FACULTY OF ENGINEERING

DEPARTMENT OF AGRICULTURAL MECHANIZATION AND IRRIGATION ENGINEERING

DESIGN AND CONSTRUCTION OF AN EVAPORATIVE COOLER FOR CITRUS FRUITS.

BY

BAGALANA FASTINO

BU/UP/2017/141

TEL: +256 753662728/ +256 770520088

EMAIL: *bagalana2000@gmail.com*

SUPERVISOR: MR. OKETCHO YORONIMO

A final year project report submitted to the Department of Agricultural Mechanization and Irrigation Engineering in partial fulfillment of the requirements for the award of a Bachelor of Science in Agricultural Mechanization and Irrigation Engineering of Busitema University, MARCH 2022

1 ABSTRACT

A Solar Powered and Temperature Controlled Evaporative Cooler of 45 kg capacity was designed and constructed to increase the shelf life of fresh citrus fruits. The cooler was tested using green freshly harvested lemon fruits and evaluated. The cooler operates on the principle of DEC. Freshly harvested citrus fruits are highly perishable. The cooler was made up of a 1.5mm mild steel sheet and lagged with cotton with one side made of sponge pad through which the water flew via a perforated half inch PVC pipe from the reservoir located at the top of the cooler. A 12 V battery powered two DC fans inserted on the side opposite to the side of sponge pad and a DHT22 sensor controlled the fans. A buzzer and LCD screen were also incorporated in the system. The temperature, RH and weight loss of fruits were statistically analyzed and the results revealed that there was a marked difference in using the cooler for pre cooling of citrus fruits as compared to the shade. The temperature in the cooler reduced up to 19.0 ℃ when compared to the shade and the RH in a cooler chamber went up to 99% . However, the testing of the system disclosed that the citrus fruits can be pre cooled with minimal changes in weight, color and no putrefying as compared to the shade which started with notable changes in weight, color and severe putrefying after 3 days. Hence, it is on advisable that market dealers and citrus processing factories adopt the use of an evaporative cooler for their preservation as this increases their shelf life

2 DECLARATION

I **BAGALANA FASTINO** hereby declare that this project report titled "**Design and Construction of an Evaporative Cooler for the Citrus Fruits"** was done by myself in the Department of Agricultural Mechanization and Irrigation Engineering, Busitema University, under the supervision of Mr. Oketcho Yoronimo. The information derived from the literature has been properly acknowledged in the text and a list of references provided. No part of this work has been presented for another degree or diploma in any institution.

SIGNATURE: ……...

DATE: …….....

3 APPROVAL

This final report was presented and submitted to the Faculty of Engineering through the Department of Agricultural Mechanization and Irrigation Engineering of Busitema University for examination and was approved for its contribution to knowledge and literary presentation

MR. YORONIMO OKETCHO

SIGNATURE: …….

DATE: …….

4 DECLARATION

I **BAGALANA FASTINO** declare to the best of my knowledge that work presented in this project proposal report is mine and has never been presented to any University or Institution of higher learning for any academic award.

SIGNATURE: ……...

DATE: ……..…..

5 DEDICATION:

I dedicate this research report project to my parents, Mr. Babalanda Pascal, Mrs. Babalanda Christine and Margate, Mr. Waiibi Moses, family of Mr. Watongola Ronald, DEO Buyende district , FAWE, and MasterCard Foundation in appreciation for their selfless care and unflinching support provided to me. In a special way, I dedicate this report to my dear wife Watera Vivian for the endless encouragements rendered to me and to the Highest God who is the Giver of life and knowledge.

6. ACKNOWLEDGEMENT

My gratitude goes to Almighty God for guidance, protection and provision throughout the preparation of this work. I am so grateful to my friendly supervisor; Mr. Oketcho Yoronimo and the project coordinator; Mr. Obeti Lawrence for their academic and moral contribution in the completion of this work. This appreciation is extended to all friends and fellow Agricultural Engineers, and the Technical staff of the Munyengera Agro-machinery Ltd in Mayuge District, who contributed in helping me to make this work a reality.

Finally, I appreciate my special friend, Ms. Malvin, Kisakye Josephine and Oprung Isaac who gave me a great deal of encouragement and advice in difficult moments during the course of this work.

TABLE OF CONTENTS

Contents

1 ABSTRACT ii
2 DECLARATION iii
3 APPROVAL iv
4 DECLARATION v
5 DEDICATION: vi
6. ACKNOWLEDGEMENT vii
7 LIST OF FIGURES xii
8 LIST OF TABLES xiii
1.0 CHAPTER ONE 1
1.1 BACKGROUND 1
1.2 PROBLEM STATEMENT: 2
1.3 Objectives of the study 2
1.3.1 Main objectives 2
1.3.2 Specific objectives 2
1.4 Justification. 3
1.5 Scope of the project: 3
2.0 CHAPTER TWO: 4
2.1 LITERAURE REVIEW 4
2.1.1 Citrus fruits and their uses 4
2.1.2 Citrus fruit spoilage 4
2.1.3 Citrus fruit ripening and quality degradation. 5
2.1.4 Pre cooling of citrus fruits 5
2.1.5 Factors affecting cooling and storage of citrus fruits 6
2.1.6 Factors affecting evaporation 6
2.1.7 Methods of evaporative cooling 7
2.1.8 Cooling pad material. 9
2.1.9 Previous studies on existing cooler technologies. 10
2.1. 10 Advantages of evaporative cooler design 15
2.1.11 Comparing alternatives 16
3.0 CHAPTER THREE 17

3.1 METHODOLOGY 17
3.1.1 Proposed principle of operation of the evaporative cooler. 17
3.1.2 Conceptual diagram for proposed evaporative cooler 18
3.1.3 Working of monitoring system: 19
3.1.4 Functional Units of the evaporative cooler 20
3.1.5 Criteria for material selection. 20
3.1.6 Design considerations. 21
3.2 SPECIFIC OBJECTIVE ONE: 22
3.2.1 Cooling chamber design: 22
3.2.2 Rear Side design 22
3.2.3 Door design 22
3.2.4 Design of right side: from geometric eqn 22
3.2.5 Design of the top side of the cooler 23
3.2.6 Arrangement of the wire mesh inside the cooling chamber. 23
3.2.7 Heat Transfer Analysis of the evaporative cooler 23
3.2.8 Respiration heat load of the produce 23
3.2.9 Field heat of the produce 23
3.2.10 Infiltration of Air 24
3.2.11 Determination of Air flow rate: 24
3.2.12 Selection of suction fan. 24
3.2.13 Determination of the rate of evaporation of water. 24
3.2.14 Determination of quantity of air needed for effective cooling 25
3.2.15 Determining the quantity of heat from air needed to evaporate off the water during the adiabatic process 25
3.2.16 Determining the volume of water needed to be heated by the incoming air. 25
3.2.17 Design of reservoir tank. 26
3.2.18 Design of Reservoir Seat: 26
3.2.19 Pad selection. 26
3.2.20 Sizing of solar power system. 26
3.2.21 Sizing of the battery. 27
3.2.22 Design of Battery Charger. 27
3.2.23 Determination of the compressive stress. 27
3.2.24 Determination of the total weight of the cooling system. 27

3.2.25 Selection of rollers. 28
3.3 SPECIFIC OBJECTIVE TWO 28
3.3.1 Construction and assembling of the evaporative cooler. 28
3.3.2 Tools and equipment. 28
3.4 SPECIFIC OBJECTIVE THREE 29
3.4.1 Testing the performance of the cooler 29
3.4.2 Performance parameters 29
SPECIFIC OBJECTIVE FOUR. 30
3.5.1 Cost Benefits Analysis of the Evaporative cooler. 30
4.0 CHAPTER FOUR: RESULTS AND DISCUSSIONS 31
4.1 Specific Objective One: Design of the machine components 31
4.1.1 Determination of the cooling space 31
4.1.2 Determination of the heat produced by lemons 31
4.1.3 Sizing of the wire mesh for pre cooling 32
4.1.4 Sizing of Cooling sponge pad. 32
4.1.5 Sizing of the galvanized iron wire mesh netting on the wall. 32
4.1.6 Design of back side of the Storage System 33
4.1.7 Design of the right-hand side 33
4.1.8 Design of the door side 34
4.1.9 Designing of the top and bottom metal plate 34
4.10.1 Determination of heat transfer in the cooling chamber 34
4.10.2 Determination of airflow rate 35
4.10.3 The quantity of air needed for effective cooling. 36
4.10.4 The quantity of heat energy from air needed to evaporate off the water during the adiabatic process 36
4.10.5 Volume of water needed to be heated by incoming air. 36
4.10.5 Sizing of the reservoir tank 37
4.10.6 Sizing of suction fan 37
4.10.7 Sizing of the Battery 37
4.10.8 Sizing of Solar Power Supply System 38
4.2 Specific objective two: Construction of the prototype. 38
4.3 Specific objective three: Testing the cooler 39
4.3.1 Load test results of the cooler 39

4.3.2 Temperature, relative humidity of the cooler 39
4.3.3 Physiological weight loss 42
4.3.4 Volume Flow Rate of Water. 44
4.3.5 Determination of the rate of cooling 44
4.4 ECONOMIC ANALYSIS 44
4.4.1 Net Present value (NPV) 45
4.4.2 Cost /Benefit ratio = total benefits/total cost 46
5.0 CONCLUSION AND RECOMMENDATIONS 47
5.1 Conclusions 47
5.2 Recommendations 47
5.3 REFERENCES 47
5.4 APPENDIX 50

7 LIST OF FIGURES

Figure 1: Shows produce in a precooling room 11
Figure 2: Shows forced air cooling process 11
Figure 3: Shows hydro cooling process 12
Figure 4: Shows vacuum cooling process 13
Figure 5: Shows a clay based cooler 14
Figure 6: Shows low cost evaporative cooling system 15
Figure 7: Proposed conceptual diagram of the evaporative cooler 18
Figure 8: Proposed processes in the cooler 19
Figure 9: Temperature monitoring system in the cooler 19
Figure 10 showing fully constructed prototype of an evaporative cooler for citrus fruits 39
Figure 11: Showing the production drawing for the prototype 50
Figure 12 Showing a fully assembled evaporative cooler for citrus fruits: 51
Figure 13: Production drawing for the prototype 52