Ref: 197/5

A hybrid solar fruit drying system for small-scale farmers in subtropical and tropical countries

Dissertation

zur Erlangung des akademischen Grades

doctor rerum agriculturarum

(Dr. rer. agr.)

eingereicht an der
Landwirtschaftlich-Gärtnerischen Fakultät
der Humboldt-Universität zu Berlin

von

M.Sc. Baher Mahmoud Ahmed Amer
geb. am 01.06.1973 in Kairo /Ägypten

Präsident
der Humboldt-Universität zu Berlin

Prof. Dr. Christoph Markschies

Dekan der
Landwirtschaftlich-Gärtnerischen Fakultät:

Prof. Dr. Dr. h. c. Otto Kaufmann

Gutachter:
1. Prof. Dr. J. Hahn
2. Dr.-Ing. K. Gottschalk
3. Prof. Dr.-Ing. C. Fürll

Tag der mündlichen Prüfung: 01.09.2006

Acknowledgements

I deeply thank ALLAH to help me and give me the power to finish this work in the right time.

I am deeply grateful and indebted to Prof. Dr. Jürgen Hahn, Professor of Agricultural Engineering, Faculty of Agriculture and Horticulture, Humboldt University, Berlin, Germany, for his kind academic supervision, valuable advice and suggestions contributing to the success of this work.

My warmest thanks, full respect and deep gratitude go to Dr.-Ing. Klaus Gottschalk responsible for Climate control, fluid dynamic, database system at the Institute of Agricultural Engineering (ATB), Bornim, Germany, for his patient supervision, inspiring guidance, critical comments, suggestions, and the never-ending support he displayed throughout this study. I wish also to express my grateful appreciation of his contributions and his support in various private matters during my stay in Germany.

Many deep thanks are due to Prof. Dr. Mohammed Yousri, Faculty of Agriculture, and Cairo University, Egypt for his academic suggestions and support and to Dr. Mohamed Omran, Egypt, for his valuable academic advice and support.

My deepest thanks and appreciation also go to the workers in the workshop especially, Mr. Röhnke for his great effort to help me to construct the solar drying unit. Additionally, to all staff members of the Post Harvest Technology in ATB for their tremendous assistance and efforts; especially to Prof. Dr. habil Christian Fürll, the head of the department; Dr.-rer. agr. Thomas Hoffmann; Dipl.-Ing. Wolfgang Schwarz, the computer administrator; Dipl.-Ing. (FH) Peter Kaulfuß, Dipl.-Ing. (FH) Ralf Zitzmann, Dipl.-Ing. (FH) Jutta Sujata and Mr. Erhard Brandt.

This work has been successfully completed thanks to the family-like and friendly atmosphere created by all members of ATB. In this connection my gratitude extends especially to Prof. Dr.-Ing Jürgen Zaske, Ex-Director of the institute and Prof. Dr. Brunch, the temporary director of ATB, Dr. Ralf Habelt and Mrs. Heidrun Lekow from Administration Department or their fruitful cooperation.

I am also grateful Benedicta Antwiwaa-Wiafe a student at the Kwame Nkrimah University of Science and Technology, Ghana who was undertaking internship program at ATB:

My sincere thanks and gratitude goes to Prof. Dr. Alya Khattab, Ex Culture Consul and Prof. Dr. Gamal EL-Refaie, the current Culture Consul of the Egyptian Embassy in Germany, for their encouragement and support through out my studies in Germany. Thanks are also extended to all members of the Culture Department and students' mission of the Egyptian Embassy in Germany for their friendly cooperation and support.

My deepest thanks and appreciation goes to the Islamic Development Bank (IDB) to give me this great chance to acquire a Ph.D. Scholarship in Germany. Additionally, for DAAD that gave me one year Scholarship in Germany to collect the literatures and learn German language.

I thank also Mr. Wael Abdel-Hakeem and Mrs Amanda for their effort to help me to prepare this thesis in the best way.

Last but not the least I would like to express my deep thanks and appreciation to my dear wife, my great parents, and my lovely son, Islam, the source of my happiness, encouragement and motivation. I therefore, dedicate this thesis to all of them beside my sisters, my mother-law and father-law.

Baher Mahmoud Ahmed Amer

ABSTRACT

Laboratory experiments and a mathematical simulation model were conducted to control the drying air properties and predict the drying time duration to achieve a successful drying process inside the solar dryer.

By using the results of the laboratory experiments and mathematical simulation model, a hybrid continuously operated solar drying system was designed, fabricated and tested in ATB to be applied in Egyptian Villages to help the farmers and the small scale producers of the dried agricultural products for producing good quality products all the year around on economical bases.

The obtained results for using this present solar drying system are:

- The solar drying system was tested from June to October 2005 and from May to June 2006. It has been proved successfully dry banana slices, apple rings and plums (whole and halves). It can raise the air temperature between 30 to 50 K above the ambient temperature under Mid-European summer conditions by using drying air velocity from 0.2 to 0.4 m/s. By using the water tank with the solar drier, part of the solar energy can be stored in the water and the original water temperature is raised to about 20-50 K during the duration of sun-shine.
- Water passing through the pipes stores the heat during the day time and then transfers it to the air to prevent the rapid decreasing of the drying air temperature when the solar radiation start to decrease after 14.00 until sun set. In the case of drying fruits, which need a long time to be dried, e.g. plums, using heaters during the night increase the cost, however, keeping high temperature is needed inside the dryer. Using the heater will lead to acceleration of the drying process as well as protect the fruits from deterioration inside the dryer because of the lengthy drying period.
- Efficiency of the solar drying system can be raised by recycling the drying air again and rejecting a small amount of it outside the drier to carry out the moisture removed from the fruits.
- Efficiency of the solar drying system can also be raised by using solar reflectors with holders to move it according to the sun angles during the day, and by turning the drier also according to the sun angles.
- The dried fruits in the solar drier were completely protected from dust, dirt, rain, insects, birds, and rodents it was a quality-dried product in terms of colour, texture, and glossiness. Hence, the solar drier was found to be technically suitable for drying of fruits, vegetables, herbs and crops.
- Where the electricity is not available in some areas or to decreasing the cost of the electricity, solar drier may be recommended for drying of fruits which need a short period to dry during the sun shine as apple rings and banana slices.
- According to a survey carried out in Egypt, it is found that this price is suitable for many farmers in Egypt and they can be easy to buy a one of it. Due to low labour costs, further price decreases can be expected if the drier is produced by small scale industry in Egypt and developing countries and the payback period for it is one year only.