخفاض إرتفاع عمود الكربون المنشط وكان أعلى زمن معالجة حوالى ٢٥,٢٧، ١٥,٤، ٨,١٨ دقيقة وأقل زمن معالجة ٣,٥٦، ١,١٥، ٢,٢٥ دقيقة بإستخدام الكربون المنشط الناتج من عيدان الذرة، مخلفات تقليم أشجار الخوخ، نوي البلح.

ب. وبدراسة خصائص المياه المعالجة نتج أن أقل نسب المواد الصلبة الذائبة هي ٣,٥٥ و٤,٢٠ و٥,٠٠ جزء في المليون وذلك بإستخدام الكربون المنشط الناتج عيدان الذرة

ومخلفات تقليم اشجار الخوخ ونوي البلح على التوالى عند ارتفاع ١ سم وأن العينات عديمة اللون والطعم والرائحة مقبولين.

ومن النتائج المتحصل عليها يمكن التوصية بـ:

١- الكربون المنشط المنتج بإستخدام النموذج الأولى ذو مواصفات جودة تعادل أو أفضل من الكربون المنشط المنتج بإستخدام النموذج المعملى (القياسى) مما يمكن إستخدام النموذج المصمم في إنتاج الكربون المنشط.

٢- للحصول على أفضل كربون منشط يستخدم النموذج المصمم يوصى بإستخدام مخلفات نوى البلح والتشغيل عند درجات حرارة ٤٠٠ ^{o}م وزمن إنحلال حرارى ساعة واحدة للحصول على أعلى جودة منتج حيث أعطى نسبة كربون٦١%، مساحة السطح ١٢٣,٦٥ م^{٢}.جرام$^{-١}$، المسامية ٥,٧٥×١٠$^{-٣}$ سم^{٣}.جرام$^{-١}$ وأعلى جودة فى معالجة مياه الشرب وإنتاجية تعادل ٣,١٦٦ كجم/ساعة وعائد ٢٠١,١٨ جنيه/ساعة.

٣- عند معاملة عيدان الذرة على درجات حرارة من ٤٠٠ ^{o}م لمدة ساعة فقد المخلف لذا يفضل تجربة الإنحلال الحرارى على درجات حرارة وأزمنة أقل.

الدراسات المستقبلية

١- التوجه إلى تجربة إنتاج الكربون المنشط من المخلفات الزراعية الغير مستغلة والمحتوية على نسبة عالية من الكربون بما يساعد على إنشاء قاعدة بيانات عن أفضل جودة الكربون المنشط للحد من استيراده والمساهمة فى النهوض بالمنتج الوطنى.

٢- نظراً لجودة الكربون المنتج فى معالجة مياه الشرب يمكن دراسة إستخدامه فى معالجة مياه الصرف.

٣- دراسة رفع إنتاجية الوحدة المصممة إما بزيادة سعة الوحدة عن طريق جرش أو طحن المخلفات قبل الإنحلال الحرارى أو تصنيع وحدة ذات سعة أكبر للمادة الخام

مما يساعد فى حل المشكلات الناجمة عن تراكم المخلفات مع الوضع فى الإعتبار للمردود المادى من تشغيلها.

اسم الطالب: مريم أحمد عامر **الدرجة:** دكتوراه الفلسفة
عنوان الرسالة: تصميم وتصنيع وحدة صغيرة لإنتاج الكربون المنشط من بعض المخلفات الزراعية.
المشرفون : دكتور : أحمد الراعى إمام سليمان
دكتور : خالد محمد عبد البارى
دكتورة : ناهد خيرى اسماعيل
قسم: الهندسة الزراعية **فرع:** **تاريخ منح الدرجة:** / /

المستخلص العربي

أُجريت هذه الدراسة بمعمل قسم الهندسة الزراعية - كلية الزراعة- جامعة القاهرة ومعمل معهد بحوث الهندسة الزراعية مركز البحوث الزراعية- في الفترة من ٢٠١٣- ٢٠١٦.

أدى العبء الإستيرادى للعديد من المنتجات الحيوية والتى يمكن إنتاجها من المخلفات الزراعية الغير مستغلة في مصر الى تشجيع دراسة إمكانية تصنيع إحدي هذه المنتجات الحيوية مثل الكربون المنشط من المخلفات. لذا كان الهدف من هذه الدراسة تصميم وتقييم آداء وجودة المنتج لنموذج أولى لإنتاج الكربون المنشط. وذلك بإتباع الخطوات التالية: ١- تجميع بيانات عن بعض المخلفات الزراعية إعتمادا على الكمية المنتجة، المحتوى من الكربون، مدى استغلالها لإختيار المخلفات تحت الدراسة. ٢- تحديد نسب بعض خصائص المخلفات قبل إجراء التجارب. ٣- إجراء عملية الإنحلال الحرارى للمخلفات في فرن معملي عند متغيرات دراسية تشمل درجات حرارة الإنحلال الحرارى (FT) ٤٠٠، ٥٠٠، ٦٠٠ و٧٠٠ °م و أزمنة إنحلال حرارى (tF) ١,٠، ١,٥، ٢,٠و ٢,٥ ساعة. ٤- تصميم وحدة صغيرة لإنتاج الكربون المنشط عند المتغيرات المثلى الموصى بها للإنحلال الحرارى من التجربة المعملية. ٥- تقييم ومقارنة جودة الكربون المنشط المنتج معملياً وبالوحدة المصممة وتقييم أداء الوحدة المصممة. ٦- إختبار تطبيقى لمعالجة مياه الشرب بالكربون المنشط المنتج من الوحدة المصممة.

تم إختيار عيدان الذرة، مخلفات تقليم أشجار الخوخ ونوى البلح لإستخدامها فى الدراسة. ومن خلال التجارب المعملية تم تحديد كمية المواد الصلبة وتركيز الكربون بكل العينات تحت الدراسة ومنها تم تحديد مستويات درجات الحرارة وزمن الإنحلال الحرارى المثلى لكل مخلف وتتمثل فى درجات حرارة الإنحلال الحرارى ٤٠٠، ٧٠٠، ٤٠٠ °م عند ١,٠، ٢,٠، ٢,٠ ساعة لمخلفات عيدان الذرة، تقليم أشجار الخوخ ونوى البلح على التوالى. والتى تم عندها إختبار جودة الكربون المنشط الناتج. ثم تم إجراء التجارب على النموذج المصمم عند نفس متغيرات الدراسة الموصى بها خلال التجارب المعملية وتحديد كمية وجودة الكربون المنشط الناتج من النموذج المصمم كما تم بالوحدة المعملية.

بالإضافة إلى إختبار تطبيقى لكفاءة الكربون المنشط المنتج فى معالجة مياه الشرب عند إرتفاعات مختلفة لعمود الكربون. وقد نتج ان أعلى نسب لكلٍ من الكربون ومساحة السطح وحجم المسام والمسح الميكروسكوبي تم الحصول عليها للكربون المنشط الناتج من مخلفات تقليم اشجار الخوخ ونوى البلح ولم يعطى مخلف عيدان الذرة نتائج مرضية.

وأظهر أداء النموذج المصمم أعلى إنتاجية حوالى ٣,١٦ كجم. ساعة$^{-١}$ للكربون المنشط الناتج من مخلف نوى البلح ١,١٣، ٠,٢٨ كجم.ساعة$^{-١}$ للكربون المنشط الناتج من مخلفات تقليم أشجار الخوخ وعيدان الذرة على التوالى. وكانت تكاليف إنتاج الكيلوجرام من مخلفات عيدان الذرة، نواتج تقليم أشجار الخوخ، نوى البلح حوالي ٢٠١,١٨، ٥٠,٢٠، ١٧,٩٢ جنيه مصرى على التوالى.

وقد اوصت الدراسة بالأتى: ١.إمكانيه إستخدام النموذج المصمم في إنتاج الكربون المنشط بجودة عالية من المخلفات الزراعية الغير مستغلة خاصة مع مخلفات تقليم أشجار الخوخ ونوى البلح بينما يفضل إجراء تجارب على الإنتاج من مخلف عيدان الذرة عند درجات حرارة وأزمنة أقل. ٢. نظرا لجودة الكربون المنشط المنتج في معالجة مياه الشرب يمكن دراسة إستخدامه في معالجة مياه الصرف. ٣. إمكانيه تصنيع وحدات ذات سعة كبيرة أو جرش المخلفات لتكفي متطلبات السوق المحلية.

الكلمات الدالة: الكربون المنشط، المخلفات الزراعية، فرن معزول، حمض الفوسفوريك، محتوى الكربون، الرماد، مساحة السطح، حجم المسام، المسح الميكروسكوبى "SEM"، معالجة المياه.

تصميم وتصنيع وحدة صغيرة لإنتاج الكربون المنشط من بعض المخلفات الزراعية

رسالة دكتوراه الفلسفة
في العلوم الزراعية
(هندسة زراعية)

مقدمة من

مريم أحمد عامر

بكالوريوس في العلوم الزراعية (هندسة زراعية)، كلية الزراعة ، جامعة القاهرة، ٢٠٠٦
ماجستير في العلوم الزراعية (هندسة زراعية)، كلية الزراعة، جامعة القاهرة، ٢٠١٢

لجنة الإشراف

دكتور/ أحمد الراعى إمام سليمان
أستاذ الهندسة الزراعية، كلية الزراعة، جامعة القاهرة

دكتور/ خالد محمد عبد البارى
مدرس الهندسة الزراعية، كلية الزراعة، جامعة القاهرة

دكتور/ ناهد خيرى اسماعيل
باحث اول نظم الهندسة الحيوية، معهد بحوث الهندسة الزراعية، مركز البحوث الزراعية

تصميم وتصنيع وحدة صغيرة لإنتاج الكربون المنشط من بعض المخلفات الزراعية

رسالة دكتوراه الفلسفة
في العلوم الزراعية
(هندسة زراعية)

مقدمة من

مريم أحمد عامر

بكالوريوس فى العلوم الزراعية (هندسة زراعية)، كلية الزراعة ،جامعة القاهرة، ٢٠٠٦
ماجستير في العلوم الزراعية (هندسة زراعية)، كلية الزراعة، جامعة القاهرة، ٢٠١٢

لجنة الحكم

دكتور/ طارق زكى حسين فودة..
أستاذ الهندسة الزراعية، كلية الزراعة، جامعة طنطا

دكتور/ محمد سامر محسن فؤاد..
أستاذ الهندسة الزراعية المساعد، كلية الزراعة، جامعة القاهرة

دكتور/ ناهد خيرى اسماعيل..
باحث أول نظم الهندسة الحيوية، معهد بحوث الهندسة الزراعية، مركز البحوث الزراعية

دكتور/ أحمد الراعى إمام سليمان..
أستاذ الهندسة الزراعية، كلية الزراعة ، جامعة القاهرة

التاريخ / / .

تصميم وتصنيع وحدة صغيرة لإنتاج الكربون المنشط من بعض المخلفات الزراعية

رسالة مقدمة من

مريم أحمد عامر

بكالوريوس فى العلوم الزراعية (هندسة زراعية)، كلية الزراعة، جامعة القاهرة، ٢٠٠٦
ماجستير في العلوم الزراعية (هندسة زراعية)، كلية الزراعة، جامعة القاهرة، ٢٠١٢

للحصول على درجة

دكتوراه الفلسفة

في

العلوم الزراعية
(هندسة زراعية)

قسم الهندسة الزراعية
كلية الزراعة
جامعة القاهرة
مصر

٢٠١٧