DRYING PEARS IN A SOLAR DRYER TO OBTAIN A TRADITIONAL PRODUCT- SOME EXPERIMENTAL RESULTS AND SUGGESTIONS

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Abstract. *In most countries, before "modern" systems allowed food to be kept under good conditions for almost any desired period of time, people were used to increase goods validity by means of solar drying. This was the case of many kinds of fruit, especially those that were not sufficiently attractive in their fresh condition. In the north of the country there was this ancient tradition of drying fruits placing them under direct solar exposure, over big granitic rocks barely covered with a thin layer of dried straw. In this particular region of the country this tradition of sun drying the fruits, especially pears, made them well know countrywide as Viseu's pear-"passa". With the last decades labor costs evolution, the quantities of this kind of product became smaller and prices higher and higher. As a result of a previous research work done on the drying of pears, where a conclusion was reached that the traditional outdoors method could be replaced by a drying process in a solar greenhouse, a project was submitted to the Portuguese Research Authority, FCT, to evaluate a value-added and cost-effective method to re-create that consumed sun-dried pear. Under the funded research project PTDC/AGR/74587/2006, a prototype solar-drier was built to study the drying process under more uniform and controlled conditions. In addition, the study looked at different methods of drying, with the possibility of improving the drying process. Fundamental research was carried on evaluating changes arising from using different solar-drier dimensions, namely height and venting openings. Different pear varieties and ripening stages were compared for the estimation of drying rate changes under the same radiation conditions as well as with and without direct solar radiation. Finally, some engineer solutions were implemented aiming at improving the internal flow uniformity and take advantage of random extraction.*

Keywords*: Drying, Solar, Fruit.*

1. INTRODUCTION

Using solar energy to dry agricultural products and increase food preservation for longer shelf life and off-season availability was widespread allover the world and has been in use for centuries. Despite being a slow process for obtaining dried preserved foodstuff, it has the advantage of being an inexpensive, pollution free process, as well as retaining some physical, chemical and, not least, organoleptic characteristics that eventually establish its quality.

There is a traditional Portuguese method of drying fruits that consist in placing them under direct solar radiation exposure, normally over large granitic rocks, precariously protected from contact with the surface by means of thin layers of dried straw. Particularly pears, in the northern region, are known to be dried in open-air sun exposure in the summer, through a complex process involving several operations, such as peeling, followed by a first drying stage at open-air of approximately a week long, then a three days shadow stocking and finally a three days period of, again, open-air (Guiné *et al.*, 2007); the dried pears produced under these conditions are called Viseu's pear- "passa".

Recently, many efforts have been made to study the drying of pears, and not only the solar type. Many aspects related to the drying process have been investigated to develop reliable processes and new drying techniques especially applied to this traditional product that is quite appreciated and that presents many interesting economical aspects (Hui *et al.*, 2006).

There are many kinds of solar dryers and their feasibility depends largely upon the kind of product to be dried and the climate conditions that are present in the location used. Solar drying has several advantages, beyond shortening drying time and lowering energy costs, such as the resulting quality, when compared with similar products obtained by industrial drying processes, microbiological characteristics of the final product, not being directly exposed to worms and insects or dust, and absence of any kind of preservatives or exposure to harmful electromagnetic radiation (Akpinar, 2008).

The factors that determine the end of this particular drying process are the level of sugar concentration and the moisture content, the drying efficiency of the process being marginal. Nonetheless, from the farmer's point of view, too much drying time equals time shortage for other agricultural activities, being exposed to unexpected and unfavorable weather conditions that can, overall, compromise the process attractiveness.

A previous research work developed in the Polytechnic Agricultural School concluded that the traditional method of drying pears outdoor could be replaced by a process of solar drying using greenhouses (Guiné *et al.*, 2007). This reduces the drying time and keeps the properties of the pears dried by the traditional method.

The main objective for this project is to incentive the small producers of this kind of dried fruits to replace traditional techniques and start using solar drying greenhouses in the process. These greenhouses are supposed to become available at low costs and are quite effective in reducing the drying time while preserving dried pears' quality.

The drying mechanism relies on complex heat and mass transfer laws. It is a typical transient phenomenon that takes place by diffusion and convection providing that temperature and concentration differences are established in the substances to dry and between the substances and the external ambient conditions. In so doing, water molecules can travel from within the substances to the surface where, desirably, the water vapor partial pressure is higher than the lower partial pressure in the surrounding media. This lower value is due to the increase in temperature caused by the greenhouse effect and helps moisture to integrate the continuous supply of fresh gas (Treybal, 1981). The intrinsic transient characteristic of this process is catalyzed by the unpredictable nature of the solar energy supply, which takes the difficulty to analyze some of the key factors of this process one step further. In order to have a reference for some of the situations observed, this work will present some results under artificially created permanent regimes.

2. FRUIT CHARACTERIZATION

Pears are well known fruits. The two varieties tested, "S^t Bartolomeu" and "Rocha", belong to the *Pyrus Communis* species, European Pear. The pear fruit dimensions are difficult to measure directly because fruit shape may vary considerably, especially the neck (narrow section of the fruit extending from the stem end). Despite variation, pear size and shape fit a fairly standard pattern in any particular orchard.

The fruits physical properties were determined applying the following methods (Demir *et al.*, 2002; Kabas *et al.*, 2006; Mitcham and Elkins, 2007): linear dimensions, such as the fruit length (from stem to blossom end), L, the larger diameter, W, and the smallest, measured at the same distance from blossom as the larger, T, were measured and the diameter calculated with Eq. (1):

$$D = (LWT)^{1/3} \tag{1}$$

The fruit volume can be accurately determined by dipping it in a container of water and measuring the amount of water displaced by the fruit, *i.e.*, using the hydrostatic method. To avoid possible infiltration of water and change of the initial characteristics of the product to dry, samples measured by this method were not used in drying. Those results are compared in Tab. 1 with the mathematically calculated volumes based on diameter values obtained using Eq. (1):

$$V = cD^3 \tag{2}$$

that incorporates the volume of the neck by means of coefficient c, a function of the pear diameter (Westwood, 1993). In the present case, a constant c value of 0.6315 was used, corresponding to a 4.6 cm average diameter. Pear samples were weighed to obtain the fruit's individual mass using a Kern centesimal scale, model 'ew', with a precision of 0.01 g. Values presented in Tab. 1 are the average of 218 fruits, for the S^t Bartolomeu variety, and 363 for the Rocha variety; the diameters obtained by measurements (Eq. 1) show differences that are, approximately, 4% higher than the hydrostatic values. Table 1 also presents the surface area and the pears' sphericity calculated using Eq. (3):

$$\phi = D/L \tag{3}$$

Table 1. Fruit characteristics

		Mass, m (g)	Volume, $V_1^{(1)}$ (cm^3)	Diameter, $D_1^{(1)}$ (cm)	Diameter, $D_2^{(2)}$ (cm)	Volume, $V_2^{(2)}$ (cm^3)	Surface area, S (cm^2)	Sphericity, ϕ (-)	Moisture content (%)
S^t Bartolomeu	fresh	63.7 ± 0.01	36.6	4.12	4.26	48.8	57.0	0.58	60.5
	dried	15.2 ± 0.01	-	-	2.41	8.8	18.2	0.33	18.1
Rocha	fresh	66.2 ± 0.01	57.3	4.68	4.87	72.9	74.5	0.67	72.3
	dried	12.3 ± 0.01	-	-	2.52	10.1	20.0	0.35	25.4

$^{(1)}$: volume measured using the hydrostatic method; $D_1 = (6V_1/\pi)^{1/3}$
$^{(2)}$: diameter calculated using Eq. (1); volume calculated using Eq. (2)

The samples were dried at 105º C in a Binder laboratory stove, model SDL115, until constant weight was reached (Guiné *et al.*, 2007) to allow calculating the overall moisture content (Tab.1), on a wet basis, defined as:

$$X = \frac{m_i - m_d}{m_i} = \frac{m_{H_2O}}{m_i} \tag{4}$$

where m_i is the initial mass of the pear, m_{H2O} is the moisture mass content of the fresh pear and m_d is the dried pear final mass.

3. DRYERS AND EQUIPMENT DESCRIPTION

3.1. Dryers

The experimental set-up designed and carried out for this study is presented in Fig. 1. It was built in the Thermodynamics and Heat and Mass Transfer (THMT) laboratory facilities and consists of two solar driers, with two to four tray structures: the structures that are placed inside the smaller drier have two trays and those inside the larger one, three, with dimensions according to Fig. 2. The framework of both greenhouses is a 3 mm thickness glass, with an average transmission coefficient, τ, of 0.88, and an average emission coefficient, ε, of 0.95 (Chauliaguet *et al.*, 1981; Mohelníková, 2008). The devices were designed to address issues concerning changes in height and different ventilating area ratios. Both structures were made with 20 mm BOSCH profiles. The preliminary tests were made indoors, more specifically in the THMT laboratory. The dimensions of the greenhouses are 1005 mm x 610 mm x 672 mm, to the bigger greenhouse, and 1005 mm x 610 mm x 360 mm, to the smaller greenhouse, *i.e.*, the two driers have a 1:2 proportional height dimension.

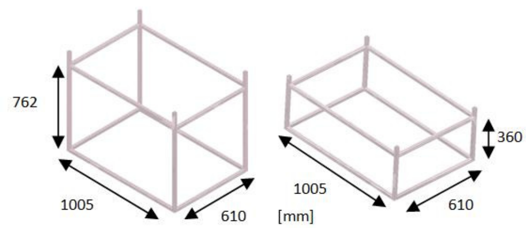

Figure 1. Diagram of the two solar dryers (large and small) used in the experiments.

The first tests, seeking to assess data acquisition software compatibility, were made inside the laboratory. Then, during the 2008 summer, the two solar driers were carried to the building's roof and south oriented. With the end of summer and the long winter and severe spring that occurred, the solar driers were put back in the Thermodynamics lab. There, the below referred 2009 tests were made using a replication of the average solar radiation intensity of 2008, months of July and August (an average of the lab recorded values and the data gathered from the National Meteorological Services). Due to low ambient temperatures, lateral 2 cm polystyrene insulation plates were positioned.

3.2. Instrumentation

To measure the relative humidity, an ADC-16 Pico Technology data acquisition system (DAS) was used. Data was treated using the Pico Log Recorder 5.20.1 software. The temperatures were measured using T and K type thermocouples with a TC-08 Pico Technology DAS. The signal was data given in Celsius degrees to the Pico Log Recorder 5.20.1 software. The pear's change of mass was measured using load cells connected to a DAS. Measurements were made using a National Instruments USB−6008 DAS; they were subsequently treated using the Lab View 8.6 software. These signals were converted in kg based on legal masses calibration provided by the National Institute of Metrology; measurement accuracy was established by comparison with a Need precision scale, model 6200D, used in parallel. As the input range of the NI DAS is from −10 V to +10 V and the output range of load cells is of the magnitude of mV, an electronic amplifier was used to increase the resolution. Finally, the received data was filtered and processed using the referred computer software.

The total incident radiation was measured using a SP-100 Apogee silicon-cell pyranometer with the output voltage processed by the 6008 USB DAS. The software used was also Labview 8.6. The air flow rate was measured with hotwire tungsten anemometers, connected to an electronic circuit built and tested to control the voltage in the sensor and to restore the equilibrium of the Wheatstone bridge (Sampaio *et al.*, 1998). The sensor calibration was made using both a fundamental positive displacement method and a traceable ADC 7000 gas analyzer. To calibrate the humidity sensors several essays were performed between saturated conditions and exsiccated chambers; the values were assessed with a ROTRONIC Hygroscop thermo hygrometer, model GT1.

4. EXPERIMENTAL PROCEDURE

The experimental procedure was based on temperature, air velocity, relative humidity and mass measurements. No-load tests were performed to evaluate the temperature and the air velocity profiles. Subsequently, similar tests were made with batches of pears, using different varieties and ripening stages and drying to approximately 18% moisture content, dry basis, when the weather conditions permitted. The first tests were made indoors because of the weather conditions. Although the tests were made during spring and summer, the uncharacteristic weather conditions, that included rainy days, affected most of the tests during those periods.

The first tests were made with the higher/larger greenhouse. The volume was divided in three sections and each of those sections had eight temperature and humidity sensors, separated by equal 4 cm distances; velocities were measured at points A1, 2 and 3, Fig. 3. With the 2008 tests a set of two consecutive trays were used (Fig. 5). 2009 tests were made initially with three consecutive trays and measurement locations indicated on Fig. 3.

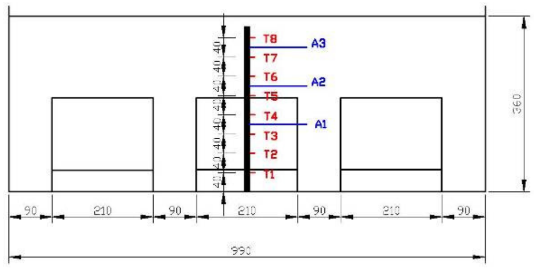

Figure 2. Initial three zone arrangement plus tray location and dimensions.

Later, to increase the load, four consecutive trays were used; the location of the measurements were those of Fig. 3.

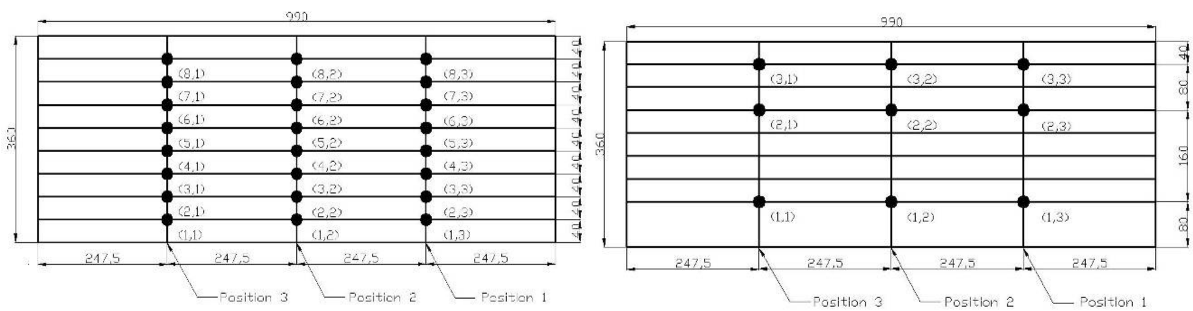

Figure 3. Subsequent and definitive sensor location: thermocouples and relative humidity sensors, matrix 8x3on the left; hot-wire anemometers, matrix 3x3 on the right (dimensions in mm).

5. RESULTS AND DISCUSSION

The drying results obtained with outdoors 2008 summer and indoors 2009 spring experiments were analyzed. The factors that affect drying rate, *DR*, in thin layer mode are air temperature, initial moisture content, on the wet, M_w, and dry, M_d basis (Eq. 4), Moisture Ratio, *MR*, air velocity and relative humidity. According to Ekechukwu (1999) and ASHRAE (2001), they are defined as:

$$M_w = \frac{m - m_d}{m} \tag{5}$$

$$M_d = \frac{m - m_d}{m_d} \tag{6}$$

$$MR = \frac{\left|M_d - M_{d,f}\right|}{\left|M_{d,i} - M_{d,f}\right|} \tag{7}$$

$$DR = -\frac{dM_d}{dt} = -\frac{M_{d,i+1} - M_{d,i}}{t_{i+1} - t_i} \tag{8}$$

$$\overline{DR} = -\frac{m_f - m_i}{t_f - t_i} \tag{9}$$

where m is the mass at time t, m_d is the fully dried mass, $M_{d,i}$ is the moisture content at time t_i, $M_{d,i+1}$ is the moisture content at time t_{i+1} and $\overline{DR}$ (Eq. 8) is the average moisture extraction rate (Fathou, 2006). Using the Page equation (Agraval and Singh, 1977; Yunfei *et al.*, 1987;), well known for its adequacy in describing the drying process of many kind of food products, it is demonstrated that the present case is not a dominant thin layer mode. That can be noticed through the observation of Fig. 4 test curve, drying rate calculated by Eq. (8) *versus* moisture rate (Eq. 7),

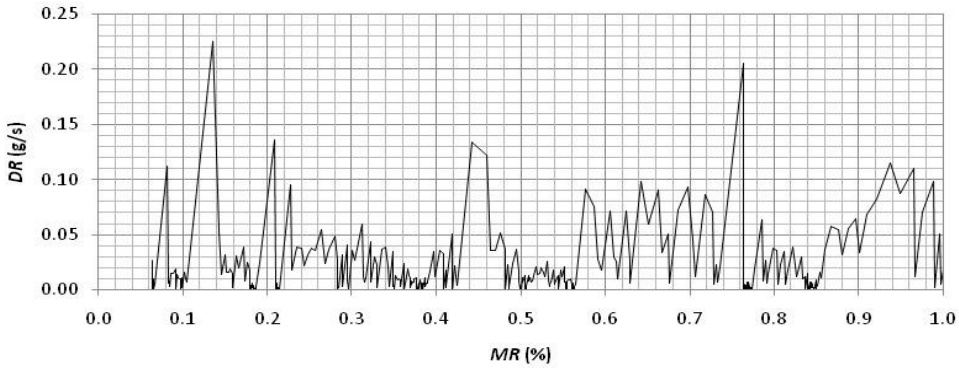

Figure 4. Drying rate *versus* moisture rate, 85 hours drying time.

in which the evolution depicted shows no familiarity with the literature constant rate and unsaturated surface drying periods. It clearly exhibits periods of zero drying rate, probably moments in which there is no moisture evaporation either in nocturnal periods or when the fruit has not supplied by diffusion, at a coordinate rate, the amount of moisture to be removed by convection. This lack of conformity to the classical drying behavior has been pointed out by some authors and seems to be a consequence of the polysaccharide-containing material (starch) in pears (Karathanos *et al.*, 1999) as well as of internal structure changes caused by water removal (Saravia and Passamai, 1997).
Thermal devices are commonly evaluated in terms of their drying rate. Another two important factors in describing the characteristics of the drying process are thermal efficiency and specific energy consumption (Pathak, *et al.*, 1991; Singh *et al.*, 2006), where m_v is the mass of moisture evaporated in total drying time, h_{lg} the latent heat, I_{av} is the daily average solar intensity on the dryer surface area, A_i is the effective energy collection area (exposed to solar radiation) and t is the time:

$$\eta = \frac{m_v h_{lg}}{I_{av} A_i t} \cdot 100 \tag{10}$$

$$S = \frac{I_{av} A_i t}{m_v h_{lg}} \cdot \frac{1}{1000} \tag{11}$$

5.1. 2008 (former) results

S[t] Bartolomeu pears were dried using solar radiation from August the 6^{th} to the 16^{th}, 2008. The research was being done under a pre-defined scheduled that had determined, in order to replicate 2007 maturity conditions, that a certain amount of pears, lots from the same orchard and from the same trees, had to be tested on three specific days, so that when the drying process was over the next lot, representing a more advanced maturity stage, could be dried.

Figure 5. Pears drying on the top of the school's roof during the summer of 2008.

Unfortunately, the weather conditions were not stable during those almost two weeks (even rain made its appearance) and the tests could not be made to the rate expected and, when the first test was finally over, pears of the second lot were not in good conditions anymore, so the third lot was used. The days that followed were also atypical, both from high ambient humidity and low air temperatures.

Test 8X had pears on all the trays, upper, middle and lower. Test 9X had pears only on the lower trays and test 10X only on the upper ones, *i.e.*, at a 5 cm height on both driers for test 9X and at 20 and 50 cm height, for the smaller and larger drier, respectively, for the 10X test. The results obtained can be briefly summarized as follows:

Table 2. 2008 tests with S^t Bartolomeu pears.

Test	Dryer	Nr of pears	Initial mass	Vent area	Ambient		Dryer		Pear	Duration
		$u.$ (-)	m_i (g)	A_i=A_e $^{(1)}$ (cm^2)	T (ºC)	RH (%)	T (ºC)	RH (%)	T (ºC)	t (h)
8X	small	36	2267	54	26	47	39	37	-	84
	large	43	2747	54			37	43	-	84
9X	small	20	1220	54	20	78	38	42	60	72
	large	22	1364	54			30	46	45	72
10X	small	24	1562	54	31	29	63	33	55	72
	large	24	1510	54			59	33	65	72

$^{(1)}$: A_i- entry section; A_e- exit section.

In all the three tests, made under very unstable weather conditions, diurnal temperature inside the larger dryer is slightly lower than the temperature occurring inside the smaller one; during the night period that difference fades away. It was found that the pears placed in the larger drier reach higher temperatures at 50 cm than those placed at 5 cm. For the smaller drier, pears placed at 5 cm reach a slightly higher value than those located at 20 cm.

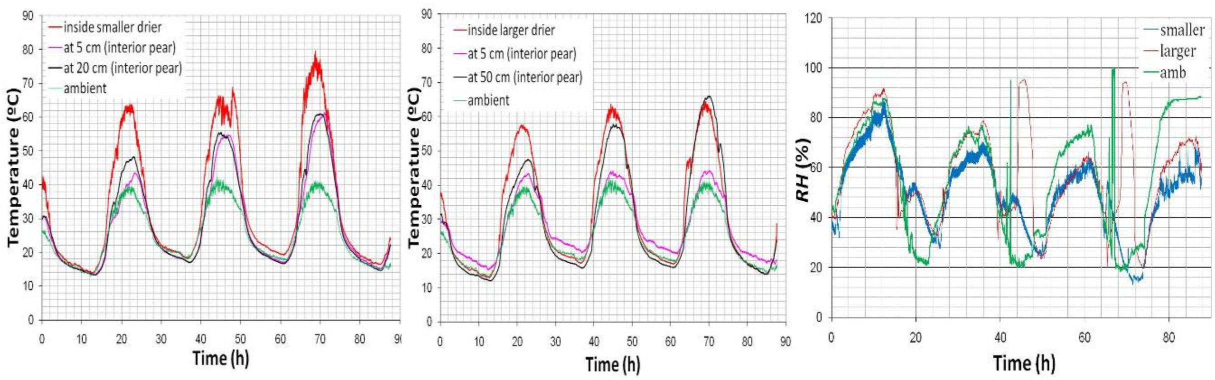

Figure 6. Temperature and relative humidity change with time (smaller and larger drier).

As expected, the solar period induces higher mass flow rates. The RH evolution reveals the existence of rain periods occurred during August 2008 and show that the larger drier has a higher permeability to ambient conditions. Pears also recuperate some of the lost mass during the night, partially due to higher relative humidity that is caused by a decrease of the ambient temperature and an increase in its hygroscopic level; part of the moisture lost during the day is reabsorbed. Morning has a higher drying rate than the afternoon. No correlation was possible with the actual solar radiation intensity because the pyranometer stopped functioning. The moisture ratio evolution does not show significant differences between the two dryers (Fig. 7). The moisture rate recovery on the third day was due to rainy periods.

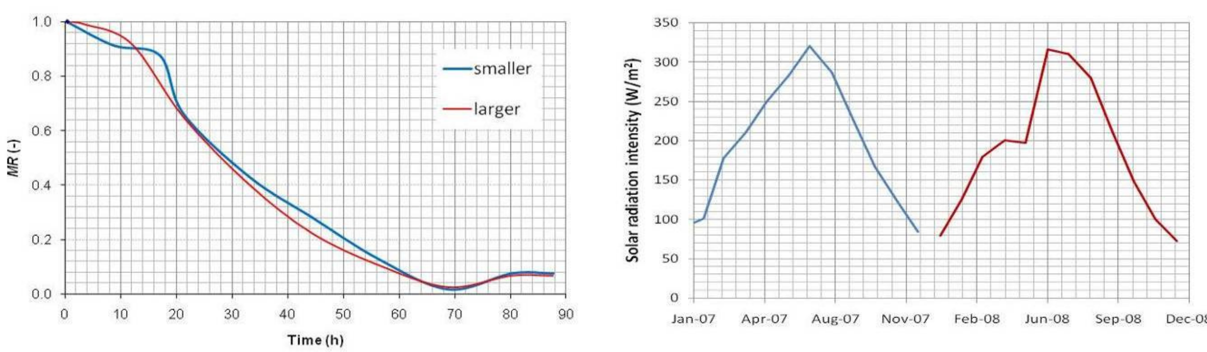

Figure 7. Moisture ratio evolution with drying time, left; solar radiation for 2007/2008, right.

5.2. 2009 results

Not having S[t] Bartolomeu pears available forced the use of alternative species. The one available that more closely resembled the size and texture of the previous fruits was the variety Rocha. The results presented concern this variety.

5.2.1. Temperature and velocity profiles at no load

Figures 8 and 9 represent dimensionless temperature (T_i/T_{amb}) and velocity profiles for several heights, the points 1 to 8 from position 1, *i.e.*, points 1.3 to 8.3 from Fig. 3, at a no load condition. They also represent the change with time, for *t*= 1, 2 and 3 minutes. Figure 8 contains three temperature profiles: the first one measured the temperature evolution for A_e/A_i= 1, *i.e.*, a ratio of 1:1, the second a ratio of 1:2 and the third a ratio of 1:3, all of them at the same position 1, the entry zone of the drier. Observing the results, the profiles are relatively stable, a slight reduction of temperature being perceptible from the 1:1 to the 1:3 ventilation ratios for the higher placed measurement. This is a common trend of the remaining positions, 2 and 3, respectively the middle and the exit zone of the smaller drier.

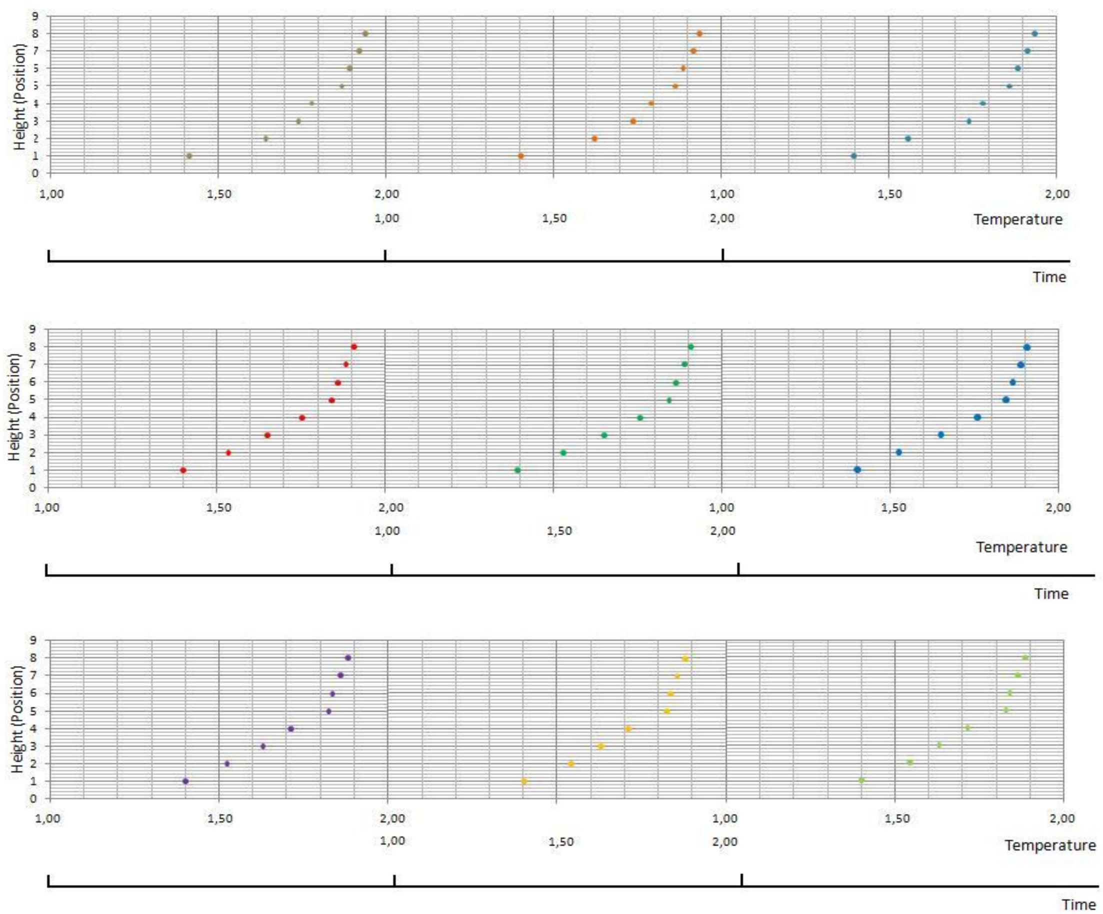

Figure 8. Dimensionless temperature profiles, smaller drier, no load, position 1 (first, left); top down: ratios of 1:1, 1:2 and 1:3, *i.e.*, A_i= 54 cm^2, constant, A_e= 54, 108 and 162 cm^2, respectively 1:1, 1:2 and 1:3.

Figure 9 below represents the velocity profiles for the smaller drier, for a vent opening ratio A_e/A_i of 1:2, The three velocity profiles exhibit the air stream condition at the entry, middle and exit zones of the drier, *i.e.*, at positions 1, 2 and 3 (Fig. 3), again in three consecutive moments, separated by 1 min each. Higher velocities occur, for all the ratios, in the lower zone of the drier, points 1.3, 1.2 and 1.1 (Fig. 3), the lowest measurement point, located at 80 mm from the bottom of the drier. A reduction of the velocity near the top of the drier, at points 3.1 to 3.3 (Fig. 3) is noticeble at all the instants measured. The pattern of lower velocity within the average/intermmediate zone, measurements at 240 mm from the bottom, between the 80 and 320 mm locations, corresponding to points 2.1, 2.2 and 2.3 (Fig. 3), does not exist at the exit zone, where the velocity gradient is regularly decreasing from the bottom to the top zone of the drier. This atypical velocity profiles can be the result of internal recirculation, a pattern detected in some CFD simulations for this situation.

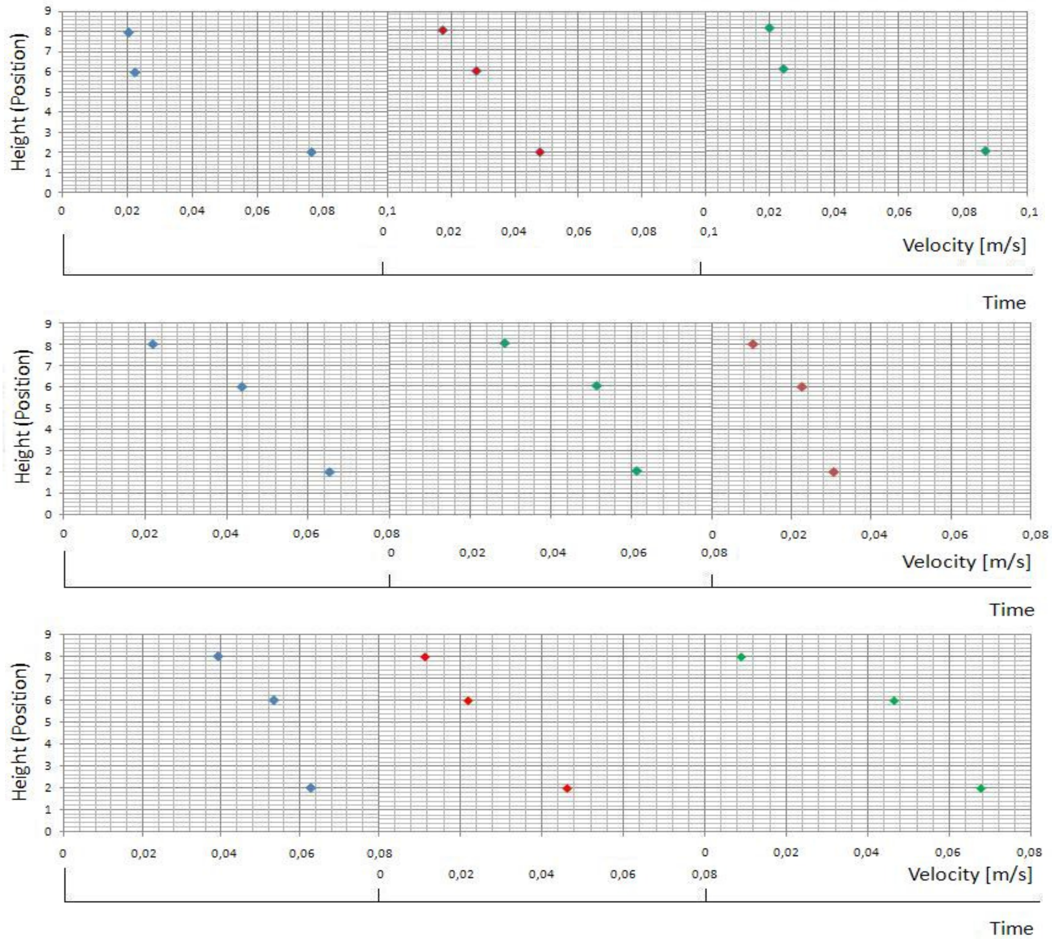

Figure 9. Velocity profiles, smaller drier, no load; top down: position 1 (entry), 2 (middle) and 3 (exit) for ratio 1:2, *i.e.*, A_i= 54 and A_e= 108 cm^2.

There seems to exist a trade-off between the higher air velocities in the lower part of the drier and the higher temperatures in the upper zones of the volume. Some authors consider that the drying air temperature is the main factor in controlling the drying rate (Kouhila, 2002; Lahsasni *et al.*, 2004).

5.2.2. Temperature, relative humidity and moisture rate with load

When loaded, the drier with a ventilation ratio of 1:2, presents the following expected temperature and moisture ratio evolution with the drying time (Fig. 10); obtained relative humidity profiles are not as common.

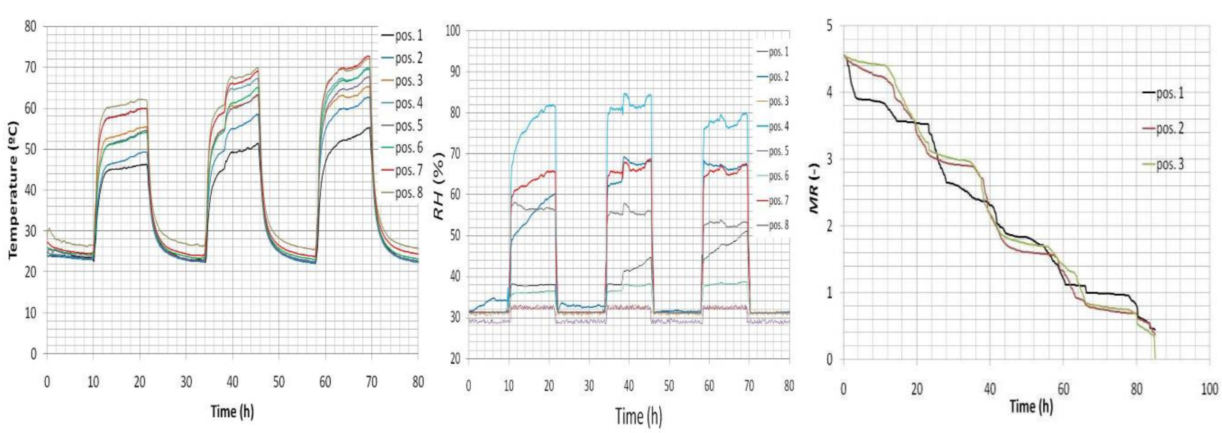

Figure 10.Temperature and RH profiles evolution, position 2 (Fig 3); moisture ratio (Eq. 7), pos. 1, 2 and 3 (Fig. 3).

Though the nocturnal period decrease in temperature induces an increase of the relative humidity values, indoors that effect is probably not as important as those registered with the 2008 experiments; the changes in the ambient conditions are not as severe within the lab facilities as outdoors.

Higher zones experience higher temperatures, with the exception of point 8 that is due to the heat transfer convection *versus* conduction effects near and through the drier ceiling.

5.2.3. Average drying rate, thermal efficiency and specific energy

Using Eq.s (9), (10) and (11), the corresponding values of the average drying rate, the difference between the initial and final mass of the product being dried divided by the total drying time, of the thermal efficiency, the thermal energy utilized in the drying process *versus* the available thermal energy, and the specific energy consumption, the solar energy required to remove 1 kg of moisture, were calculated and are presented in Tab. 3:

Table 3. Average values of Drying Rate (*DR*), thermal efficiency (η) and specific energy consumption (*S*).

			DR	η	*S*
			(g/s)	(%)	(MJ/kg)
2008	smaller	pos.1	0.00229	5.10	46.954
	larger	pos.1	0.00245	5.46	43.826
2009	smaller	pos.1	0.00394	8.80	27.208
		pos.2	0.00477	10.66	22.507
		pos.3	0.00489	10.92	21.970

In Tab. 3 results, the lines referrred to as “pos.1”, “pos.2” and “pos.3” are the three zones of Fig. 2, entry, middle, exit, each one being monitored in terms of moisture removal. Drying rates are higher at the exit zone of the driers, no noteworthy differences appear from the smaller and the larger drier exposed to direct solar radiation. Air velocities are always higher near the bottom but more important near the exit, position 3. That apparently leads to higher average drying rates and thermal efficiency and lower specific consumption. A more precise analysis should be possible if data on mass changes at positions corresponding to the eight different levels of Fig. 3 were acquired. A major factor that distinguishes the 2008 results from 2009’s is the lateral insulation placement that increased the retention of thermal energy within the drier.

5.2.4. Random ventilation

The experiments were made outdoors and the acquired data allowed the comparison of internal air velocities on natural convection mode with random extracted (forced) convection mode, for load and no load cases. The atmospheric pressure was 970 hPa and the ambient air was at 28 and 8º C, average values for day and night periods, respectively.

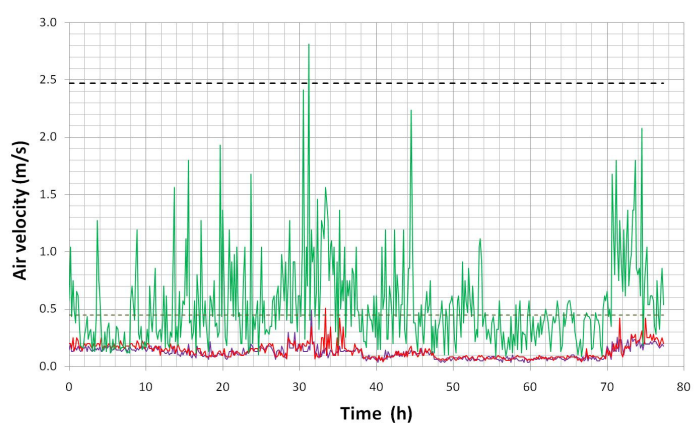

Figure 11. Wind mill (left) and air velocity under random forced extraction, inlet vent area A_i= 54 cm^2. Internal measurements made at positions 2.2 and 3.2 (Fig. 3), red and blue, respectively; green line: solid- inlet air velocity, dashed- average value (0.45 m/s). External (wind) air velocity- black line, dashed, average value (2.47 m/s).

Figure 11 shows that the use of a windmill can provide an increase by a factor of *circa* 4 in the average superficial air velocity, as well as a more homogeneous spatial distribution. Unfavorable meteorological conditions avoided registering the effects of long periods of ‘effective’ random extraction on the average drying rate of the process.

6. CONCLUSIONS

Some results of an experimental work on drying pears in a solar dryer were presented. Changes in drier's height, for the same load, do not seem to influence significantly the major values acquired, particularly the drying rate. Spatial temperature profiles did show some small changes of values with time; nonetheless, the pattern remained the same. Ratios of surface vents influence temperature and velocity and the drying rates are higher near the exit zone of the driers. Random ventilation using a wind mill naturally increased the air stream. This possibly virtuous influence on the drying rate needs further investigation, as such outcome is controversial in the literature.

7. ACKNOWLEDGEMENTS

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