

DEVELOP AND EVALUATE DIFFERENT TYPES OF TRADITIONAL SOLAR COOKERS

By

FATMA MORGAN ABDEL AZIZ MOHAMED

B.Sc. Agric. Sc. (Agricultural Engineering), Ain Shams University, 2013

A Thesis Submitted in Partial Fulfillment

Of

The Requirements for the Degree of

MASTER OF SCIENCE

in

**Agricultural Sciences
(Farm Machinery and Power Engineering)**

Department of Agricultural Engineering

Faculty of Agriculture

Ain Shams University

2018

Approval Sheet

DEVELOP AND EVALUATE DIFFERENT TYPES OF TRADITIONAL SOLAR COOKERS

By

FATMA MORGAN ABDEL AZIZ MOHAMED

B.Sc. Agric. Sc. (Agricultural Engineering), Ain Shams University, 2013

This thesis for M.Sc. degree has been approved by:

Dr. Hussain Mohamed Hussain Sorour

Prof. of Agricultural Engineering, Faculty of Agriculture,
Kafrelsheikh University

Dr. Mohamed Magdy Mustafa Khallaf

Prof. Emeritus of Food Science and Technology, Faculty of
Agriculture, Ain Shams University

Dr. Mostafa Fahim Mohammed Abdel-Salam

Associate Prof. of Agricultural Engineering, Faculty of Agriculture,
Ain Shams University

Dr. Mubarak Mohammed Mostafa

Prof. Emeritus of Agricultural Engineering, Faculty of Agriculture,
Ain Shams University

Date of Examination: 17 / 3 / 2018

DEVELOP AND EVALUATE DIFFERENT TYPES OF TRADITIONAL SOLAR COOKERS

By

FATMA MORGAN ABDEL AZIZ MOHAMED

B.Sc. Agric. Sc. (Agricultural Engineering), Ain Shams University, 2013

Under the supervision of:

Dr. Mubarak Mohammed Mostafa

Prof. Emeritus of Agricultural Engineering, Department of
Agricultural Engineering, Faculty of Agriculture, Ain Shams
University. (Principle Supervisor)

Dr. Mostafa Fahim Mohammed Abdel-Salam

Associate Prof. of Agricultural Engineering, Department of
Agricultural Engineering, Faculty of Agriculture, Ain Shams
University.

Dr. Mohamed Fathey Mohamed Atia

Lecturer of Agricultural Engineering, Department of Agricultural
Engineering, Faculty of Agriculture, Ain Shams University.

ABSTRACT

Fatma Morgan Abdel Aziz Mohamed: Develop and Evaluate Different Types of Traditional Solar Cookers, M.Sc. Thesis, Department of Agricultural Engineering, Ain Shams University, 2018.

The shortage and the cost of fuel are urgent issues that is continuously increasing. This study aims to develop and evaluate the performance of two different types of solar cookers viz. box type and truncated pyramid type. The both of the cookers were modified to improve the thermal performance. The experiments were carried out in Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, Shubra El-Khemia, Egypt (Latitude $30^{\circ} 11' N$, Longitude $31^{\circ} 24' E$).

The modified solar cookers were tested with different quantities of rice for cooking and biscuit dough for baking. The thermal performance was evaluated by using first figure of merit F1, second figure of merit F2, thermal efficiency, costs and maturity of cooking.

The added heat energy by the modification of the box cooker was 33.8, 50.2 and 108.7kJ for 0.5, 1.0 and 2.0L, respectively. The added heat energy by the modification of the truncated pyramid cooker was 35.5, 66.9 and 167.2kJ for 0.5, 1.0 and 2.0L, respectively. The modified box cooker achieved a higher thermal efficiency than the non- modified box cooker by about 23% at the maximum water mass of 2.0L. The modified cooker achieved a higher thermal efficiency than the non- modified truncated pyramid cooker by about 36% at the maximum water mass of 2.0L. The mean heat energy gained of the modified box cooker and modified truncated pyramid cooker for 2.0L of water is found to be 459.8kJ and 451.4kJ, respectively, so the modified box-type solar cooker is recommended for using.

Keywords: Solar energy applications, Solar cooker, Box solar cooker
Truncated pyramid cooker.

ACKNOWLEDGEMENT

Thanks to **ALLAH** for his gracious kindness in all the endeavors the author has taken up in her life.

I would like to express my deep appreciation and gratitude to **Prof. Dr. Mubarak Mohamed Mostafa**, Prof. Emer. of Agric. Eng., Fac. Agric., Ain Shams Univ. for suggesting the problem of study and for his kind supervision throughout this work. I am grateful for his valuable discussions, suggestions and helpful criticism, which helped me to finalize this work.

My deepest appreciation to **Prof. Dr. Mahmoud Ahmed El-Nono** (late) who had an enormous impact on shaping my scientific and professional character. I am proud because I was his disciple.

Dr. Mostafa Fahim Mohamed Abdel-Salam, Associate Prof. of Agric. Eng., Fac. Agric., Ain Shams Univ., for kind supervision, continuous encouragement and valuable advices throughout this work. I shall never forget that, he always was a continuous source of encouragement and support in many aspects during my study.

I would like to give a special acknowledgment and appreciation to **Dr. Mohamed Fathey Atia**, Lecturer of Agric. Eng., Fac. Agric., Ain Shams Univ., for supervision, problem suggestion, continuous encouragement, valuable advices throughout this work, kind help and for reviewing the manuscript.

Special thanks to all staff members of Agricultural Engineering Department, for their valuable help during carried out the experiments of this work.

Finally, special thanks to **Mahmoud Abdel Hamid**, deepest appreciations are going towards my family for their understanding, patience and loving encouragement.

CONTENTS

	Page
LIST OF TABLES	III
LIST OF FIGURES	IV
1. INTRODUCTION.....	1
2. REVIEW OF LITERATURES	3
2.1. General overview on situation of energy in Egypt	3
2.2. Solar energy in Egypt	4
2.3. Overview on solar cookers.....	5
2.3.1. Solar panel cookers	13
2.3.2. Solar box cookers	13
2.3.3. Solar parabolic cookers	17
2.4. Cooking characteristics.....	21
3. MATERIALS AND METHODS.....	23
3.1. Specification of the box type solar cooker	23
"the first prototype".....	
3.1.1. Non-modified box solar cooker.....	23
3.1.2. Modified box solar cooker	24
3.2. Specification of the truncated pyramid type solar cooker	
"the second prototype".....	26
3.2.1 Non-modified truncated pyramid solar cooker.....	28
3.2.2. Modified truncated pyramid solar cooker.....	28
3.3. Experiments and Measurements.....	30
3.4. System evaluation.....	33
3.4.1. Stagnation temperature test (first figure of merit F1)...	33
3.4.2. Determination of F2 (Second figure of merit F2)...	33
3.4.3. Thermal performance of the system.....	34
3.5. Textural analysis of cooking test.....	35
3.6. Cost estimation	36
4. RESULTS AND DISCUSSIONS	37
4.1. The thermal performance of the solar cookers	37

II

4.1.1. The results of the stagnation test	37
4.1.2. Effect of the modification on the water heating.....	39
4.1.3. First figure of merit (F1).....	40
4.1.4. Second figure of merit (F2).....	40
4.1.5. Energy efficiency of the solar cooker	41
4.2. Productivity of the solar-cooked rice.....	45
4.3. Textural properties	48
4.4. Maturity of cooking	48
4.5. Cost evaluation	48
5. SUMMARY AND CONCLUSION	49
6. REFERENCES	52
7. APPENDIXES	62
ARABIC SUMMARY	

III

LIST OF TABLES

Table No.		Page
1	Comparison between absorber plate temperature of modified and non-modified box solar cookers.....	62
2	Comparison between absorber plate temperature of modified and non-modified truncated pyramid solar cookers.....	63
3	The water temperature of modified box solar cooker of 0.5, 1.0, 2.0 liter of water.....	64
4	The water temperature of modified truncated pyramid solar cooker of 0.5, 1.0, 2.0 liter of water.	65

LIST OF FIGURES

Figure No.		Page
1	Energy sources in Egypt IEA (2013)	3
2	The potential of solar energy in Egypt TUB, (2013) .	5
3	Types of solar cookers: (a) solar panel cooker; (b) solar parabolic cooker; and (c) solar box cooker, Cuce and Cuce, (2013)	6
4	A schematic diagram of solar cooker box type, Saxena et al. (2011)	7
5	Non-modified box solar cooker, the dimensions in mm.....	24
6	Modified box solar cooker.....	26
7	Schematic diagram of truncated pyramid type solar cooker.....	27
8	Non-modified truncated pyramid solar cooker, the dimensions in mm.....	29
9	Modified truncated pyramid solar cooker.....	30
10	Schematic diagram of experiments was carried out on the cookers.....	31
11	The block diagram of the proposed system of solar cooker.....	32
12	Tinius Olsen bench top materials testing machines model H5ks, USA.....	35
13	Comparison between absorber plate temperature of modified and non-modified box solar cookers.....	38
14	Comparison between absorber plate temperature of modified and non-modified truncated pyramid solar cookers.....	38
15	Comparison between water temperature of modified box solar cooker of 0.5, 1.0 and 2.0 liter of water.....	39

Figure No.		Page
16	Comparison between water temperature of modified truncated pyramid solar cooker of 0.5, 1.0 and 2.0 liter of water.....	40
17	Time versus energy efficiency for 0.5L of water in box solar cooker.....	42
18	Time versus energy efficiency for 1.0L of water in box solar cooker.....	43
19	Time versus energy efficiency for 2.0L of water in box solar cooker.....	43
20	Time versus energy efficiency for 0.5L of water in truncated pyramid solar cooker.....	44
21	Time versus energy efficiency for 1.0L of water in truncated pyramid solar cooker.....	44
22	Time versus energy efficiency for 2.0L of water in truncated pyramid solar cooker.....	45
23	Cooking rice in the non-modified box solar cooker.	45
24	Cooked rice in the non-modified truncated pyramid cooker.....	46
25	The time required for cooking different quantities of rice in modified box cooker.....	47
26	The time required for cooking different quantities of rice in modified truncated cooker.....	47
27	The operational cost of cooked rice (LE/kg).....	48

INTRODUCTION

Renewable energy is accepted as a good alternative for fossil fuels for the future. This is primarily due to fact that renewable energy resources have some advantages when compared to fossil fuels. However, environmental concerns and limited energy sources make renewable energy technology a good alternative for fossil fuels. It is important to harness that resources in view to find solution to energy shortage and environmental degradation.

Solar energy is now considered to be the most effective and economic alternative resource. Egypt has a high potential for production the energy from sunrays that can be considered as a reliable energy source, where Egypt characterized by average daily solar energy ranged from 5 to 8 kWh/m² and sunshine duration per year extends to about 3500 hours (Sorensen, 2004).

Cooking is one of the daily main activities for people. Cooking in a rural and remote areas mainly depends upon conventional energy sources such as straw, wood, coal, kerosene and other petroleum products for cooking, that it's led to air pollution. Electric cookers and liquid petroleum gas (LPG) are also used for cooking, on the other hand, the price of electricity is increasingly, and the supply of LPG is also burdened due to increasing population. Therefore, the solar energy is stongly required to stand next to the conventional energy sources in order to decrease the demand on the convential energy.

Solar cooking is one of the thermal solar applications that use solar radiation as an energy instead of using the traditional sources of energy. Saving fuel, saving cost, safe and healthy can be achieved by using solar cooker.

Solar cooking saves not only fossil fuels but also keeps the environment free from pollution without hampering the nutritional value of the food. The problem arises when fuel is either scarce or highly

expensive. The problems are encountered more pronounced in remote and rural areas.

Therefore, the work conducted in this study presents two developed different prototypes of solar cookers. The performance of the two solar cookers has been investigated. The specific aims of this study are:

- 1- develop solar cooker systems.
- 2 - study the affecting factors to the performance of the system.
- 3 - use and test the developed cooker in the cooking and baking.
- 4 - determine the overall efficiency and the performance rate.
5. evaluate the system.

REVIEW OF LITERATURE

2.1. General overview on situation of energy in Egypt

NREA, (2008) to overcome the crisis of energy, the Egyptian government has taken numerous steps to address the crisis such as expanding the usage of renewable energy to reach 20% of production by 2020.

IEA, (2011) showed that Egypt has been witnessing a growing consumption of electricity. Electricity demand has grown significantly in recent years due to the socio-economic development. Peak electricity demand increased by more than 200 %, from 6902 MW in 1990 to 22500MW in 2010.

IEA (2013) showed that Egypt depends on various energy sources such as natural gas, crude oil, hydropower, coal, in addition to renewable energies represented in the solar, wind and biomass energy. Egypt's energy mix is made up of: natural gas 53 %, oil 41 %, hydropower 3 %, coal 2 %, and renewables 1%, as indicated in **Fig. (1)**.

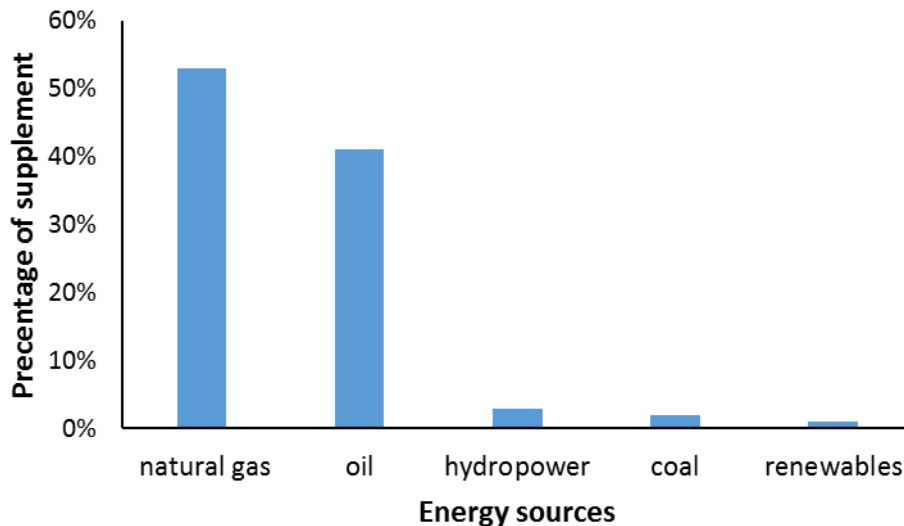


Fig. (1): Energy sources in Egypt, (IEA, 2013).

AfDB, (2012) and Gawdat, (2013) reported that as for renewable energy, Egypt is considered by many observers to be a country which has

REVIEW OF LITERATURE

the right environment to meet a large proportion of its energy needs by utilizing wind and solar power. Due to its location, topography and climate, Egypt is one of the best in the world which is suitable for setting up solar and wind energy systems. However, the country's potential in renewable energy is not properly utilized and it accounts for a minor share for Egypt's energy mix.

Nick, (2014) showed that Egypt's growing population and industrial development led to a significant rise in the demand for energy products in all sectors (residential, transportation and industrial). Subsequently the consumption of oil, gas and electricity has been boosted,.

USEIA, (2014) showed that Egypt is the second largest producer of natural gas in Africa yet. Egyptian consumption of natural gas has been increasing by approximately 7 % per year. So, the increasing level of consumption compared with the level of production led Egypt to become importer of natural gas over the last few years.

2.2. Solar energy in Egypt

TUB, (2013) reported that Egypt enjoys with annual solar radiation as shown in **Fig. (2)** ranging from about 1800 to more than 2500 kWh/m² per year. Because its geographic location, Egypt lies among the Sun Belt countries where solar energy is abundant.

Sorensen (2004), ERCCU (2006), Ibrahim (2012) and USEIA, (2014) showed that sunshine duration ranging from 9 – 11 hours per day with has approximately 325 days of sunshine over the year and approximately with about 2300 - 4000 sunshine hours annually. The daily average solar energy has a magnitude of 5 to 8 kWh/m² with relatively steady daily profile and small variations making it very favorable for utilization. Both the solar radiation atlas and the German aerospace center