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EXPERIMENTAL INVESTIGATIONS OF A SOLAR DRYER UNDER LABORATORY CONDITION

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Summary

The present study represents results of experimental and simulation investigations of a solar dryer under laboratory conditions to dry algae. In order to accurately analyse the performance of the solar dryer, the experiments have been carried out under the controllable laboratory condition. In addition, controllability of ambient condition allowed analysing the drying kinetics of algae. As a heat source of the dryer, lamps with powers of 500, 1000 and 1500W have been used. The different types of algae were used as the drying materials. It has been observed that there is a good convergence between the obtained experimental and simulation results.

Keywords: solar drying, drying rate, algae.

1. Introduction

The seaweed industry is grown but it is also become a source of income if carried out by communities, associations as well as individuals. Seaweed is widely used in production of food and medical products and industry manufacture at present (Fudholi et al. (2011)). Ge et al. (2011) reported brown seaweed Laminaria japonica can be used for the production of alginate, iodine and mannitol. They reported that seaweed excellent prospects as a potential feedstock for the production of bioethanol. Seaweed as an energy resource to produce biogas has been studied by Vergara-Fernandez et al. (2007). Solar drying system is one of the most attractive and promising applications of solar energy systems in tropical and subtropical countries. The technical development of solar drying systems can proceed in two directions. Firstly, simple, low power, short life, and comparatively low efficiency-drying system. Secondly, high efficiency, high power, long life expensive drying system (Fudholi et al., 2010).

The wide variety of dehydrated foods, which today are available to the consumers and the interesting concern for meeting quality specifications and energy conservation, emphasize the need for a thorough understanding of the drying process. Mathematical modelling of thin layer drying is important for optimum management of operating parameters and prediction performance of drying process. It is essential to set out accurate models to simulate the drying curves under different drying conditions. The description and prediction of the drying kinetics of a given material is still a weakness in the modelling of drying process. There is a great need for stable and reliable model to quantify and predict drying rates and drying times with a satisfying accuracy (Saeed et al., 2008a; Saeed et al., 2008b).

Drying kinetics is generally evaluated experimentally by measuring the weight of a drying material a function of time. Drying curves may be represented in three different types of plots that are moisture content versus time, drying rate versus time and drying rate versus moisture content.

The aim of the study is to accurately analyze the thermal performance of solar dryer by the controllable laboratory condition.

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2. Methods and Materials

2.1. Experimental set-up

The experimental set-up consists the following: an air solar PV-T collector; a solar drying chamber; three lamps with powers of 500, 1000 and 1500W; thermocouples with a data logger connected to a net-book; a flow meter; a humidity meter; a balance. The air solar PV-T collector with the size of 1004×704×55 mm and it consists of a transparent cover (polycarbonate sheet with surface area of 0.7 m^2 and thickness of 1 cm), a PV module with 12W electrical power, an absorber (a special welt mat), an extractor with running power of 4.8W and minimum air flow rate of 60 m^3/hour. A hole with a diameter of 12.5 cm is made on the backside of the collector for the hot air outlet. A special aluminium tube with 12.7 cm diameter is connected between the air solar PV-T collector and the drying chamber (Fig.1). The backside of the collector is made of special aluminium perforated plate which conduces to enter the air flow from ambient. The solar drying chamber is made of metal triangle and wooden frames which are covered with polycarbonate sheets. From inside of the drying chamber, absorbers (thin aluminium sheet with a thickness of 0.3 mm) are placed to absorb the direct incidence of solar radiation which negative influences on the properties of drying algae (Halimov et al., 2012). Five trays are placed inside the drying chamber with distance of 20 cm between each other. The size of the chamber is 100×100×70 cm. On topside of the chamber, an additional extractor with running power of 15W is installed to remove the humid air from the inside of the chamber. The trays are made of wooden frame covered with a plastic mesh, the size of each is 95×65 cm.

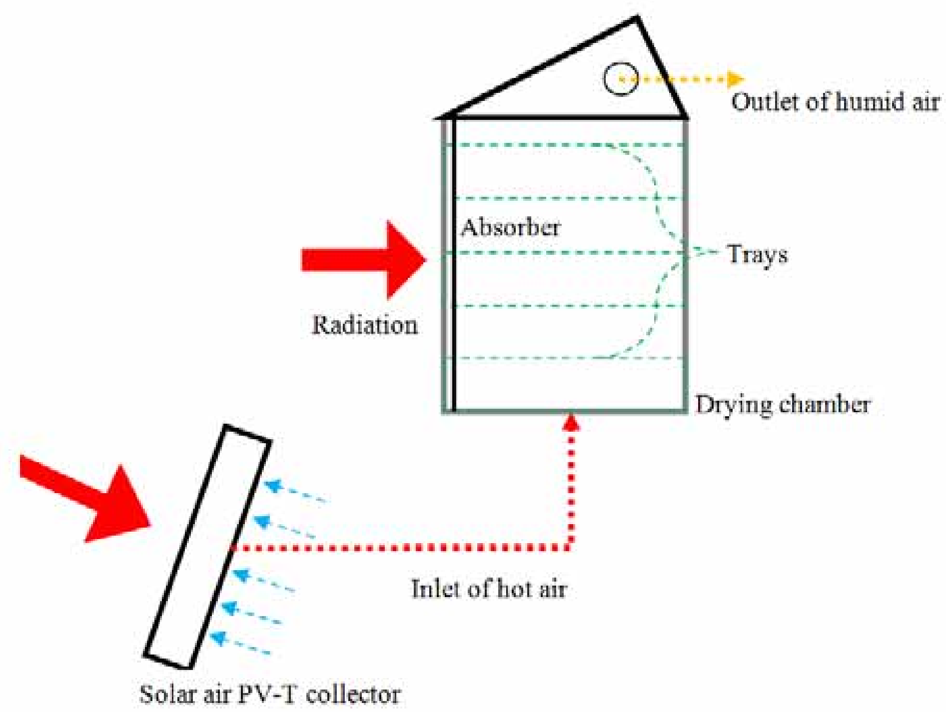
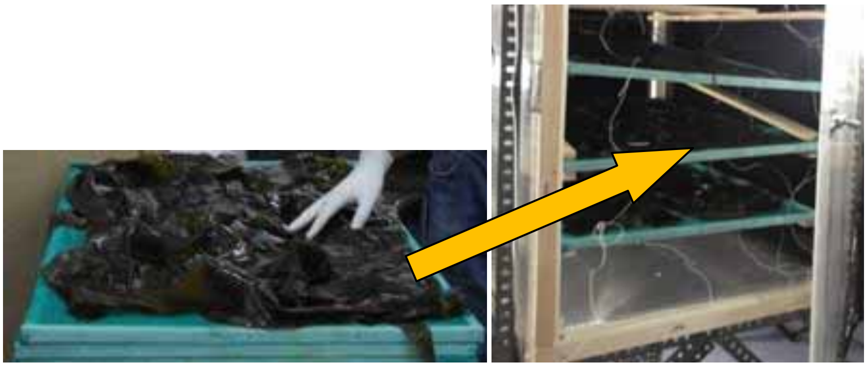
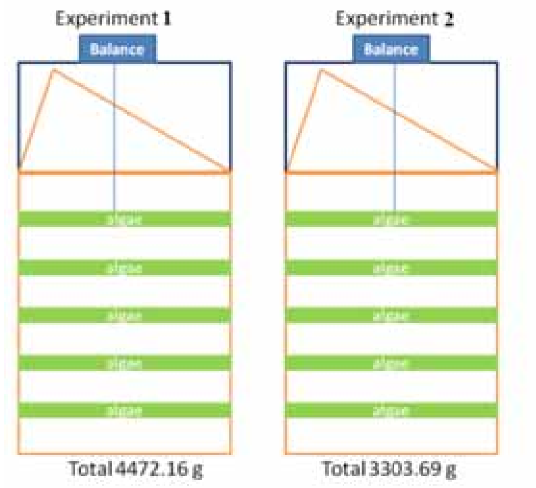


Fig.1: Schematic view of the solar drying system.

2.2. Experimental procedure

In order to run the system, at the first, biomass (algae, i.e. in our case brown seaweeds – *Laminaria* have been used) has been prepared and loaded in the drying chamber (Fig 2a) and the balance is installed on the top side of the drying chamber, as it is seen from the Fig 2b. In order to provide the uniformity of drying processes in the drying chamber, the algae were uniformly distributed as a single layer on a tray (Fig 2a).An important property of materials processed by direct radiation drying is their absorptivity for radiation. Fortunately, most solids have relatively high absorptivity, but they may change as drying proceeds, the surface of the materials becoming less or sometimes more "black" during the process. Food materials and crops are very sensitive to the drying conditions. Drying must be performed in a way that does not affect seriously their colour, flavour, texture or nutritional value. Thus the selection of drying conditions, as temperature, is of major importance. Many products need pre-treatment, similar to pre-treatment applied to conventional drying systems. For solar drying some products are pre-treated to facilitate drying or to keep their flavour and texture (Belessiotis and Delyannis, 2011).


a)



b)

Fig. 2: Experiment

The simulator power lamps were installed in the fixed places, i.e. the lamp with power of 1500W was directed to the surface of the solar air PV-T collector, and the others (two lamps with power of 500W), in turn, were directed to the walls of drying chamber (Fig.3).

Fig.3: Irradiating the solar dryer by the power lamps during the experiment.

During the experiments, the inlet and outlet air flow velocities were constants (inlet and outlet air flow velocities are 0.28 and 1.13 m/s, respectively). The velocities were measured with a flux meter. The experiments were conducted with two different masses (5117.74 and 3303.69 g) of algae to compare the drying constants. Dynamical changing of biomass during the drying was observed and recorded with a digital balance (the range of measurement is 0-5000 g with an accuracy of ±0.01 g) every 30 min. The relative humidity of air inside and outside the drying chamber has been measured by relative humidity sensors (HMP60, measuring range: 0–100% HR; −40˚C to +80˚C). The measurement of temperatures was performed using thermocouples of type K (0.2 mm diameter) and a PicoLog data logger with reading accuracy of ±0.01˚C. The irradiation emitted by the lamps was measured with a Pyranometer (Kipp&Zonen, 0–2000W/m^2, 1mv = 1W/m^2). A luxmeter was also used to observe and analyse a distribution of irradiation on the surfaces of collector and drying chamber walls.

2.3. Mathematical description

Data obtained from measurements in a test that measured the weight of the time before being used for the analysis of drying kinetics of material need to be changed first in the form of moisture content data. The moisture content of materials can be calculated by two methods on the basis of either wet or dry basis using the following equation:
The moisture content wet basis

$$M = \frac{w(t)-d}{w} \times 100\% \quad (1)$$

The moisture content dry basis

$$X = \frac{w(t)-d}{d} \quad (2)$$

where, $w(t)$ is mass of wet materials at instant t, and d is mass of dry materials.
The moisture ratio (MR) can be calculated as

$$MR = \frac{M-M_e}{M_0-M_e} \quad (3)$$

where, M_e and M_0 are equilibrium and initial moisture contents, respectively.

So, an equation for the average efficiency of the solar dryer could be written as the following

$$\eta = \frac{q_{eva}}{q_{in}} = \frac{\dot{m}L}{(A_{dc}+A_{cs})\cdot(I_1+I_2)} \quad (4)$$

where, A_{dc} and A_{cs} are surface areas of the drying chamber and collector, respectively. I_1 and I_2 are the intensities of the radiation emitted by the lamps, directed to the drying chamber and collector surface.

3. Results

As the obtained results show that the falling period of drying rate in the 1-sample takes place when its moisture content becomes 47% (Fig. 4).

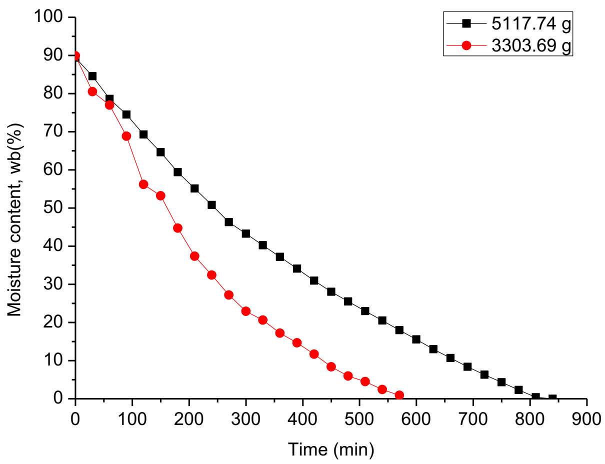


Fig.4: The moisture content wet basis during the drying.

Until the falling period of the drying rate, the most of energy expands to evaporate the water from the drying material. The falling period of drying rate for the 2-sample begins since its moisture content below 26% (Fig.4). Two different experiments results allow calculating the efficiency of the solar dryer. Mass difference in the samples is 1814.05 g. However, the time difference for drying of the mass is 230 minutes. The incident radiation on the surfaces of the drying chamber and solar air PV-T collector is measured. According to the measurements, the value is 700 $W \cdot m^{-2}$. The efficiency of the solar dryer could be calculated by (4). The latent heat of water evaporation is $2.4 MJ \cdot kg^{-1}$.

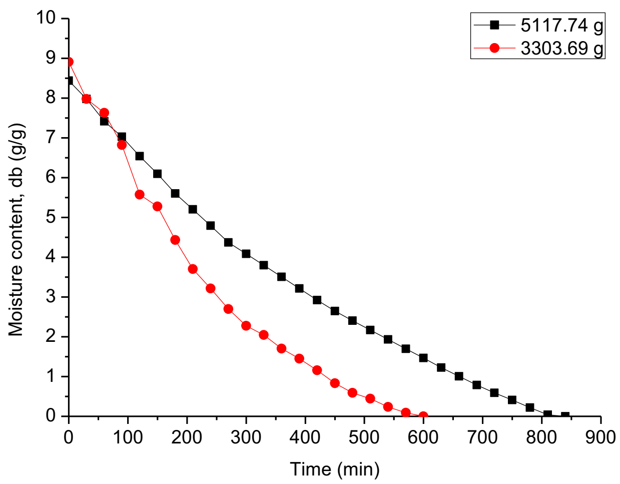


Fig.5: The moisture content wet basis during the drying.

Establishing of equilibrium temperatures in the air solar PV-T collector and solar drying chamber has taken place in one hour after the start of exposure by the lamps. Laboratory room's temperature was almost constant, i.e. it was between 24 and 25°C (Fig 6).

Tab.1: Experimental data of total, bio- and dried masses of algae within 1-experiment.

	Total mass	Biomass	Dried mass
Tray 1	1479.25	960.16	519.09
Tray 2	1584	1235.84	348.16
Tray 3	1487.31	1187.82	299.49
Tray 4	1506	1188.92	317.08
Sample1	765.6	545	220.6
Total	**6822.16**	**5117.74**	**1704.42**

Tab. 2: Experimental data of total, bio- and dried masses of algae within 2-experiment.

	Total mass	Biomass	Dried mass
Tray1	1233.2	716.53	121.95
Tray2	1238.95	744.73	291.78
Tray3	1240.2	703.12	331.53
Tray4	1278.34	804.76	359.25
Sample2	662.8	334.55	91.25
Total	**5653.49**	**3303.69**	**1195.76**

The analyses on the tables 1 and 2 data show that, the mean efficiencies of the solar dryer during the first and second experiments became 0.15 and 0.21 respectively.

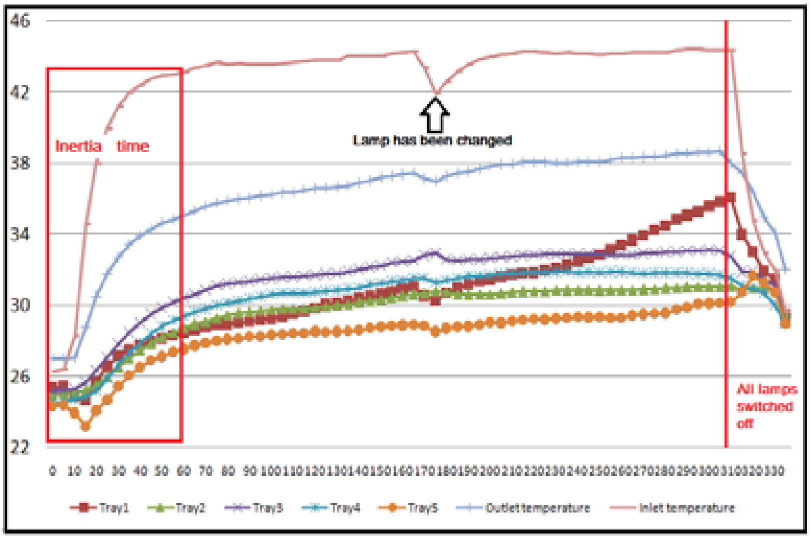


Fig.6: Temperature dynamics in the solar drying system.

As it is seen the equilibrium outlet temperature of hot air from the air solar PV-T collector during the experiments was 44˚C. Taking into account the velocity of hot air from the air solar PV-T collector is 0.28 m s^{-1}, and the flux density of incident radiation on the surface of the air solar PV-T collector is 700W m^{-2}, it is easy to calculate the thermal efficiency of the air solar PV-T collector that becomes 0.3. The temperature in the 1-tray in 4 hours after the start of experiment increases dramatically by 6 ˚C within one hour, which could be characterized by the falling of drying rate in the tray.

4. Conclusion

In order to accurately analyse the performance of the solar dryer, the experiments have carried been out under the controllable laboratory condition. Controllability of ambient condition allowed analysing the drying kinetics of algae and thermal performance the drying system. As experiments shown the temperature of exhaust air from the solar drying chamber has high potential which might be useful to reuse. The temperature of exhaust air is achieved by the incident of radiation on the walls of the solar drying chamber. According to the conducted experiments the mean efficiencies of the solar dryer during the first and second experiments became 0.15 and 0.21 respectively.

5. References

Belessiotis V., Delyannis E. 2011. Solar drying. Solar Energy, no. 8, vol. 85, pp. 1665–1691.

Fudholi A. Sopian K, Ruslan MH, Alghoul MA, Sulaiman MY. 2010. Review of solar dryers for agricultural and marine products. Renewable & Sustainable Energy Review, 14, 1-30.

Fudholi A., Othman M. Y., Ruslan M. H., Yahya M., Zaharim A. and Sopian K., 2011 Techno-economic analysis of solar drying system for seaweed in Malaysia. in Proceeding of the 7th IASME/WSEAS Int. Conf. on Energy, Environment, Ecosystems and Sustainable Development (EEESD, 11), France.

Ge L., Peng W, Haijin M. 2011. Study on saccharification techniques of seaweed wastes for the transformation of ethanol. Renewable Energy, vol. 36, pp. 84-89.

Halimov A.S., Agüera A.L., V. Gandara, Akhatov J.S., 2012. A study the influence of absorbing layer to the efficiency of solar drying chamber. International Symposium on Power Electronics, Electrical Drives, Automation and Motion, Sorrento (Italy) June 20-22, pp. 87-92.

Saeed, I.E., K. Sopian and Z. Abidin. 2008a. Drying characteristics of roselle (1): mathematical modeling and drying experiments. Agricultural, Engineering International: the CIGR Ejournal. Manuscript FP 08 015.vol.X.

Saeed, I.E., K. Sopian and Z. Abidin. 2008b. Drying characteristics of roselle: study of the two-term exponential model and drying parameters. Agricultural Engineering International: the CIGR E-journal. Manuscript FP 08 016.vol.X.

Vergara-Fernandez A., Vargas G, Alarcon N, Velasco A. 2007.Evaluation of marine laminaria japonica as source of biogas in a two-stage anaerobic reactor system". Biomass Bioenergy, vol. 32, pp. 338-344.