FABRICATION OF A MULTIPURPOSE SOLAR DRYER FOR PRESERVATION OF AGRICULTURAL PRODUCTS

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ABSTRACT

Food preservation is very essential for human survival, since most food items are perishable and as such can get damaged if they are not properly preserved. There are different ways of preserving food items such as processing the food to a finished food and package it, putting the food items in the fridge, drying either slowly or quickly using fire or smoking. Sun has been utilized for some time now for different applications including cooking, heating, power generation as well as drying of food items. The research is to fabricate a multipurpose solar drier, so as to reduce the issue of wastage of food products through decay and attack by animals. This will go a long way to eradicating or reducing the wastage the farmers normally encounter when fresh food is to be kept for more than two days. The component has the capacity to rapidly eliminate moisture contents from fresh Agricultural produce in order to save them from damage. The result of the fabrication show that the starting temperature of the atmosphere was 38^oC, while in the direct chamber was 45^oC and 40^oC in the indirect chamber and the end temperature was 40^oC for the atmosphere, 45^oC for the indirect chamber and 52^oC for direct chamber. The highest temperature is 45^oC for atmosphere and 63^oC and 74^oC for the indirect and direct chamber respectively. The weight of the content outside reduced from 20kg to 15.70kg with efficiency of 21.5%, in the direct chamber it reduced from 20kg to 10.40kg with efficiency of 48%, while in indirect chamber it reduced from 20kg to 12.20kg.

KEYWORDS: Agriculture, Food, Preservation, Drying, Multipurpose, Solar, Solar-Dryer

INTRODUCTION

Energy is the motive force behind the sustained technological development of any nation and Nigeria is blessed with reasonably high quantities of various energy resources. These include the non-renewable such as crude oil, natural gas, coal and uranium and the renewable such as biomass, solar, wind and hydro energy. At present, the dominant energy source used in Nigeria is oil and its derivatives, accounting for over 75% of the total energy consumption, except in the rural areas where biomass in the form of fuel wood dominates (Bolaji and Olalusi, 2008).

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photovoltaic, solar thermal electricity and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces (Abdul-Fadl and Ghannam, 2011).

Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy (Fudholi, Sopian, Ruslan, Alghoul and Suleiman, 2010). Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favourable thermal mass or light dispersing properties, and designing spaces that naturally circulate air (Amer, Hossain and Gottschalk, 2010).

Solar thermal energy can be useful for drying wood for construction and wood fuels such as wood chips for combustion. Solar is also used for food products such as fruits, grains, and fish. Crop drying by solar means is environmentally friendly as well as cost effective while improving the quality. The less money it takes to make a product, the less it can be sold for, pleasing both the buyers and the sellers (Forson, Nazha, Alkuffo and Rajakaruna, 2007). Technologies in solar drying include ultra-low cost pumped transpired plate air collectors based on black fabrics. Solar thermal energy is helpful in the process of drying products such as wood chips and other forms of biomass by raising the temperature while allowing air to pass through and get rid of the moisture (Amanlou and Zomorodian, 2010).

Food preservation is very essential for human survival, since most food items are perishable and as such can get damaged if they are not properly preserved. There are different ways of preserving food items such as processing the food to a finished food and package it, putting the food items in the fridge, drying either slowly or quickly using fire or smoking (El-Baltagi, Ganea and Essa, 2007). Sun has been utilized for some time now for different applications including cooking, heating, power generation as well as drying of food items (Lamnatou, Papanicolaou, Belessiolis and Kyriakis, 2010).

Drying was virtually the only method of food preservation until around the end of 18th century when solar drying was developed (Whitefield, 2000). In Nigeria, this method of food preservation is still the most cost effective, particularly in the rural areas where power is not available and there is poverty highly pronounced (Abiola *et al.*, 2011).

Problem Statement

Food preservation is very essential for human survival, since most food items are perishable and as such can get damaged if they are not properly preserved. There are different ways of preserving food items such as processing the food to a finished food and package it, putting the food items in the fridge, drying either slowly or quickly using fire or smoking. Sun has been utilized for some time now for different applications including cooking, heating, power generation as well as drying of food items.

The crude methods employed by local farmers for drying lead to contamination of food items and as well as losing some vital nutrients of the food items through burning and over drying. This fabrication will help check these irregularities that occurred in the old methods of fish preservation.

Aim and Objectives

The aim of the fabrication is to fabricate a Multipurpose Solar Dryer for preservation of Agriculture Products.

The objectives of the fabrication is:

a) To provide a preservative equipment for Agricultural produce
b) To save the energy wasted in search of firewood and preparation of firewood for preservation
c) To provide a hygienic method of drying agricultural produce instead of directly exposed t sun.
d) To provide a better way of preservation that will preserve the nutrients of food items after drying as there will be control of air flow.
e) To provide a better method of meat or fish drying that will avoid burning.
f) To provide a safe drying method that will safe product from rodents, dogs, cats, even passer by attack.
g) To save labour of evacuating the product when it is night and when rain is about to fall.

Design Consideration and Calculation

The solar dryer consists of the following components:

I. A flat plate collector with glass coated with black paint, insulated to prevent down ward heat loss from the collector plate, a duct that circulates the heat transfer air to carry heat away from the collector surface and a container of sheet metal painted black to protect the entire assembly from the environment and from heat loss due to convection.
II. A dryer chamber of square container of sheet metal painted black with three perforated wire mesh cabinet beds or trays for placing food items.
III. A Chimney in form of a truncated square pyramid on square prism to provide exit for the steam generated from drying food items.

General Design Consideration

The collector and drying chamber are made of mild steel sheet and insulated using foam to prevent heat loss. The absorber plate for the solar collector is made of mild steel sheet painted black and supported 8cm above the bottom the collector to allow air circulation exist below and above the absorber plate. The collector is tilted at angle $+15^{o}$ south to the horizontal to allow free flow of water or any liquid that drops on top to make the cover free from wet. Inlet air aperture at the collector and exit air aperture as chimney at the drying chamber provide ventilation and air circulation by buoyancy, which help in carrying out the released vapour from the food products as it flow pass it. The design components measurement value is as shown below:

Collector area = 1.50m x 1.50m = $2.25m^2$

Collector volume = 1.50m x 1.50m x 0.64m = $1.44m^3$

Area of collector vent opening = 0.52m x 0.85m = $0.442m^2$

Area of drying chamber = 2m x 2.44m = $4.88m^2$

Volume of drying chamber = 2m x 2.44m x 1.23m = $6.00m^3$

Solar Collector Design Consideration

The collector useful energy, which is the performance of the collector is given as:

$$Q_c = A_c F_R (S - U_1)(T_f - T_a) \quad \textbf{Eqn. 1}$$

Where:

- Q_c = Collector useful energy gain (J/hr)
- S = Average energy flux (J/hr m^2) reaching the collector plate per hour
- U_1 = Overall heat transfer coefficient of the collector (J/hr m^2 ^oC)
- F_R = Collector efficiency factor depending on the thermal properties of the absorber plate, the cover plate, air and the insulating material.
- Ac = Area of collector (m^2)
- T_f = Outlet air temperature (^oC)
- T_a = Ambient air temperature (^oC)

Drying Chamber Design Consideration

The useful energy gain by the collector is the measure of the thermal performance of the drying chamber of the solar dryer, given as:

$$Q_u = \rho A_2 V_2 C_p (T_o - T_1) \quad \textbf{Eqn. 2}$$

Where:

- ρ = is the density of air.
- A_2 = area of the collector at outlet
- V_2 = velocity of air through the chamber at the outlet of the collector
- SA_2V_2 = mass flow rate of air in kg/s
- C_P = specific heat capacity of air
- T_1 = inlet air temperature (K)
- T_o = outlet air temperature (K)

Volume Flow Rate of Air

The air flow rate can be calculated using the following relations:

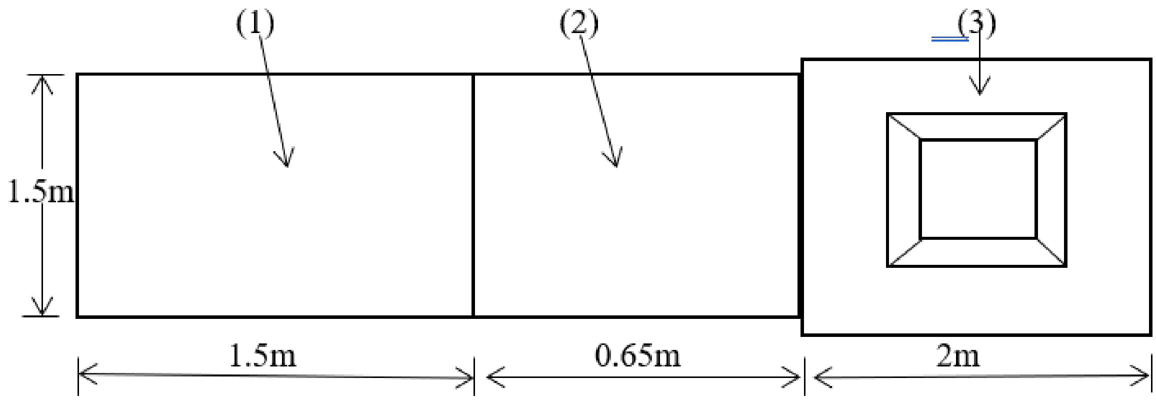
$$R = VA \quad \textbf{Eqn. 3}$$

Where:

- R = volume flow rate of air in m^3/s
- V = velocity of air in m/s
- A = area of the collector vent opening in m^2

Efficiency of the dryer is given as:

$$\varepsilon = \frac{Q_s}{Q_T} x\ 100\% \quad \textbf{Eqn. 4}$$



(1) Solar Collector and Air Heater
(2) Stone Bed for Heat Generation
(3) Drying Chamber

Fig. 1: Plan view of the Solar Dryer

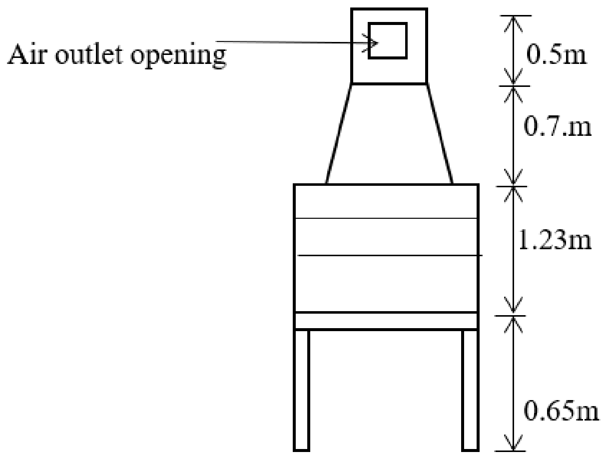


Fig. 2: Rear View of the Solar Dryer

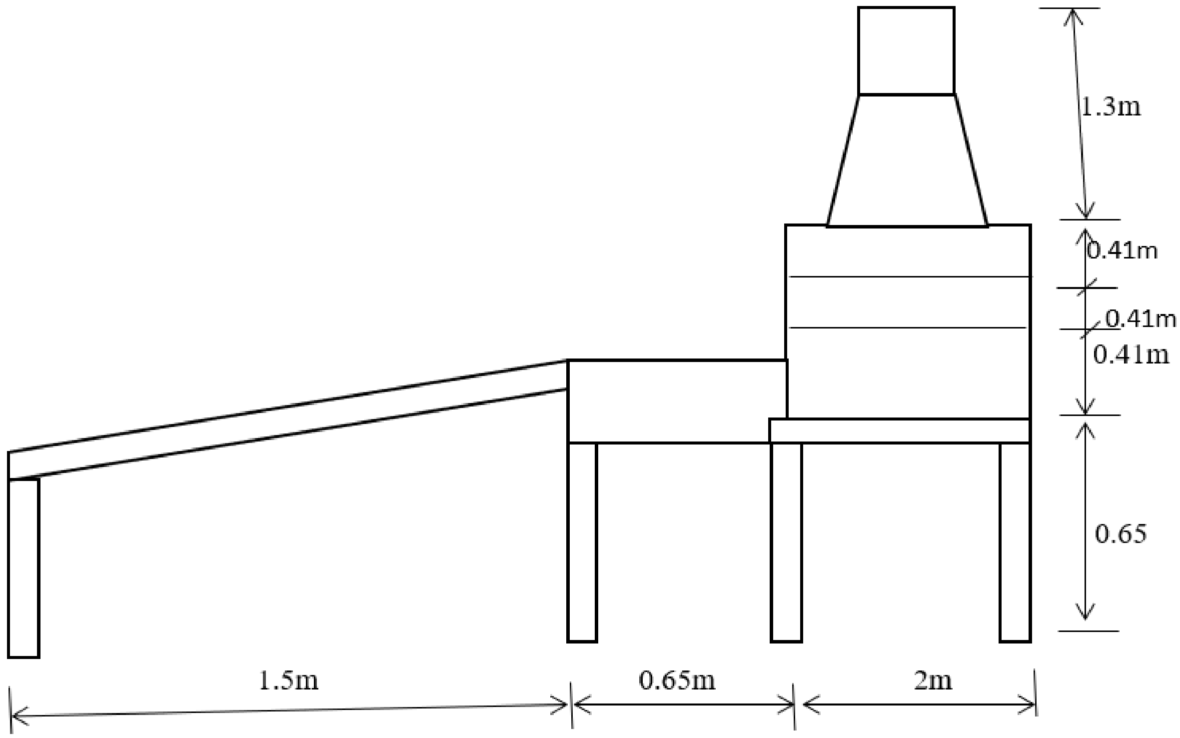


Fig. 3: Side View of the Solar Dryer

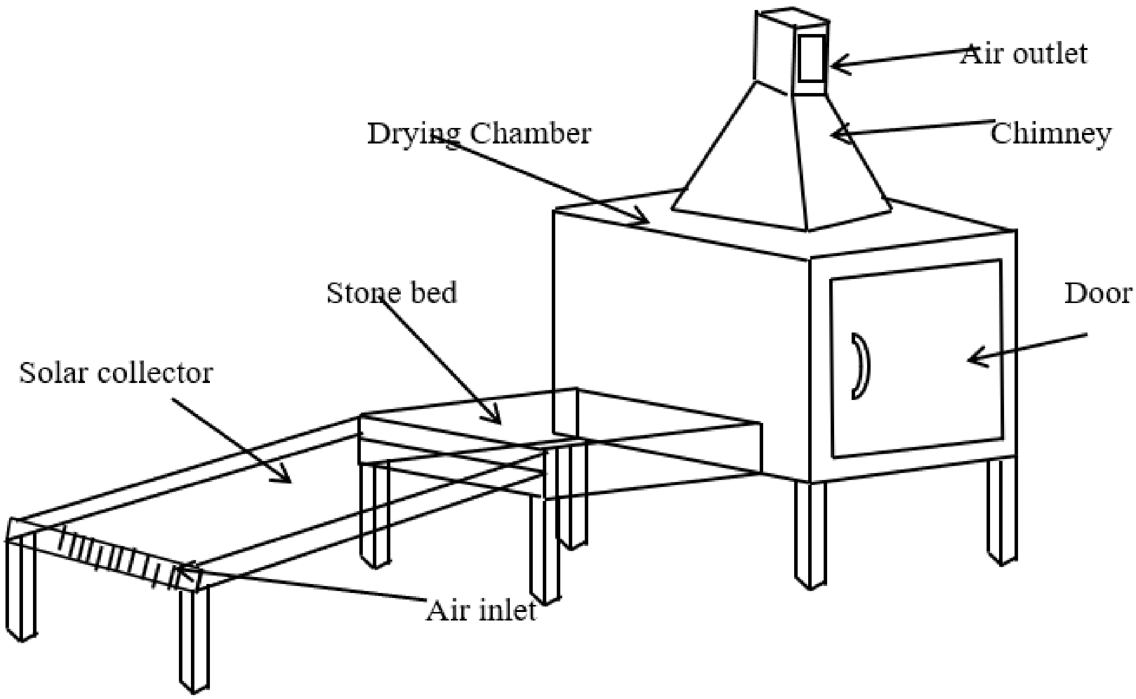


Fig. 4: Assembly Drawing of the Solar Dryer

Plate 1: Front View of the Dryer before and after Finishing

Plate 2: Interior View of the Drying Chamber

TESTING, RESULTS AND DISCUSSION

The component was tested with 20kg of Potatoes, and the results taken at 30 minutes intervals for a period of 7 hours starting from 10:00am and the results tabulated as shown below:

Room Temperature at the start of the test = 30^{o}C
Room Temperature at the end of the test = 34^{o}C
Initial Atmospheric Temperature at the start of the test = 38^{o}C
Final Atmospheric Temperature at the end of the test = 40^{o}C
Initial Direct Chamber Temperature at the start of the test = 45^{o}C
Final Direct Chamber Temperature at the end of the test = 52^{o}C
Initial Indirect Chamber Temperature at the start of the test = 40^{o}C

Final Indirect Chamber Temperature at the end of the test = 45°C
Initial weight of potatoes at the start of the test = 20.00kg
Final weight of the potatoes at the end of the test = 14.60kg
Starting time of the test = 10:00am
Ending time of the test = 3.00pm

Table 1: Results Obtained from the Test of the Solar Dryer

S/No.	Time (min.)	Atmosphere Temperature (°C)	Direct Chamber Temperature (°C)	Indirect Chamber Temperature (°C)	Weight of Potatoes (kg)		
					Direct Dryer	Indirect Dryer	Air/Sun
1	0	38	45	40	20.00	20.00	20.00
2	30	38	50	43	19.10	19.30	19.80
3	60	39	56	47	18.00	18.70	19.40
4	90	40	58	52	16.80	18.20	19.00
5	120	40	64	55	16.10	17.30	18.60
6	150	45	69	60	15.50	16.70	18.20
7	180	45	74	63	14.70	16.00	17.60
8	210	45	74	62	14.20	15.40	17.30
9	240	44	70	58	13.40	14.60	17.00
10	270	42	68	54	12.40	13.70	16.70
11	300	42	64	50	11.60	13.00	16.40
12	330	40	58	48	11.00	12.60	16.10
13	360	40	52	45	10.40	12.20	15.70

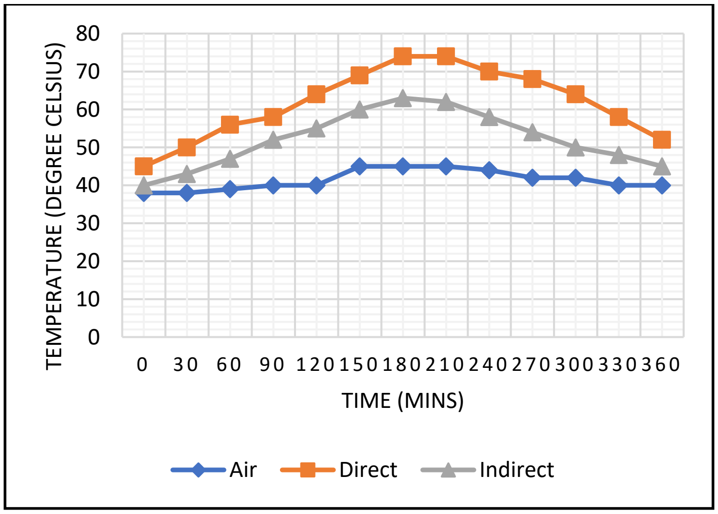


Fig. 5: Temperature Change with Time

Table 5 show the variations in temperatures of the three environments with time. It can be seen that the temperature at the direct chamber is her than the other two, due to the absorption and emission of heat by the chamber. This is followed by the indirect chamber, due to the influx of heat from the direct chamber through air pressure. The starting temperature of all the three environments are: Atmosphere (38°C); Direct Chamber (45°C) and Indirect Chamber (40°C). The highest temperature attained by each environment are: Atmosphere (45°C); Direct Chamber (74°C) and Indirect Chamber (63°C). The temperature of the various environments at the end of the test are: Atmosphere (40°C); Direct Chamber (52°C) and Indirect Chamber (45°C). From the above, it implied that at certain period the temperature in the direct chamber can make water hot though not to boiling point.

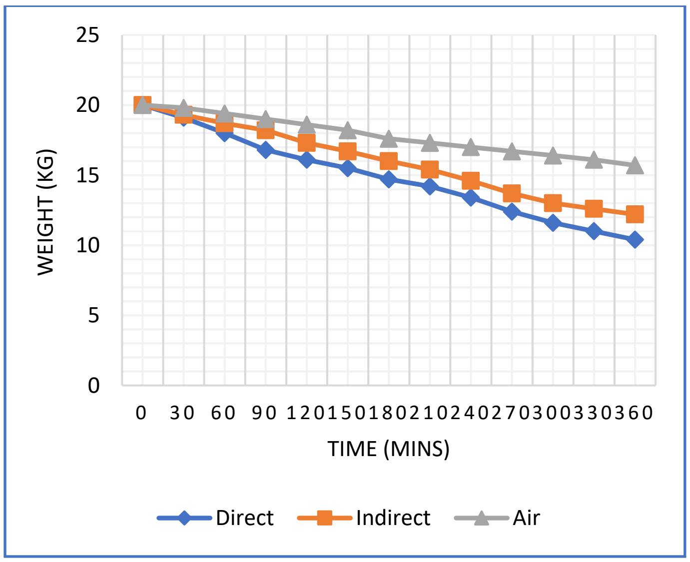


Fig. 6: Graph of Weight of Tomatoes against Time

From table 6, it can be seen that within the range of the time for the test the weight of tomatoes in the direct drying chamber reduced from 20kg to 10.40kg, for the indirect drying chamber from 20kg to 12.20kg, while the air drying reduced from 20kg to 15,70kg. This shows that the contents in the direct chamber dried faster, followed by the indirect chamber, while outside the chamber dried slower.

The efficiencies of drying in the chamber as compared with the drying outside is given as.

$\varepsilon = \frac{Q_s}{Q_T} x\, 100\% = \frac{20 - 10.40}{20} x\, 100 = \frac{9.6}{20} x\, 100 = 48\%$ for the chamber dried

$$\varepsilon = \frac{Q_s}{Q_T} x\, 100\% = \frac{20 - 12.20}{20} x\, 100 = \frac{7.8}{20} x\, 100 = 39\%$$

$\varepsilon = \frac{Q_s}{Q_T} x\, 100\% = \frac{20 - 15.70}{20} x\, 100 = \frac{4.3}{20} x\, 100 = 21.5\%$ for the air dried

From the efficiency calculated above, it implies that the direct chamber dried more efficient, followed by indirect chamber drying and in air is less efficient. Apart from that, the chambers are more hygienic and protective from pest and rodents attack.

CONCLUSION

From the results obtained from the test conducted, it can be concluded that the chamber multiplied the temperature received from the atmosphere and that contributed to the rapid drying as compared to the air drying. Also, the contents are better protected from germs and animal attack as compared to the ordinary air or sun drying.

References

Abiola Olufemi Ajayeoba et al Int. Journal of Engineering Research and Applications www.ijera.com ISSN: 2248-9622, Vol. 4, Issue 3(Version 6), March 2014, pp.13-20

Abul-Fadl, M.M. and Ghanem, T.H. (2011). Effect of vegetables. Journal of Food Engineering, 37: 293-304.

Amanlou, Y. and Zomorodian, A. (2010). Applying CFD for designing a new fruit cabinet dryer. Journal of Food Engineering, 101: 8-15.

Amer, B.M.A., Hossain, M.A. and Gottschalk, K. (2010). Energy in Agriculture, Design and performance evaluation of a new hybrid solar dryer for banana. Energy Conversion 2:341-354. http://dx.doi.org/10.1016/j.rser.2012.04.041

Bolaji, B.O. and Olalusi, A.P. (2008). Performance evaluation of a mixed-mode solar dryer. AU Journal of Technology, 11(4): 225-231.

El-Beltagi, A., Gamea, G.R. and Essa, A.H.A. (2007). Solar drying characteristics of strawberry. Journal of Food Engineering, 78: 456-464.

Forson, F.K., Nazha, M.A.A. Akuffo, F.O. and Rajakaruna, H. (2007). Design of mixed-mode natural convection solar crop dryers: application of principles and rules of thumb. Renewable Energy, 32: 2306-2319.

Fudholi, A., Sopian, K. Ruslan, M.H. Alghoul, M.A. and Sulaiman, M.Y. (2010). Review of solar dryers for agricultural and marine products, Renewable and Sustainable Energy Reviews, 14: 1-30.

Lamnatou, C., Papanicolaou, E. Belessiotis V. and Kyriakis, N. (2010). Finite-volume modelling of heat and mass transfer during convective drying of porous bodies - Non-conjugate and conjugate formulations involving the aerodynamic effects. Renewable Energy, 35: 1391-1402.

Whiterfield, V. (2000). Careful use of Scarce Resources and the internet. *International Conference on Solar Energy*, Nov. 29, 2000. Pp 2.